INSTITUTO TECNOLÓGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

CAMPUS MONTERREY

DIVISIÓN DE INGENIERÍA Y ARQUITECTURA
PROGRAMA DE GRADUADOS EN INGENIERÍA

Optimization of the Savonius wind turbine using a genetic algorithm

TESIS

PRESENTADA COMO REQUISITO PARCIAL PARA OBTENER EL GRADO DE

MAESTRO EN CIENCIAS
ESPECIALIDAD EN SISTEMAS DE MANUFACTURA

POR:

CÉSAR HUMBERTO VILLARREAL LEAL

MONTERREY, N.L. **DICIEMBRE DE 2008**

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Los miembros del comité de tesis recomendamos que el presente proyecto de tesis presentado por el Ing. César Humberto Villarreal Leal sea aceptado como requisito parcial para obtener el grado académico de:

Maestro en Ciencias en Sistemas de Manufactura
Especialidad en Diseño del Producto

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MONTERREY, N.L. **DICIEMBRE DE 2008**

Agradecimientos

A mis papás Magda y César, gracias por la formación que me dieron y el ejemplo que me siguen dando.

A Denisse por ser mi mejor amiga, por su apoyo y ayuda para escribir esta tesis.

A mis hermanas Magda y Lorena, por su apoyo.

A mi asesor Dr. Noel León por mostrarme las herramientas usadas en la presente tesis.

A mis sinodales Dr. Armando Llamas, Dr. Eduardo Uresti y Dr. Martín Bremer por sus consejos, aportaciones e interés.

A todos aquellos que de alguna forma contribuyeron a la realización de esta tesis.

Executive summary

This Thesis presents a methodology for an automated optimization of the rotor of a Savonius vertical axis wind turbine. This optimization was performed using an automated process integrated in a multidisciplinary design optimization software. In it, a genetic algorithm was in charge of the optimization of the selected variables. In this case the variables were the rotor profile shape, diameter and tip speed ratio of the wind turbine. This rotor's variations were evaluated by calculating its power coefficient (C_P) using computational fluid dynamics (CFD).

There were performed three optimizations. The first was single objective in order to maximize the C_P, this was accomplished by performing modifications to the shape of the rotor profile. The second was multi objective in order to maximize the C_P and minimize the difference of it in the unsteady CFD analysis (C_{Pdif}). The previous was achieved by making variations to the rotor's shape profile, size and TSR. The third optimization was single-objective (maximizing the C_P) and it involved performing the same variations as the second optimization.

Keywords: Vertical axis wind turbine, Savonius, shape optimization, power coefficient, computational fluid dynamics, genetic algorithm.

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Nomenclature

λ: tip speed ratio

ρ: density (kg/m^3)

ω: angular velocity of the rotor (rad/s)

A: sweep area of the wind turbine (m^2)

C_P: power coefficient

C_{Pdif}: Difference between the highest and lowest value of the C_P in one CFD analysis

C_Q: torque coefficient

d: wind turbine rotor diameter (m)

E_k: kinetic energy (J)

H: height of the wind turbine rotor (m)

m: mass (kg)

P: power (W)

Q: torque (Nm)

r: wind turbine rotor radius

V: wind velocity (m/s)

Acronyms

CAD: Computer aided design

CAE: Computer aided engineering

CFD: Computational fluid dynamics

GA: Genetic algorithm

HAWT: Horizontal axis wind turbine

MDO: Multidisciplinary design optimization

TS: Time step

TSS: Time step size

TSR: Tip speed ratio

VAWT: Vertical axis wind turbine

WT: Wind turbine

Chapter 1

Introduction

The importance of the development of new renewable technologies to generate electricity have impulsed the development of the wind turbines. Actually, in the market exists a great variety of design of this kind of devices. Those designs have certain characteristics that make them suitable for different uses. The characteristics of the helical Savonius vertical axis wind turbine (VAWT) have shown excellent capabilities for the urban media, such as the ability to extract power from turbulent winds and the generation of less noise and vibrations.

Nevertheless its positive characteristics, the efficiency of this kind of wind turbine is behind the traditional horizontal axis wind turbines (HAWT). For that reason it is important to develop a Savonius VAWT with a superior efficiency (power coefficient, C_P).

As the shape of the rotor its the responsible of capturing the kinetic energy of the wind and convert it into mechanical energy, it must be modified in order to increase the C_P of the wind turbine. For that reason this investigation focused in the optimization of the shape of the blades of the rotor. This optimization involved the rotor profile shape, diameter and working velocity of it (tip speed ratio or TSR). In order to do that, a process was created. In it, the rotor shape was modified and the C_P was calculated using computational fluid dynamics (CFD) in an automated way. All of this automated process was directed by a genetic algorithm who was in charge of the search of an optimal shape.

This investigation is divided in 6 Chapters. The second consists in the theoretical background in which wind energy, computer aided design (CAD), computer aided engineering (CAE) tools (such as CFD) and genetic algorithms concepts are described. Then, in the third chapter the methodology is mentioned. In it, the automation strategies are presented and the optimization process is described. Then, in the fourth chapter the results of different design optimizations are shown. After that, in the fifth chapter some recommendations are presented and finally in the sixth chapter the conclusions are exposed.

1.1. Objective

The present investigation would look to improve the performance of a Savonius wind turbine for urban environments. This improvement will focus in two objectives, maximize the C_P and minimize the difference of C_P that its present when this kind of wind turbine rotates.

1.2. Hypothesis

It is possible to develop a Savonius wind turbine with superior performance modifying the rotor's shape, size, and the working velocity (TSR) at which the wind turbine operates. The rotor's shape can me modeled using splines in order to have more variation freedom. The modified wind turbine can be found using a genetic algorithm that can iterate several designs in which the parameters variates until the objective is achieved. This process can be automated and can be integrated using a computer to avoid C_P testing with real models in wind tunnels which are highly time and money consuming.

1.3. Justification

Due to the manufacturing restrictions, the previous improvements of the Savonius C_P has been made using only basic shapes that involve lines and arcs. Those shape optimizations can be improved using splines because they offer a superior possibility of variation than the combination of lines and arcs.

With the actual manufacturing processes it is possible to make wind turbine rotors using the shapes created with splines. A couple of possible manufacturing processes' is injection molding of polymers or thermoforming. Using this technology we can manufacture very complicated shapes and the costs can be significantly dropped when they are produced at large scale. This is an opportunity worth of exploring, considering the numerous advantages that this kind of wind turbine represent.

Chapter 2

Theoretical background

This chapter presents the theoretical background in which this investigation takes place. First, there's a description of the concepts that sustain the subject of wind energy. Then, a background of computer aided design and engineering is explained. Finally, important information about genetic algorithms is mentioned.

2.1. Wind power

The wind is a source of renewable energy that has been used by several ancient cultures to pump water and grind grain. Now, this resource is used to produce electricity using wind mills also called wind turbines (WT). This devices are capable of extracting power from the wind and there are different kinds of WT's that are going to be described on the next section.

To define the total power of the wind, first it is needed to understand the kinetic energy of the wind that is expressed by equation 1. This expression defines that the kinetic energy is the half of the mass times the square velocity of the wind.

$$\mathrm{E}_k = \frac{1}{2} m \cdot V^2 \qquad 1$$

As the energy transfered in time is equal to power, the mass from the last equation can be changed to mass flow as shown in the equation 2.

$$P = \frac{1}{2} \dot{m} \cdot V^2 \qquad 2$$

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2.1. Wind power

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$$\mathrm{E}_k = \frac{1}{2} m \cdot V^2 \tag{1}$$

As the energy transfered in time is equal to power, the mass from the last equation can be changed to mass flow as shown in the equation 2.

$$P = \frac{1}{2} \dot{m} \cdot V^2 \tag{2}$$

Due that the mass flow is equal to the volumetric flow times the density,

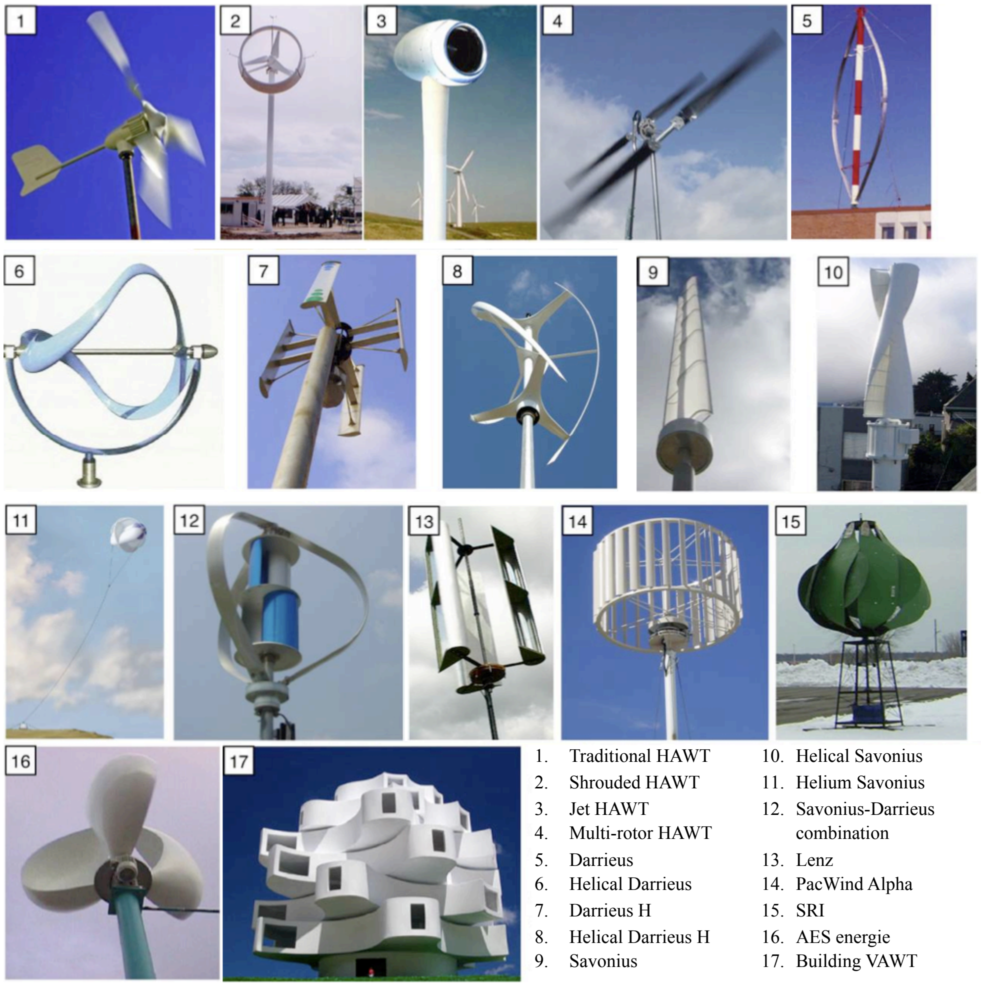
$$\dot{m} = \rho \cdot A \cdot V \tag{3}$$

The total power of the wind can be expressed as follows,

$$P_{wind} = \frac{1}{2} \rho \cdot A \cdot V^3 \tag{4}$$

2.1.1. Wind turbines

There are different kinds of turbines to capture the power of the wind, some of them are shown in the Figure 1. The most common are the horizontal axis wind turbines (HAWT), the Darrieus WT and the Savonius WT. Every one of those WT had evolve to generate the variations shown in the same Figure.



1. Traditional HAWT
2. Shrouded HAWT
3. Jet HAWT
4. Multi-rotor HAWT
5. Darrieus
6. Helical Darrieus
7. Darrieus H
8. Helical Darrieus H
9. Savonius
10. Helical Savonius
11. Helium Savonius
12. Savonius-Darrieus combination
13. Lenz
14. PacWind Alpha
15. SRI
16. AES energie
17. Building VAWT

Figure 1. Wind turbines. [generated by the author according to different internet sources]

This investigations focuses on the Savonius WT. This kind of device was invented by a Finnish engineer called Sigurd J. Savonius in 1922 and it was patented in 1926. It is classified as a vertical axis wind turbine (VAWT) although it can be installed horizontally or diagonally also. Aerodynamically its principle is based on the difference of the drag force that the wind exerts over the two blades whose profile its similar to an "S" (See Figure 2). The force difference is generated because when the air gets in contact with the blades one of those is concave and the other is convex according to the wind direction. This cause an effect that will try to move both blades in different directions but because the force exerted over the concave blade is superior that the force exerted over the convex blade the rotor will rotate.

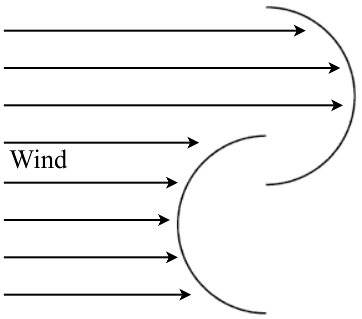


Figure 2. Typical profile of a Savonius WT rotor.

The change of the rotor shape according to the wind direction when the rotor is in movement will cause a cyclic load. In order to avoid that kind of behavior it was developed the helical Savonius. With the helical shape it is assure that a constant load will be applied to the electric generator, the vibration will be eliminated and the WT will be able to start with any wind direction.

The helical Savonius presents advantages over the HAWT that makes them capable to be installed on urban media. Some of the advantages are the following:

- It doesn't generate noise because the velocity of rotation doesn't exceed the wind velocity.
- It doesn't generate vibrations because of its helical shape and this allows them to be installed on buildings.
- It is safe with the animal life because its blades seems like solid objects.
- It doesn't need to be oriented to the wind (omni-directional)
- It can generate electricity with turbulent winds due to its omni-directional capacity.
- Starts at 1 to 3 m/s (10.8 km/hr, 7.75 MPH).

- Low maintenance as consequence of its low working speed and its few mobile parts.
- It can be manufactured with low cost materials and processes
- It can be installed in any position (but only the vertical is omni-directional).
- Attractive design.
- It can be installed on places with low average speeds as 4.5m/s (excellent for urban media).

On the other hand, the disadvantages are:

- Less efficient than the HAWT.
- The helical model has a complicated geometry.
- The general idea is that this is an obsolete technology.
- The actual market offers this kind of device at very high prices.

This characteristics point to the opportunity areas of this technology, and here is where it can be researched to offer a superior product for the society. From those points, the low efficiency according to the HAWT will be the focus on the present investigation.

2.1.2. Efficiency

The efficiency or C_P of a WT is defined as the total power extracted by the device over the total power of the wind, as expressed on the equation 5.

$$C_P = \frac{P_{WT}}{P_{wind}} \qquad 5$$

As the power of the wind can be expressed with the equation 4 and the power of a rotating body is equal to the torque times its angular velocity, the equation 6 can be expressed as follows.

$$C_P = \frac{Q \cdot \omega}{\frac{1}{2}\rho \cdot V^3 \cdot A} \qquad 6$$

As the optimization of the C_P is the main objective of this investigation, in this section it is shown the main improvements made to the Savonius WT according to this characteristic since the beginning of this technology.

On the Figure 3 it is shown the C_P of the most common types of WT's in which this parameter variates according to the TSR. This is because each wind turbine has an optimum working velocity, this velocity is called tip speed ratio (TSR or λ) and it is the relative velocity of the tip of the blade according to the wind velocity regarding to the equation 7. For the Savonius WT the TSR is around 0.8 to 1.

$$\lambda = \frac{r \cdot \omega}{V} \qquad 7$$

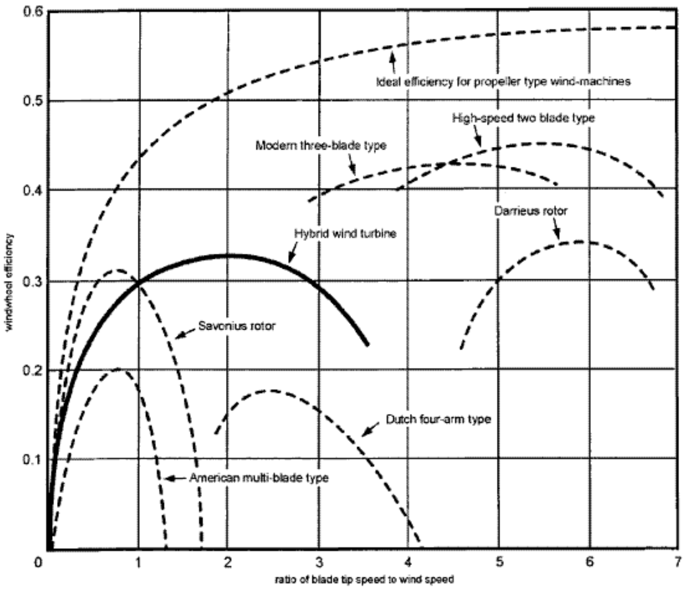


Figure 3. C_P according to the TSR for the most common WT's. [Becker, 2006]

On the last Figure it is clear that the Savonius rises at a maximum C_P over 30% compared with the 45% of the HAWT's. In the same Figure, a theoretical limit called the Betz' law is shown. This limit was determined in 1919, and it affirms that the device can extract a maximum of 59.26% of the wind energy.

$$C_{P\max} = \frac{16}{27} = 0.5926 \qquad 8$$

It must be clear that the limit shown in Figure 3 shows the Betz limit for propeller type WT, so this diminishing of the $C_{P\max}$ at lower TSR is only for HAWT's.

The Betz law supports the fact that the WT needs to take energy from the wind, this involves taking out velocity from it. So if you take velocity from it, the mass flow rate over the WT rotor will decrease and this will impact negatively in the power output. So there is a tradeoff between the velocity taken out from the air and the mass that passes through the rotor. This tradeoff is satisfied at its optimum point when the wind velocity at the outlet is 1/3 times the velocity of the inlet and these reaches the $C_{P\max}$ shown on Equation 8.

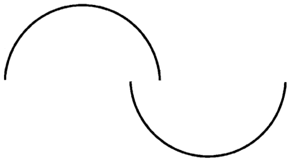
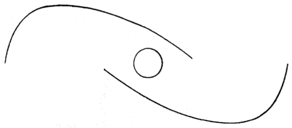
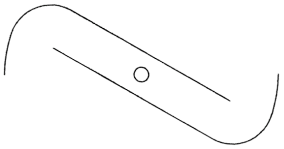
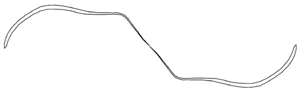
As an example, the power of a 10m/s wind that passes through an area of 1m^2 has approximately a power of 612.5 watts. From this total power of the wind, if the most efficient WT is built, it will be able of extracting only 363 watts according to the Betz law.

2.1.3. Evolution of the Savonius wind turbine

It is known that in order to maximize the C_P it is needed to modify the shape of the rotor because it is the responsible of capturing the kinetic energy of the wind and convert it into mechanical energy. For that reason the profile of the rotor is the principal point of interest, while the diameter may be a factor that can improve the performance.

In order to improve the efficiency of the Savonius WT there have been different investigations. All of this investigations have focused in shapes using profiles with a constant thickness in order to make them easy to manufacture. In the Table 1 are shown the principal improvements made to the C_P modifying the rotor profile.

Table 1. Savonius rotor CP improvements.

Rotor	Patent date	TSR	C_P	Reference	Profile Shape
Savonius	1926	0.85 0.85-1.15	~26.5 ~27	Blackwell 1977[*] Moutsoglou 1995[*]	
Benesh	1988	NA 0.85-1.15	33 ~29.5	US Pat. 4,784,568 Moutsoglou 1995[*]	
Benesh	1996	NA	37	US Pat. 5,494,407	
Rahai	2008	1.45	>40	US Pat. 7,393,177	

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[*] Wind tunnel test

2.1.3.1. Savonius rotor

The typical Savonius rotor consists in two semicircular buckets and has been improved on a couple of investigations. These projects claim that they have obtained shapes with superior C_P's.

The first formal research in this field was made by Blackwell in 1977. The improvement consisted in the creation of several one meter diameter wind turbines with two and three buckets and different overlaps. This investigation carried out by the prestigious SANDIA laboratories concluded that the optimum ratio overlap/diameter was between 0.1 and 0.15 reaching a C_P of approximately 26.5%.

One research was made by Valdès and Ramamonjisoa (2006) in which the optimal shape was obtained using an algorithm that modified the shape of the device. This shape modification was limited to semicircular blades in order to manufacture them with oil drums. On this investigation the design variants for improving the C_P were evaluated with a mathematical model that described the behavior of this WT.

Another research was made by Menet and Bourabaa (2003). They made variations to the overlap/diameter ratio in order to increase the C_P. The C_P on that investigation was obtained through a CFD analysis which is not detailed in the publication. The range of values evaluated for the ratio was 0.1 to 0.5 and they concluded that the optimum performance was obtained at a ratio overlap/diameter of 0.242.

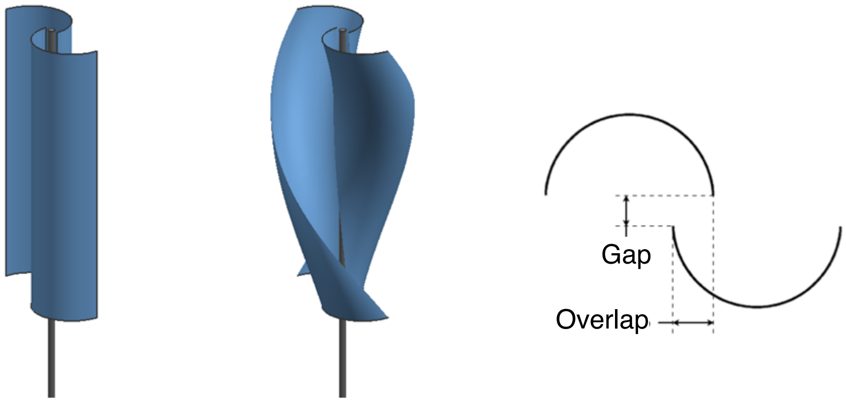


Figure 4. a) Savonius wind turbine b)Helical Savonius wind turbine, c) Savonius rotor profile.

2.1.3.2. Benesh rotor

Alvin H. Benesh developed two rotors with superior performance than the existing technologies at those times. The first was developed in july of 1987 and the patent 4,784,568 was released on november of 1988. In the patent, Benesh claims that its rotor reaches a C_P of 33%.

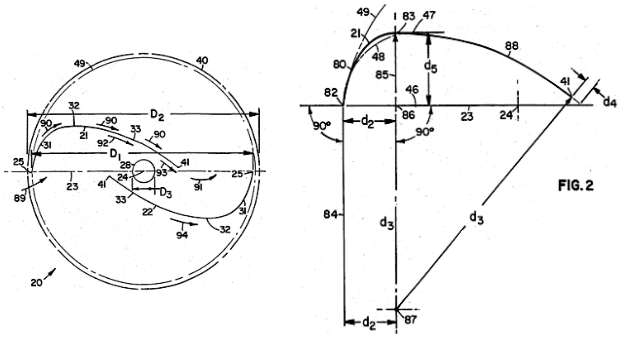
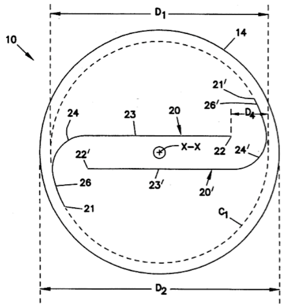


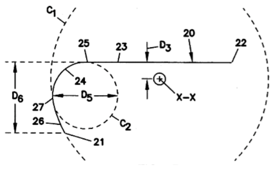
FIG. 2

$D_1 =$	D_1	$d_6 =$	$1.5D_1$
$D_2 =$	$1.05D_1$	$d_7 =$	$0.125D_1$
$D_3 =$	$0.1D_1$	$d_8 =$	$0.275D_1$
$D_4 =$	D_1	$d_9 =$	$0.125D_1$
$d_1 =$	$0.133D_1$	$d_{10} =$	$0.4D_1$
$d_2 =$	$0.151D_1$	$d_{11} =$	$0.067D_1$
$d_3 =$	$0.775D_1$	$d_{12} =$	$0.8D_1$
$d_4 =$	$0.025D_1$	$d_{13} =$	$0.575D_1$
$d_5 =$	$0.2D_1$	$d_{14} =$	$1.43D_1$

Figure 5. Benesh rotor shape. [Benesh, 1988]

The second design was developed in december of 1994 and in february of 1996, the patent 5,494,407 was released. In that document, the rotor shown in the Figure 6 was presented and according to Benesh, it could achieve a C_P of 37%.





Dimension	Ratio of Rotor Diameter
D_1	1 D_1
D_2	1.1 D_1
D_3	.075 D_1
D_4	.172 D_1
D_5	.3 D_1
D_6	.32 D_1

Figure 6. Benesh rotor shape. [Benesh, 1996]

2.1.3.3. Rahai rotor

This model is the newest development in the modification of a Savonius rotor. It was developed by Hamid R. Rahai in november of 2005 and the patent 7,393,177 was released on july of 2008. The rotor shape is presented in the Figure 7.

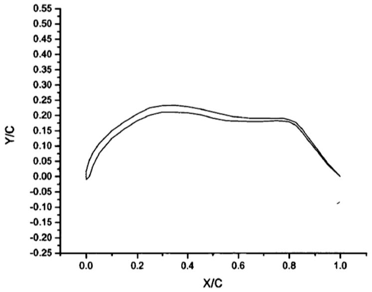


Figure 7. Rahai rotor shape. [Rahai, 2008]

This investigation consisted in an optimization of the Benesh (1988 Patent) profile, modifying it through the use of Hicks-Henne functions. The strategy of shape modification produced shapes as the ones shown in the Figure 8. It should be noted that Rahai also added one factor to the shape modification that is not shown in that Figure; that is the overlap. Those shapes were then evaluated using a computational fluid dynamics (CFD) 2D steady analysis.

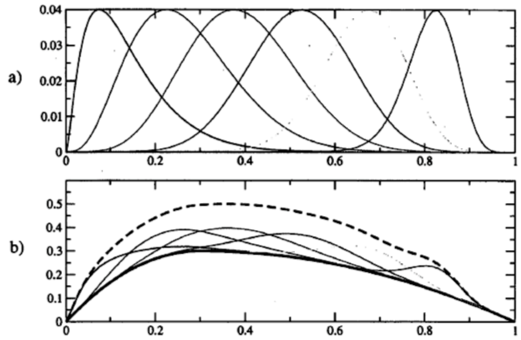


Figure 8. Shape variations made by Rahai. [Rahai, 2008]

The optimization process was carried out implementing a non-linear sequential quadratic programming scheme using a multidisciplinary design optimization (MDO) software. In this case the MDO software used was iSIGHT. This process was completely automated and the result is compared with the initial design in the following Figure.

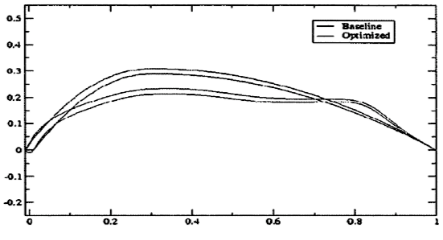


Figure 9. Initial (Benesh 1988) and optimized profile. [Rahai, 2008]

In figure 10, Rahai compares the C_P of its rotor with Benesh's 1988 C_P and the C_P of the Savonius rotor. It doesn't mention the wind velocity at which it was evaluated but it does say that the values for the Benesh and Savonius rotor where obtained by Moutsoglou and Weng.

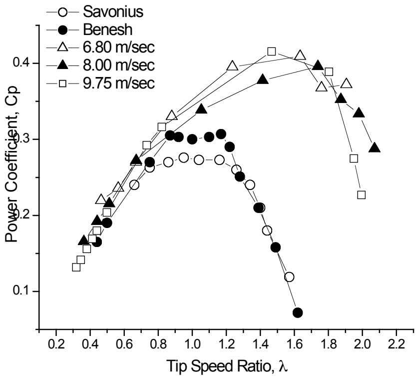


Figure 10. C_P comparison for the Rahai, Benesh 1998 and Savonius rotors. [Rahai, 2008]

The optimized rotor has the shape specified on Figure 7. It is worth mentioning that it is only the blade's shape and it must be added the overlap. In this case the zero overlap design was the one with better performance.

On Figure 11 it is shown one of the 2D steady CFD analysis. It is a velocity contour of the optimized blade with an overlap of 48%.

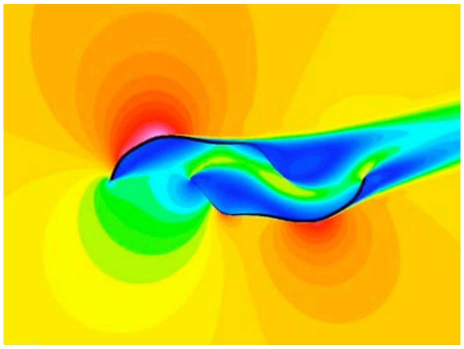


Figure 11. 2D Steady CFD analysis of a Rahai rotor with 48% of overlap ratio. [Rahai, 2005]

With this results it can be concluded that the optimized rotor can generate electricity rotating at higher angular speed than the rest of the Savonius rotors. The patent declares that this rotor can achieve a C_P superior to 40% at a TSR of 1.5. This results must be taken with discretion given that they don't present neither wind tunnel tests nor any of their CFD analysis parameters. Furthermore the CFD analysis was performed steady and due to the nature of the Savonius rotor, it must be evaluated as unsteady.

2.1.3.4. Hybrid wind turbines

Another Savonius wind turbine has been developed using a combination of two different VAWT's. This development has two different origins. The first development was made some decades ago, in order to assist the Darrieus WT on the starting given it could not start by itself. The second development appeared as an intent to improve the C_P of the Savonius WT. It was invented by William S. Becker and the patent was released on november of 2006. He declared that his hybrid VAWT could reach a C_P higher that 30% at TSR around 2 (See Figure 3). This means that the working velocity is higher than any of the previous Savonius rotors.

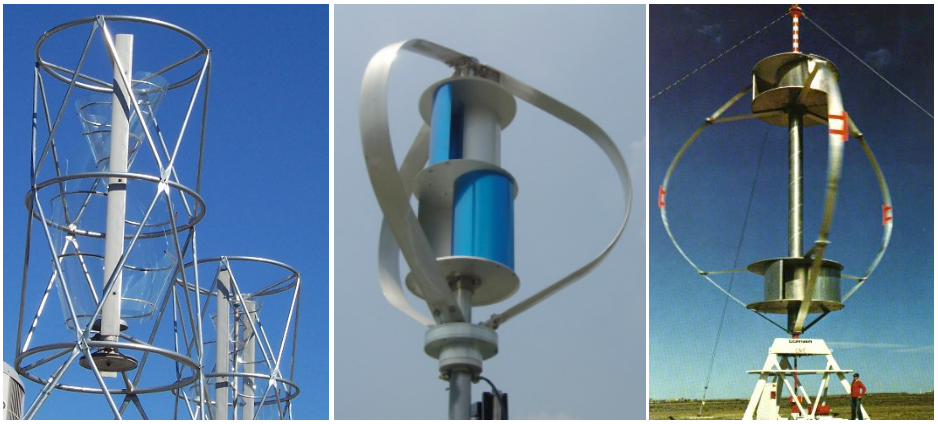


Figure 12. Combination of Savonius-Darrieus rotors, Becker at left and traditional combination at center and right. [generated by the author according to different internet sources]

2.1.4. Market overview

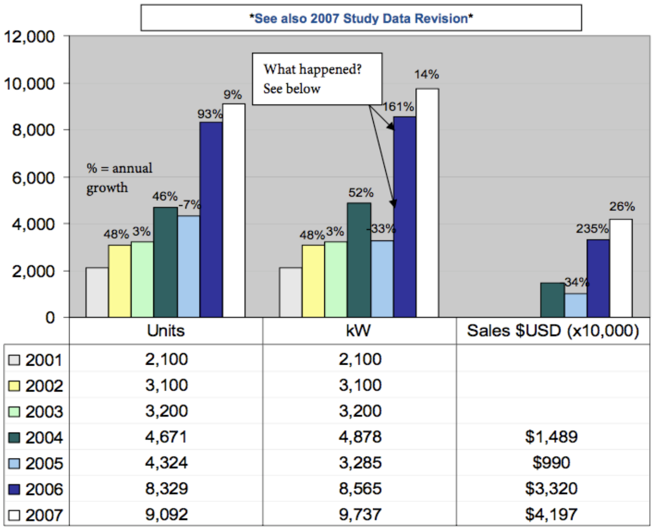
The necessity to electrify zones that don't have access to the electric grid have impulsed the presence of different kinds of devices that take advantage of alternative sources of energy such as low scale wind and solar energy systems between 50 and 2000 watts. This needs have created a new niche market that has been filled with products especially designed to meet the necessities of this kind of lone places. Those devices include wind turbines, photovoltaic cells and solar boilers and are now considered as mature products.

On the other hand, the development of that kind of devices, the rising of the fossil fuel prices, and the growing interest of the people to reduce their impact in the environment has created a new market opportunity that include urbanization's with access to the electric grid. This new consumers can be connected to both their renewable energy devices and to the electric grid to consume electricity from it when the devices aren't taking energy from the wind or/and sun. This kind of grid/device connection can reduce a big percentage of the monthly electricity bill and at the same time it reduces the negative impact to the environment.

This new market has created new companies that offer a wide variety of small HAWT but on the last years, there are arising some VAWT that have better characteristics to make them suitable for the urban media.

According to the American Wind Energy Association (AWEA), the U.S. small wind turbine market grew 14% and deployed 9.7 MW of new capacity on 2007. This small WT market consists of devices with a capacity bellow 100 kW and an average of approximately 1 kW.

On the Figure 13 it is clear that in the year 2005 the sales went down in an alarming rate. That is explained because in California -the principal consumer of this kind of technology- the incentives for small wind systems decreased dramatically in 2004.



	Units	kW	Sales $USD (x10,000)
□ 2001	2,100	2,100	
🟨 2002	3,100	3,100	
🟩 2003	3,200	3,200	
■ 2004	4,671	4,878	$1,489
🟦 2005	4,324	3,285	$990
■ 2006	8,329	8,565	$3,320
□ 2007	9,092	9,737	$4,197

Figure 13. Growth of U.S. small wind market. [AWEA, 2008]

The application of incentives on this kind of technology increases the demand for this products. According to AWEA,

> “In its current (and historic) state without a federal-level incentive to assist consumers purchase small wind systems, the U.S. market continues to grow an estimated 14-25% annually. Grid-connected, residential-scale systems 1-10kW in capacity constitute the fastest growing market segment.[...] The advent of a 30% federal Investment Tax Credit could lead to an estimated 40-50% annual growth, similar to that experienced by the U.S. solar photovoltaic (PV) industry with the

> 2005 creation of such a credit. AWEA, its allies, and industry are actively advocating for legislation that would create a 30% credit for turbines 100kW and under.”

(AWEA; 2008: 3)

On Figure 14 the increase on the sales of on-grid WT’s with capacities greater than 1kW is visible and it gives us very important information of the tendency of the market.

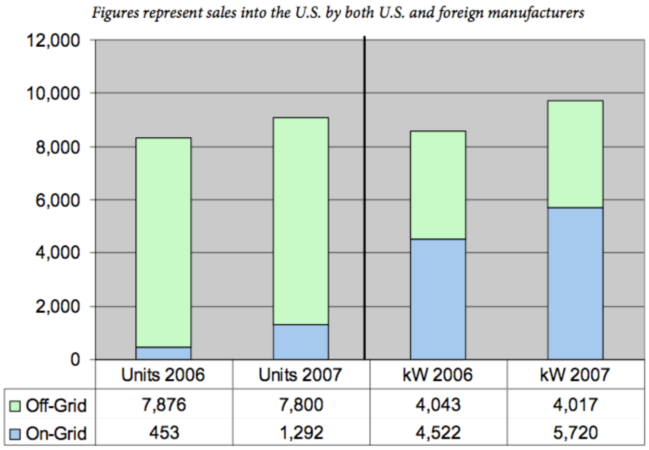


Figure 14. U.S. market: On-grid Vs. Off-grid. [AWEA, 2008]

2.2. Computer aided design

The computer aided design (CAD), is a software that is primarily used on the engineering, design and architecture industry. The main function of this tool is to aid the design and elaboration of technical drawings of products. This software is capable of modeling 2D and 3D drawings, surfaces and solids that virtually represents products or parts of them.

The 2D model creation is commonly driven by basic shapes as lines and arcs that are placed together in a plane. On the other hand to create 3D solids, different kind of features like extrusions, revolves or sweeps are applied to the mentioned basic shapes. Then those solids are detailed with features like rounds, chamfers, boolean operations, among others. The next Figure exemplifies a 2D and a 3D model.

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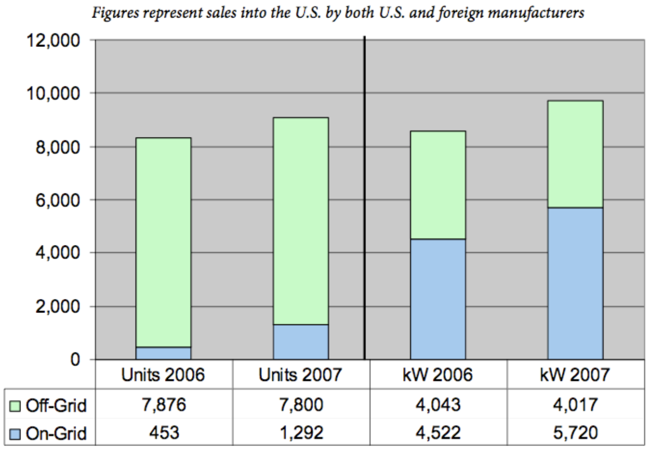

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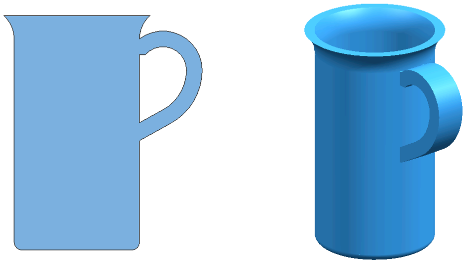


Figure 15. 2D and 3D part modeled on a CAD software.

The dimensions and positions of the lines and arcs mentioned on the last paragraph can be defined by parameters with values that can be changed. This changes of values generates modifications to the model and can be defined in order to facilitate the model modification. This kind of technique is called parametric modeling. It can be useful to modify models but the possibilities are limited by the parameters defined at the moment of the creation of the model. On Figure 16 it is illustrated a parametric model with different parameter values. In it the height, radius and thickness of the handle where modified.

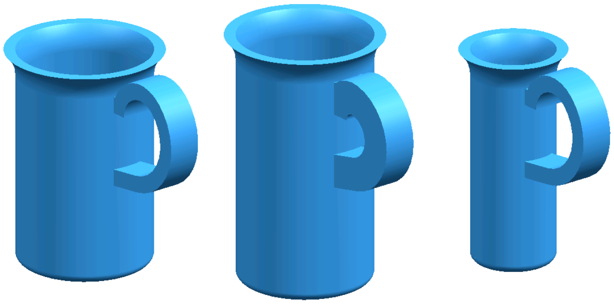


Figure 16. Modifications to a parametrized model.

Another kind of shape that can substitute the lines and arcs is commonly called spline. This shape is a curve defined piecewise by polynomials and its correct name is B-spline which is a generalization of the Bézier curve. It is created by adding control points that define the position of the curve. From this points only the first and the last are in contact with the curve, the other points only serve as “magnets” that attracts the curve in a smooth way as seen on Figure 17. The smoothness of the curve can be modified by changing the degree of the B-spline. This degree can be set as linear, quadratic, cubic, or greater, but it needs to have a degree smaller than the number of control points on the curve.

There is another approach called interpolation B-spline. This technique differs from the simple B-spline because with this approach all the control points are in contact with the B-spline curve. This difference can be observed on Figure 17 and makes it superior in the CAD parametric modeling.

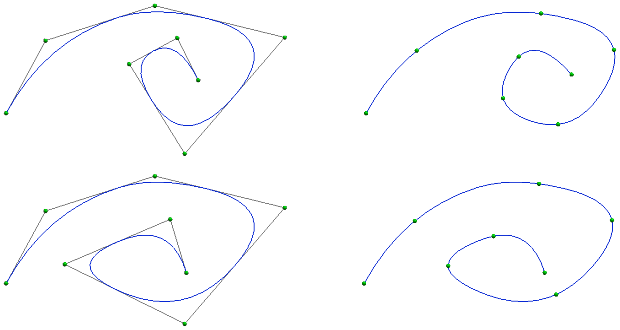


Figure 17. Quadratic b-spline (left) and quadratic interpolation b-spline (right).

The parametric modeling using B-splines can offer superior possibilities when trying to modify a model. On Figure 18 is shown a model made with B-splines that has been modified. Such modifications can produce shapes that a combination of circles and lines never could generate.

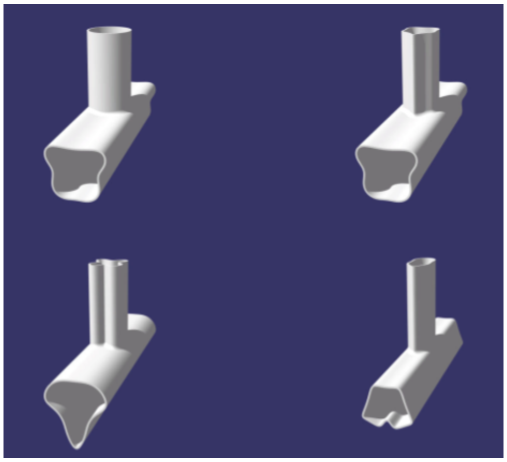
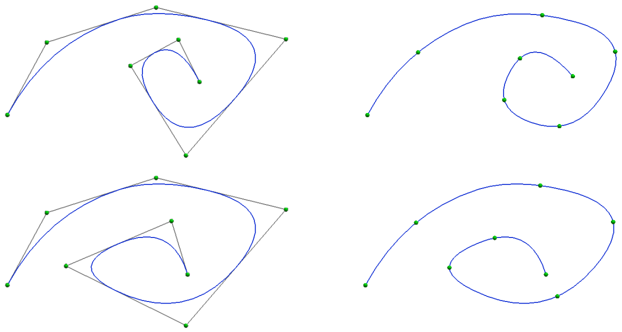


Figure 18. Modifications to a parametrized model created with splines. [Cueva, 2006]

2.3. Computer aided engineering

This technology is another of the computer aided field (CAx). It is a tool that helps the engineering teams to simulate, analyze, and manufacture products virtually. This can save money and time to the development of new products because it decrease errors and helps to design robust products and processes.

The CAE includes areas like Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) and Multibody Systems.



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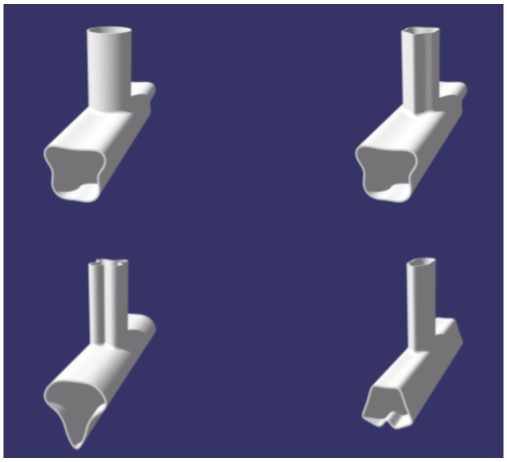

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The CAE includes areas like Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) and Multibody Systems.

To use a CAE software it is needed to follow three steps, the first is the pre-processing, the second is the analysis solver and the third is the post-processing.

On the pre-processing stage the virtual model is defined and discretized dividing it in small sections or elements. The group of elements is defined as a mesh. Then the initial and boundary conditions are set. This conditions are the forces applied to the model, material properties, movement of parts, among others. Finally the solver is defined. This involves the selection of equations of motion, turbulence, species, among others.

The second stage involves the analysis of the model defined on the first stage. This stage can be highly demanding with the workstation. Some analysis are restricted to very powerful computers.

On the third stage the results are analyzed using visualization and plotting tools. This tools can show the loads, power, energy, temperature or whatever the engineer is analyzing.

2.3.1. Mesh

As the previous section mentioned, the mesh is the discretization of the model that is being analyzed. That force us to create a detailed mesh to obtain an accurate representation of the model in order to obtain good results.

Depending on the model, every mesh is composed by several 2D and/or 3D elements. Every element is defined by nodes positioned on each vertex and the second order elements have one more node positioned on the center of every edge. On the Figure 19 are illustrated the most common types of elements. The first column illustrates 2D elements, the first two are called triangular (tri) and quadrangular (quad), the next two are are defined as second order tri and second order quad. The second column shows tetrahedral (tet), pyramid, pentahedral (also called wedges and triangular prisms) and hexahedral (hex) elements. On the third column can be observed the same as in the second column but defined as second order. It can be notice that the second order elements has more nodes, this generates more precise results but also it demands a more powerful computer to solve it.

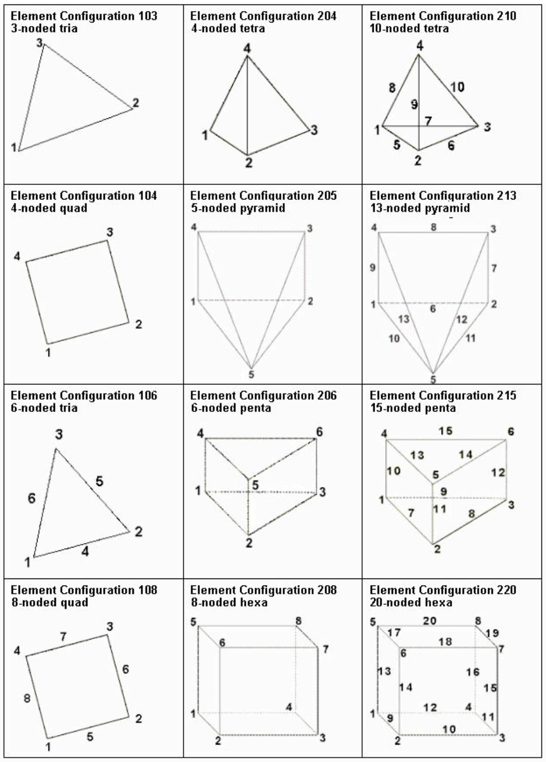

Figure 19. Most common element types. [Altair Engineering, 2007]

To create a mesh first it is needed to define the size, number or density of elements desired on each edge. Then the surfaces are meshed with tri, quad or mixed elements according to the mesh of the edges. The next step (only for 3D models) is to mesh the solids using any kind of elements, this mesh is created according to the surfaces mesh. On the Figure 20 can be seen a representation of a 2D tri mesh and a 3D hex mesh.

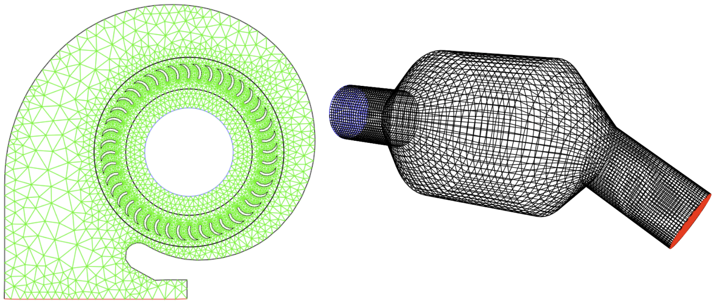

Figure 20. Examples of a 2D and 3D mesh. [Fluent, 2006]

The mesh creation is made automatically by the software according to the defined mesh size. This automatic process is very simple when using tri/tet elements but in the case of the quad/hex it can be very time consuming and require some experience. The reason of continuing using this kind of elements is its superior accuracy over the rest kind of elements. According to Fluent,

> “For simple geometries quad/hex meshes can provide high quality solutions with fewer cells than a comparable tri/tet mesh. [...] For complex geometries, quad/hex meshes show no numerical advantage, and you can save meshing effort by using a tri/tet mesh.”
>
> (Fluent; 2001: 2-9)

There are two kinds of mesh according to the elements distribution on the model, the unstructured or paved and the structured or mapped (Shown in Figure 21).

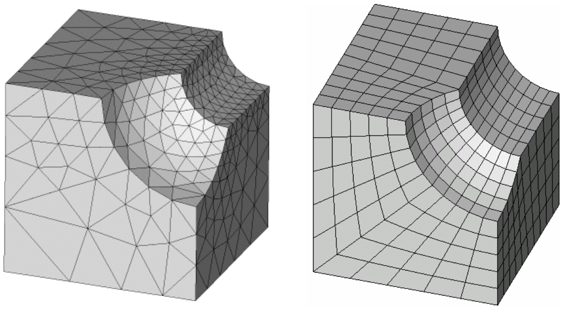

Figure 21. Comparison of unstructured (left) and structured (right) meshes. [ANSYS, 2007]

The unstructured mesh is the most easy to create. It is made defining only the density or size of the elements on every face of the model and is generated automatically with any kind of elements. On the other hand the structured mesh is a more accurate way of discretizing the models but it is considerably more difficult to create. It can be created with any kind of elements but mainly it is used with quad and hex. Due to the difficulty of meshing this kind of elements the meshing process commonly fails and require some changes in the mesh size or a different meshing approach.

On CFD analysis is common to find another characteristic in the elements. It is a more detailed mesh that is placed on the edges that has a interaction between solids and fluids. It is called boundary layer and it is created to generate more accurate results in the zones with fluid/solid interaction where the laminar/turbulent transition flows should appear.

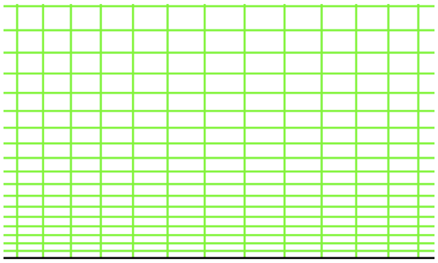

Figure 22. Boundary layer. [Fluent, 2006]

2.3.2. Computational fluid dynamics

This tool is used to model and measure the flow of fluids. To this flow it can be added heat, mass transfer, phase changes, chemical reactions and interaction with moving solids in order to accurately represent the analyzed system or device.

The CFD codes are based on two main aspects, the physical modeling and the numerical methods.

The physical model translate the information of the analyzed system or device contained on the mesh into a set of equations that relate the governing equations of mass, momentum (Navier-Stokes equations) and energy conservation (thermodynamics 1st law). There are different approaches to compute this task. The most used methods are finite volume method (FVM), finite difference method and finite element method. From this approaches the FVM is the most widely used in commercial CFD software such as: Fluent, STAR-CD, CFX, OpenFOAM, Phoenics, FloWorks, Numeca, among others. When this task finishes it process ti creates a set of partial differential equations that needs to be solved.

The numerical method is in charge of solving that differential equations. To complete that task the numerical method first needs to transform each differential term into an algebraic relation. This transformation can be done with different techniques for every set of equations. The momentum or Navier-Stokes equations are typically solved using SIMPLE, SIMPLER, SIMPLEC or PISO methods. For other terms such as turbulence, convection, etcetera, there are methods such as first order upwind, second order upwind and QUICK.

The transformation of the differential equations creates a linear system of equations that can be solved using iterative methods. Typical direct methods cannot be used because they are computationally expensive, inefficient for large sparse matrices and the non-linearity of the coefficient of the system's matrix forces to use iterative methods. This iterative method compute the results of the CFD analysis until it converges, another way saying it, is that it will compare the results of the new computation with the results of the las computation and when the error stays lower than the user defined value, the solution is reached.

When the analysis is time dependent it must be added one more consideration, the time. The CFD analysis can be steady when the flow reaches a point where the solution converges or unsteady when the fluid never reaches a steadiness and it can be caused by the creation of vortexes or because the physical model involves solids in movement or cyclic flows. For the unsteady analysis the term of time should be added to the conservation equations. This forces us to discretize it and it can be done as first or second order. The unsteady analysis consist in an analysis that will be computed several times. The separation in time of every one of those analysis is defined as time step size (TSS) and it will consist in as many time steps (TS) as needed, usually until a cyclic result that doesn't change is observed.

The pre-processing stage of a common CFD analysis consists in the following steps:

- Import the mesh file.
- Solver selection: this step consist in the selection of the type of analysis, discretization method for the time and conservation equations, turbulence models.
- Operating conditions: Conditions such as gravity, operating temperature and operating pressure.
- Boundary conditions: The conditions of the physical model are set in this step. Pressure inlet, velocity inlet, pressure outlet, velocity outlet, outflow, mass flow inlet, fan, wall, symmetry, porous media and radiator are some of the possible boundary conditions.
- Initial conditions: This conditions are a initial guess of the results that the analysis is going to generate. Usually it is defined as a velocity, pressure and turbulence intensity that is assigned to the surfaces and solids, but there is another approach defined as interpolation. This approach consist in taking the results from another similar solved analysis that can be a more close initial guess and can save computation time.
- Residuals: Here the user select the accuracy of the results by defining the acceptable value for the residuals.
- Solve: In this step the the number of iterations is defined for steady analysis and the TSS, TS and number of iterations for each time steps is defined for unsteady analysis.

After the convergence is reached. The user can obtain the results as an image with contours, vectors or as a plot. Some of possible results that can be computed are pressure, total pressure, dynamic pressure, density, velocity magnitude, density, temperature, turbulence intensity, among others. On the Figures 23 and 24 it is observed the resultant total pressure contour and velocity vectors for the analysis of a 2D blower.

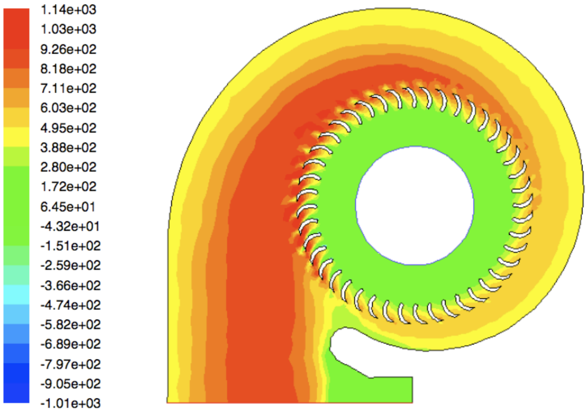

Figure 23. CFD total pressure contour. [Fluent, 2006]

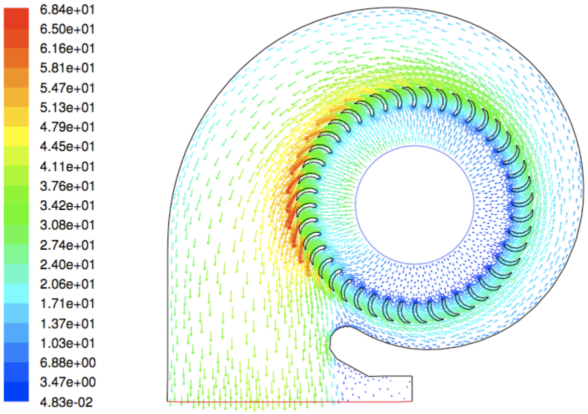

Figure 24. CFD velocity vectors. [Fluent, 2006]

Some other considerations must be defined when a CFD analysis is performed. One of them is the compressibility of the fluid that can be neglected when the Mach number (M) in the system is much less than 1 ($M<0.1$). Another consideration is the type of flow that is going to be analyzed, it can be inviscid, laminar of turbulent.

The turbulence is a fluid flow that seems to be random and chaotic in 3 dimensions and it is very difficult to accurately modeling it. There are different models to describe this kind of phenomena such as Spalart-Allmaras, *k*-ε Standard, *k*-ε RNG, *k*-ε Realizable, *k*-ω Standard, *k*-ω SST, Reynolds stress, detached eddy simulation and large eddy simulation. From these models only the Splarat-Allmaras, *k*-ε, *k*-ω and Reynolds stress method can be applied in 2D simulations in the most common commercial CFD codes. From these models the *k*-ε is the simplest of the “complete models” and according to Fluent,

> “The standard k-ϵ model in FLUENT falls within this class of turbulence model and has become the workhorse of practical engineering flow calculations in the time since it was proposed by Launder and Spalding. Robustness, economy, and

> reasonable accuracy for a wide range of turbulent flows explain its popularity in industrial flow and heat transfer simulations."
>
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The standard k-ε model has been modified to improve its performance in different flow conditions. From those developments, the Realizable k-ε model "provide superior performance for flows involving rotation, boundary layers under strong adverse pressure gradients, separation, and recirculation" mentioned Fluent (2006).

2.4. Genetic algorithms

A genetic algorithm (GA) is a searching technique based on the evolution of species and genetics. From the evolution of the species, the GA's has taken the techniques of selection according to fitness, crossover (also called recombination or hybridization) and mutation. From the genetics field, the GA's use the codification of the chromosome (also called genotype) as basis to code in strings the search space of a problem. Therefore the search can be performed modifying the chromosomes until the objective is reached.

As mentioned, the genotype is expressed as a string of genes that are represented with numbers (0001011101) in any numeral basis although the most common is the binary representation. This genotype can be translated to some characteristics called phenotype. An analogy to this can be that some person has certain gene o group of genes into its chromosome that represents green eyes, this representation of the genotype is defined as the phenotype.

On Table 2 it is presented a representation of the genotype, phenotype and fitness. In this Table is shown a binary genotype on the first column that is translated to its phenotype form which in this case is the value for the variable x. This translation is made by converting the binary number value to decimal. Then the fitness is calculated with a specified function, simulation or analysis, which in this case is the equation 9.

$$f_{(x)} = \sqrt{x^3} \qquad 9$$

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Table 2. Representation of genotype, phenotype and fitness.

Genotype or Chromosome	Phenotype or Variable value	Fitness or Evaluation
1 0 1 0 1	21	96.23
0 0 1 1 0	6	14.69
1 0 0 0 1	17	70.09

The genotypes can represent more than one variable. The example shown in the Figure 25 represents a 10 bits genotype formed by two variables, each one with a length of 5 genes. Each of this group represents a variable that can be decoded changing it numeral basis from binary to decimal. In this example the variable *x* (0 1 0 1 0) represents a decimal value of 10, and the variable *y* (1 1 0 0 1) represents a value of 25. As the length of both sets of genes are 5, each of this variables can represent 31 (2^{5-1}) possible of combinations.

$$\overbrace{0\ 1\ 0\ 1\ 0}^{x}\ \overbrace{1\ 1\ 0\ 0\ 1}^{y}$$

Figure 25. Genotype representation with two variables.

Supposing that a GA is trying to obtain the values for x and y that maximize the equation 10 using the genotype defined on the last Figure. It can be concluded that the variable x will have 31 possible values to search for an optimum between 0 and 2 and the variable y will have the same 31 possible values between 0 and 1.

$$f_{(x)} = \sqrt{\frac{x^3}{y}}\ ,\ x=0\ldots2,\ y=0\ldots1 \tag{10}$$

So for the variable *x* the genotype 00000 will represent the value 0 and the genotype 11111 will represent the value 2. The values between this limits will be obtained when changing the value of the genotype in it binary basis and it will represent 31 values between them.

The process of a GA can be explained with the next steps, and it can be observed on the Figure 26.

1. Genotypical representation selection: The first step to implement a GA is to select the type of codification of the genotype. In order to complete this task, it is needed to define the numeral basis, number of variables and length of genes for every variable. The length

of every coded variable needs to be defined with enough resolution in order to achieve the optimization task.

2. Initial population generation: It must be defined the number of individuals for the initial population and its values. By default this is defined randomly, but they can be defined manually.

3. Individual evaluation: Once the population is ready, the evaluation takes place. Depending on the problem, the evaluation can be an equation, simulation on CAE software or any situation that offers an evaluation of the fitness.

4. Reproduction: This task divides in three stages that are inspirited in the evolution of species. It is a very important step because in it takes place the creation of new individuals.

    a. Selection: In this stage the individuals with better fitness according to the objective are selected to breed a new generation of individuals.

    b. Crossover: Here the selected individuals on the last stage are placed in pairs and then their genotypes are crossed using a crossover operator. This operator cuts each genotype in a random gene and then changes the sections after the cut from one individual to the other. This process generates two child's from two parents. The occurrence of this process can be present in every set of parents but also it can be defined to occur with a defined probability.

    c. Mutation: This operator consist in randomly change the value of the bits inside a genotype. It is used with a low probability of occurrence in order to generate “errors” in some individuals. This has the propose to avoid local optima by preventing similar genotypes becoming to similar to each other.

5. The steps 3 and 4 repeats until the GA reaches the objective.

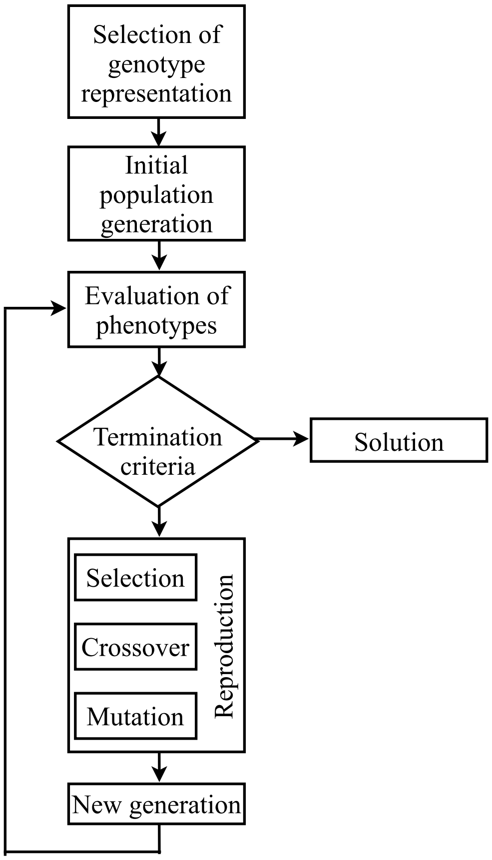

Figure 26. Diagram of a genetic algorithm. [Arcos, 2006]

Chapter 3

Methodology

On this chapter, the methodology used for the optimization of the Savonius rotor is presented. It consists in the automation of the optimization process aided by multidisciplinary design optimization (MDO) software. The optimization consists in the improvement of the wind turbine performance modifying the shape of the rotor profile and the TSR.

Inside the MDO environment are different types of optimization algorithms that can be chosen. Among these, a genetic algorithm was selected to direct the automated design optimization process. In this automated process, different kinds of softwares were involved to carrie out different tasks. First, a CAD software is needed to modify the shape of the Savonius rotor, then a meshing software discretize the geometry created with the CAD system. After that, a 2D CFD analysis is carried out to calculate the C_P of the shape. At the end of this process, the GA inside the MDO software analyzes the results of the generation of individuals and generates the child's that will be analyzed on the next generation.

3.1. Strategies for the integration of the optimization process

The mentioned process is simple, but it needs the knowledge of CAD, CAE such as mesh software and CFD and MDO software. Also it requires the ability of integrating all of this softwares using automating strategies such as macros, journals and DOS script.

In this section the strategies used for the setup of the automated process are presented. First, the modification of the model in CAD is described. Then, the mesh technique used is analyzed. This is followed by the CFD analysis and the process of reading the results.

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On this chapter, the methodology used for the optimization of the Savonius rotor is presented. It consists in the automation of the optimization process aided by multidisciplinary design optimization (MDO) software. The optimization consists in the improvement of the wind turbine performance modifying the shape of the rotor profile and the TSR.

Inside the MDO environment are different types of optimization algorithms that can be chosen. Among these, a genetic algorithm was selected to direct the automated design optimization process. In this automated process, different kinds of softwares were involved to carrie out different tasks. First, a CAD software is needed to modify the shape of the Savonius rotor, then a meshing software discretize the geometry created with the CAD system. After that, a 2D CFD analysis is carried out to calculate the C_P of the shape. At the end of this process, the GA inside the MDO software analyzes the results of the generation of individuals and generates the child's that will be analyzed on the next generation.

3.1. Strategies for the integration of the optimization process

The mentioned process is simple, but it needs the knowledge of CAD, CAE such as mesh software and CFD and MDO software. Also it requires the ability of integrating all of this softwares using automating strategies such as macros, journals and DOS script.

In this section the strategies used for the setup of the automated process are presented. First, the modification of the model in CAD is described. Then, the mesh technique used is analyzed. This is followed by the CFD analysis and the process of reading the results.

Finally the GA used is described and the integration of the whole process in the MDO software is discussed.

All of this tasks automated by macros and journals must be able of analyzing different rotors shapes and at different TSR. For that reason, the variables of the design shape and the operation conditions such as the TSR must be introduced to the macros and journals of every design iteration. In order to do that, the MDO software is capable of editing the macros and journals adding this variables in the correct position of the text.

3.1.1. CAD

For the modification of shape propose, first a parametric 2D model of the Savonius rotor was created using the commercial software Unigraphics NX5. As it needed to have enough flexibility to generate a big space of search it was decided to create it using interpolation B-splines. This curve was created using six control points that could be moved changing its position using a polar coordinate system as seen on Figure 27. From this control points only the black one was fixed, the other five points was defined as variables. The angles were named from a1 to a5 and the lengths were defined from l1 to l5. The lengths were defined as a proportion of the diameter, so in case of a diameter length change their values also change to form the same shape. This strategy is useful if the GA used the diameter as a variable to optimize because using certain values of l1...l5 with different diameter values the shape will have the same appearance but with different size.

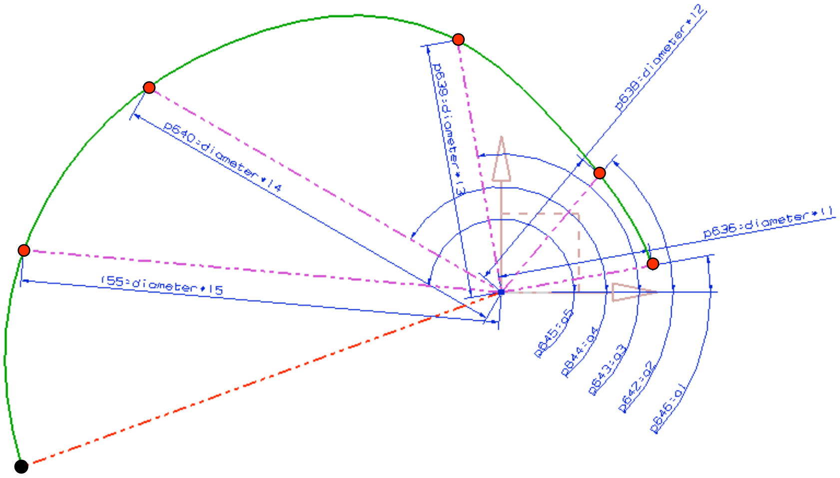

Figure 27. Parametrized interpolation B-spline used to model one blade of the rotor.

Finally the GA used is described and the integration of the whole process in the MDO software is discussed.

All of this tasks automated by macros and journals must be able of analyzing different rotors shapes and at different TSR. For that reason, the variables of the design shape and the operation conditions such as the TSR must be introduced to the macros and journals of every design iteration. In order to do that, the MDO software is capable of editing the macros and journals adding this variables in the correct position of the text.

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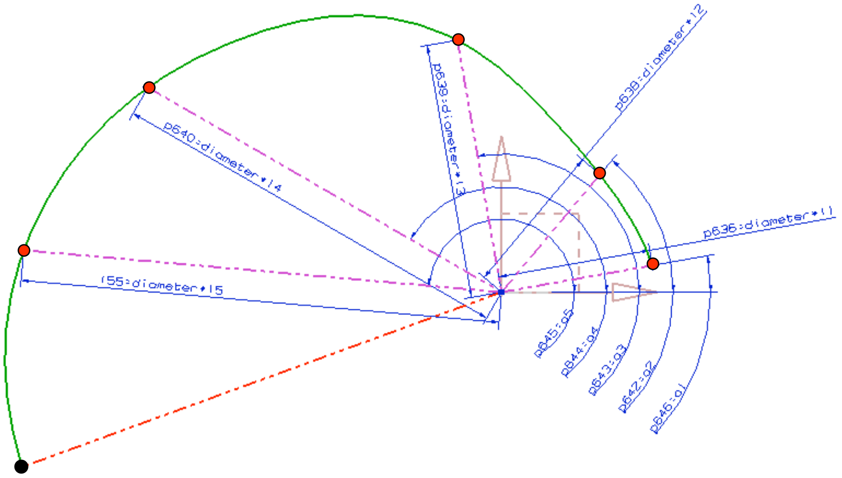

Figure 27. Parametrized interpolation B-spline used to model one blade of the rotor.

The next step in the model generation is to apply a thickness to the curve created before and round it on the extremes using a radius equal to the half of the thickness so that the shape had tangent edges. This thickness can also be used as a variable in the optimization process. The next step was to generate a rotated copy and positioned it at 180 degrees to create the second blade of the rotor.

After the rotor was defined, the next step was to determine the fluid zone that was going to be analyzed with CFD. This zone needed to be divided in two surfaces. The first is the rotor zone: it needed to have a circular shape with the rotor centered in it, also it needed to have a space between the tip of the blades and the edge of the surface. A 10% of the rotor diameter was used as the separation mentioned before. The second zone was the fluid around the rotor. This zone was needed in order to avoid tunnel effects that concentrate the fluid, which are negative in the analysis and must be avoided. Cochran *et al* in 2004 used a fluid zone with a size of 10 turbine diameters for each direction. For this zone, ti was increased the size in the direction to the outlet (right) in order to minimize the influence of the boundary condition of the outlet (Pressure=0). On the next Figure it can be observed the two zones and three rotor modifications of the traditional Savonius with overlap.

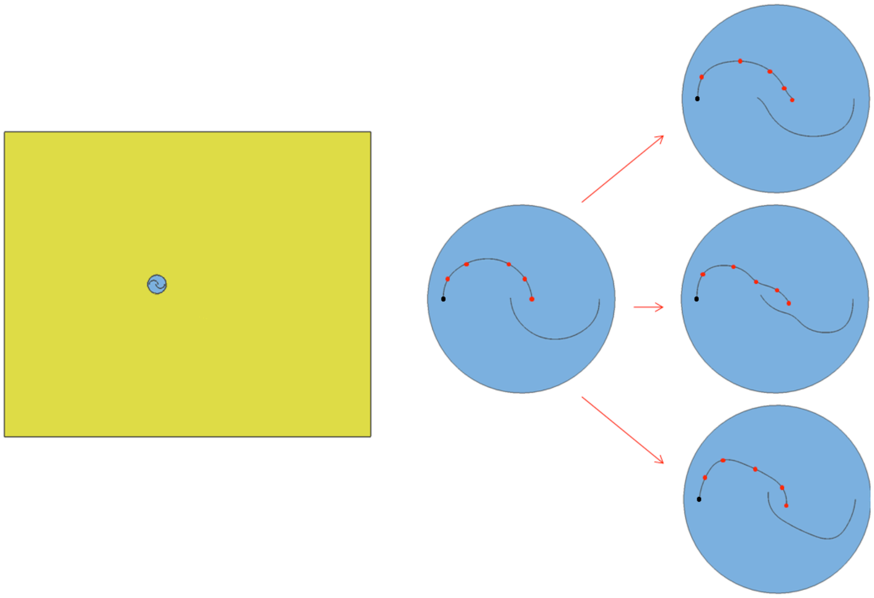

Figure 28. 2D Savonius rotor modeling and possible rotor modifications.

Nevertheless the analysis is 2D, the diameter changes can be translated as shapes modifications observer on the Figure 29.

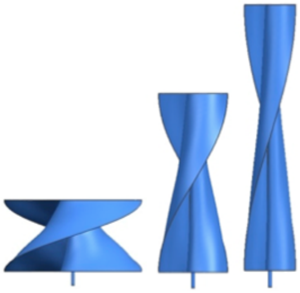

Figure 29. Rotor diameter modification maintaining the sweep area.

The polar coordinate system proposed has advantages over the cartesian system because it is easier to assign ranges to the variables that avoid the overlap of the points. On Figure 30, an example of the search space for every control point is illustrated. In it can be seen at left the range for every variable and at right the area delimited by those ranges.

0.05 < l1 < 0.2
0.1 < l2 < 0.25
0.15 < l3 < 0.3
0.25 < l4 < 0.45
0.45 < l5 < 0.5

-20 < a1 < 60
70 < a2 < 110
115 < a3 < 145
150 < a4 < 170
175 < a5 < 195

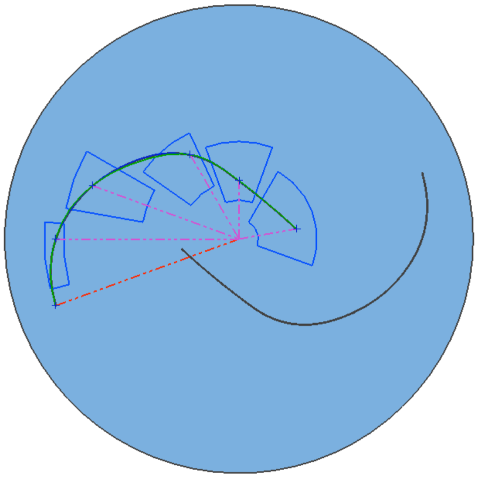

Figure 30. Search space for a specific range for the variables using polar coordinate system.

This kind of modeling is suitable to match the main optimized Savonius rotors presented on the theoretical background. In Figure 31 are presented different rotors created using the variables values detailed on Table 3. This rotors match the shapes of the Savonius, Benesh 1988 and Benesh 1996 rotors.

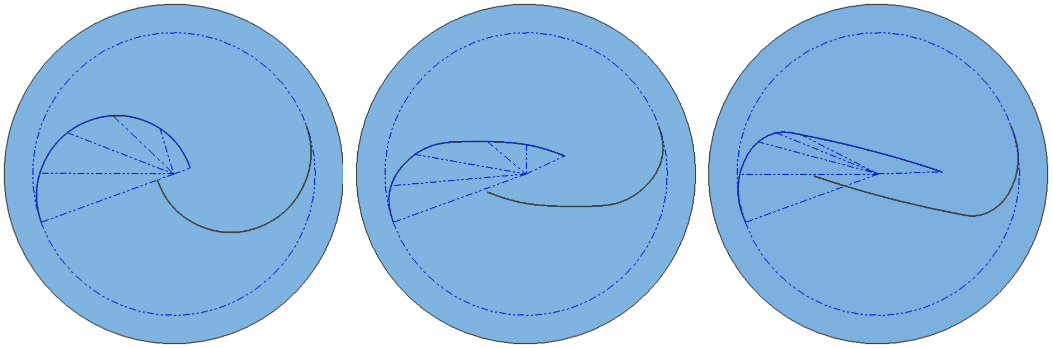

Figure 31. Rotor shape modification.

Table 3. Values for the angles and lengths.

Variable	Savonius		Benesh 1988		Benesh 1996	
number	Angle	Length	Angle	Length	Angle	Length
1	20	0.0625	25	0.1519	2	0.228
2	107	0.17	90	0.105	153	0.31
3	136	0.3	140	0.18	158	0.39
4	159	0.405	170	0.4	165	0.44
5	180	0.475	185	0.48	180	0.49

For the automation of this step of the optimization process, the Savonius 2D model was modified using a macro. This macro was created using the user interface of the CAD system. Then it was edited and the word COUNTER (gray marked in the macro code) was added to the file names that the macro ask the CAD software to export. When the MDO starts a design optimization process, it will modify this word with the design iteration number that the GA is performing. At the end of the process, all of the design iterations will be placed in the folder Analysis. As this macro is going to be edited, it will be named template_CAD.macro and after the MDO software edits it, its name will change to CAD.macro and will be stored in the Analysis folder.

The macro automatically opens the 2D model detailed before named ROTOR.prt. Then the variables are imported to the model using an external file called DIMENSIONS.exp. This file includes the variables that the GA are optimizing, and the MDO software can edit this file including the values of each variable on every design iteration. Using this technique it is possible to modify the CAD model according to the GA individuals. The next step is to export the shape as a parasolid file with the name rotor.x_t, then is exported an image of the rotor such as the ones presented on the Figure 30 with the name rotor-COUNTER-CAD.png and the file is saved as rotor-COUNTER-CAD.prt.

- File: template_DIMENSIONS.exp

```
l1=
l2=
l3=
l4=
l5=
a1=
a2=
a3=
a4=
a5=
```

- File: template_CAD.macro

```
NX 5.0.0.25
Macro File: C:\MDO\Analysis\CAD.macro
Macro Version 7.50
Macro List Language and Codeset: english 17
Created by pc on Sat Sep 15 19:00:34 2007
Part Name Display Style: $FILENAME
Selection Parameters 1 2 0.216535 1
Display Parameters 1.000000 7.913386 2.834646 -1.000000 -0.358209 1.000000 0.358209
*****************
RESET
MENU, 0, UG_FILE_OPEN UG_GATEWAY_MAIN_MENUBAR !
FILE_DIALOG_BEGIN 0, ! filebox with tools_data
FILE_DIALOG_UPDATE 2
FOCUS CHANGE IN 1
FOCUS CHANGE OUT 1
FOCUS CHANGE IN 1
FILE_DIALOG_END
FILE_BOX -2, c:\MDO\ROTOR.prt  C:\MDO\*.PRT  0 ! Open Part File
   SET_VALUE: 0 ! FSB item
WINDOW RESIZE 1.000000 9.379921 6.742126 -1.000000 -0.718783 1.000000 0.718783
WINDOW RESIZE 1.000000 9.379921 6.446850 -1.000000 -0.687303 1.000000 0.687303
DIALOG_BEGIN "Persistent Dialog" 7200 ! Persistent
BEG_ITEM  0 (1 BOOL 7200) = 0  ! Detailed View
DIALOG_PERSISTENT_END 7200
DIALOG_BEGIN "Persistent Dialog" 7201 ! Persistent
BEG_ITEM  0 (1 BOOL 7201) = 0  ! Detailed View
DIALOG_PERSISTENT_END 7201
DIALOG_BEGIN "Persistent Dialog" 7202 ! Persistent
DIALOG_PERSISTENT_END 7202
WINDOW RESIZE 1.000000 9.379921 6.112205 -1.000000 -0.651626 1.000000 0.651626
WINDOW RESIZE 1.000000 9.379921 5.777559 -1.000000 -0.615950 1.000000 0.615950
FOCUS CHANGE IN 1
MENU, 0, UG_INSERT_DLEXPRESSION UG_GATEWAY_MAIN_MENUBAR !
ASK_ITEM  1 (1 OPTM 0) = 1  ! Named
ASK_ITEM 19 (1 STRN 0) = ""  !
DIALOG_BEGIN "Expressions" 0 ! DA1
BEG_ITEM  1 (1 OPTM 0) = 1  ! Named
BEG_ITEM  2 (0 COMB 0) = ""  !
BEG_ITEM 11 (1 OPTM 0) = 0  ! Number
BEG_ITEM 12 (1 OPTM 0) = 2  ! Length
BEG_ITEM 13 (1 OPTM 0) = 1  ! mm
BEG_ITEM 19 (1 STRN 0) = ""  !
BEG_ITEM 1376256 (1 STRN 0) = ""  !
BEG_ITEM 28 (1 OPTT 0) = 0 0 ! Measure Distance
BEG_ITEM 33 (1 OPTT 0) = 0 0 ! New Requirement
EVENT FOCUS_OUT 0 0, 19, 0, 0, 0!
ASK_ITEM 19 (1 STRN 0) = ""  !
ASK_ITEM 1376256 (1 STRN 0) = ""  !
ASK_ITEM 19 (1 STRN 0) = ""  !
EVENT ACTIVATE 0 0, 6, 0, 0, 0! <DLC> Import Expressions from File
```

```
FILE_BOX  -2,  C:\MDO\Analysis\DIMENSIONS.exp    C:\MDO\Analysis\*.EXP    0  !  Import
Expressions File
   SET_VALUE: 0 ! FSB item
ASK_ITEM  1 (1 OPTM 0) = 1  ! Named
OK 0 0 ! OK Callback
ASK_ITEM 1376256 (1 STRN 0) = ""  !
ASK_ITEM  1 (1 OPTM 0) = 1  ! Named
ASK_ITEM 12 (1 OPTM 0) = 2  ! Length
ASK_ITEM 13 (1 OPTM 0) = 1  ! mm
END_ITEM  1 (1 OPTM 0) = 1  ! Named
END_ITEM  2 (0 COMB 0) = ""  !
END_ITEM 11 (1 OPTM 0) = 0  ! Number
END_ITEM 12 (1 OPTM 0) = 2  ! Length
END_ITEM 13 (1 OPTM 0) = 1  ! mm
END_ITEM 19 (1 STRN 0) = ""  !
END_ITEM 1376256 (1 STRN 0) = ""  !
END_ITEM 28 (1 OPTT 0) = 0 0 ! Measure Distance
END_ITEM 33 (1 OPTT 0) = 0 0 ! New Requirement
DIALOG_END -2, 0 ! Expressions: OK
FOCUS CHANGE IN 1
MENU, 0, UG_FILE_SAVE_AS UG_GATEWAY_MAIN_MENUBAR !
FILE_DIALOG_BEGIN 0, ! filebox with tools_data
FILE_DIALOG_UPDATE 2
FOCUS CHANGE IN 1
FOCUS CHANGE OUT 1
FOCUS CHANGE IN 1
FILE_DIALOG_END
FILE_BOX -2, C:\MDO\Analysis\rotor-COUNTER-CAD.prt   C:\MDO\Analysis\*.PRT   0 ! Save
Part File As
FOCUS CHANGE OUT 1
FOCUS CHANGE OUT 1
FOCUS CHANGE IN 1
MENU, 0, UG_VIEW_POPUP_ORIENT_TOP UG_GATEWAY_VIEW_POPUP !
MENU, 0, UG_FILE_EXPORT_PNG UG_GATEWAY_MAIN_MENUBAR !
DIALOG_BEGIN "PNG Image File" 0 ! ExSpecial
 BEG_ITEM  0 (1 WIDE 0) = "rotor-COUNTER.png"  ! PNG File
 BEG_ITEM  3 (1 BOOL 0) = 0  ! Use White Background
 EVENT VALUE_CHANGED -50 0, 3, 0, 0, 0! Use White Background
 ASK_ITEM  3 (1 BOOL 0) = 1  ! Use White Background
 EVENT ACTIVATE -50 0, 1, 0, 0, 0! Browse...
 ASK_ITEM  0 (1 WIDE 0) = "rotor-COUNTER.png"  ! PNG File
 FILE_BOX -2, C:\MDO\Analysis\rotor-COUNTER-CAD.png  C:\MDO\Analysis\*.PNG  0 ! PNG
Image File
 ASK_ITEM  0 (1 WIDE 0) = "C:\MDO\Analysis\rotor-COUNTER-CAD.png"  ! PNG File
 END_ITEM  0 (1 WIDE 0) = "C:\MDO\Analysis\rotor-COUNTER-CAD.png"  ! PNG File
 END_ITEM  3 (1 BOOL 0) = 1  ! Use White Background
DIALOG_END -2, 0 ! PNG Image File: OK
FOCUS CHANGE IN 1
MENU, 0, UG_FILE_EXPORT_PARASOLID UG_GATEWAY_MAIN_MENUBAR !
DIALOG_BEGIN "Export Parasolid" 0 ! DA2
 BEG_ITEM  0 (1 WIDE 0) = ""  ! Name
 BEG_ITEM  3 (1 OPTM 0) = 0  ! 18.0 - NX 5.0
FOCUS CHANGE IN 1
FOCUS CHANGE IN 1
 CURSOR_EVENT 1001 3,1,100 ! single_pt, mb1/0+0, U_Sel_sngl (T+:0+0)
 CPOS -151.916524701874,369.838160136286,0
 END_ITEM  0 (1 WIDE 0) = ""  ! Name
 END_ITEM  3 (1 OPTM 0) = 0  ! 18.0 - NX 5.0
DIALOG_END -2, 0 ! Export Parasolid: OK
FOCUS CHANGE IN 1
FOCUS CHANGE IN 1
FOCUS CHANGE OUT 1
FOCUS CHANGE IN 1
FILE_BOX -2, C:\MDO\Analysis\rotor  C:\MDO\Analysis\*.X_T  0 ! Export Parasolid
MENU, 0, UG_FILE_SAVE_PART UG_GATEWAY_MAIN_MENUBAR !
MENU, 0, UG_FILE_QUIT UG_GATEWAY_MAIN_MENUBAR !
```

In order to execute the macro inside Unigraphics NX5 using a DOS batch, the following code must be used. To complete the macro, the files ROTOR.prt and DIMENSIONS.exp must be in the specified path because the macro will use them to create the modified rotor.

```
ugraf.exe -key:CAD.macro
```

3.1.2. Meshing

The mesh used to discretize the Savonius rotor and the fluid around it was made using quadrilateral (quads) elements with boundary layer in the edges of the rotor's blades using the commercial software GAMBIT 2.3.16. This mesh contains approx. 18,500 elements in the fluid and approximately 35,000 elements in the rotor. This mesh is finer than the one used by Cochran *et al* in 2004 whose model had 50,000 elements. On that investigation the analysis were repeated with finer meshes with over 110,000 elements and the CFD results matched closely, which states the grid independency of the results using only 50,000 elements.

In order to automate the mesh creation, first a mesh called MESH.dbs was defined and created in the fluid zone. This helps because as this zone is the same in all the design variations, it can be previously defined for all of them. As mentioned, this mesh consisted in approx. 18,500 quads with boundary conditions of velocity in the inlet, pressure in the outlet and symmetry on the sides as seen in the following Figures.

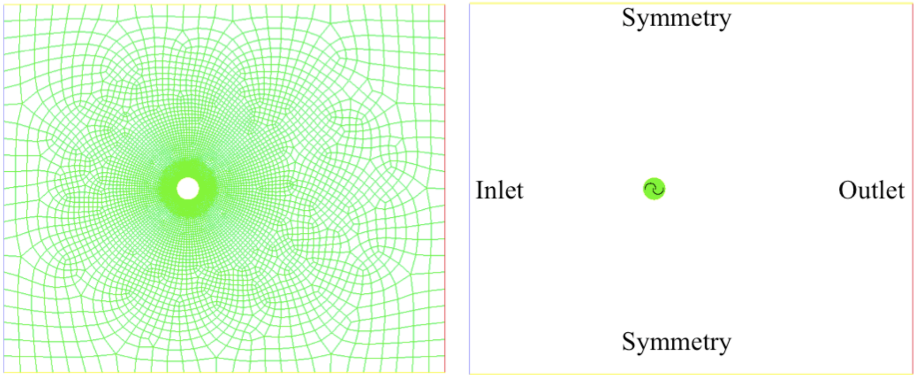

Figure 32. Fluid zone mesh and rotor mesh with detailed boundary conditions.

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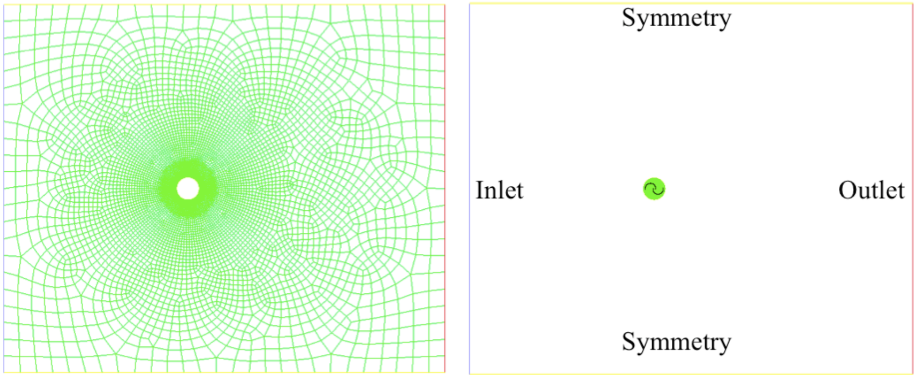

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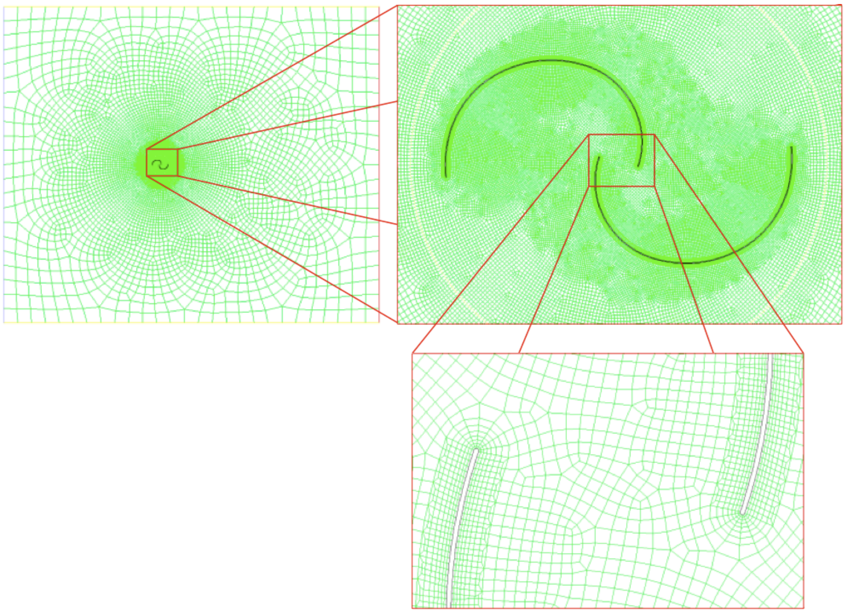

Figure 33. Detailed view of the mesh.

The automation of the process was carried out by a journal called MESHING.jou. This journal opens the file MESH.dbs which contains the mesh of the fluid zone. Then it imports the rotor shape exported in the CAD model called rotor.x_t and meshes it. In this task a logic function checks if an error has occurred and if it happens it makes little changes in the mesh size in order to complete the task. This errors are common but with that function they are reduced at a rate of approximately 2% of the design iterations. At the end of the process the mesh is exported as mesh.msh.

- File: MESHING.jou

```
identifier name "MESH" old \
  nosaveprevious
import parasolid "rotor.x_t" scale 1 \
  tolerant
edge picklink "edge.13"
edge mesh "edge.13" successive ratio1 1 intervals 400
$a = 2.7 * 4
$b = 6
$x9 = ARCLEN("edge.9")
$x10 = ARCLEN("edge.10")
$x11 = ARCLEN("edge.11")
$x12 = ARCLEN("edge.12")
$x14 = ARCLEN("edge.14")
$x15 = ARCLEN("edge.15")
$x16 = ARCLEN("edge.16")
$x17 = ARCLEN("edge.17")
IF COND ($x9 .GT. 5)
  $x = $x9 / $a
  $y = INT($x) * 4
  edge mesh "edge.9" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.9" add
ELSE
  edge mesh "edge.9" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.9" add
ENDIF
IF COND ($x10 .GT. 5)
```

```
  $x = $x10 / $a
  $y = INT($x) * 4
  edge mesh "edge.10" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.10" add
ELSE
  edge mesh "edge.10" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.10" add
ENDIF
IF COND ($x11 .GT. 5)
  $x = $x11 / $a
  $y = INT($x) * 4
  edge mesh "edge.11" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.11" add
ELSE
  edge mesh "edge.11" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.11" add
ENDIF
IF COND ($x12 .GT. 5)
  $x = $x12 / $a
  $y = INT($x) * 4
  edge mesh "edge.12" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.12" add
ELSE
  edge mesh "edge.12" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.12" add
ENDIF
IF COND ($x14 .GT. 5)
  $x = $x14 / $a
  $y = INT($x) * 4
  edge mesh "edge.14" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.14" add
ELSE
  edge mesh "edge.14" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.14" add
ENDIF
IF COND ($x15 .GT. 5)
  $x = $x15 / $a
  $y = INT($x) * 4
  edge mesh "edge.15" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.15" add
ELSE
  edge mesh "edge.15" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.15" add
ENDIF
IF COND ($x16 .GT. 5)
  $x = $x16 / $a
  $y = INT($x) * 4
  edge mesh "edge.16" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.16" add
ELSE
  edge mesh "edge.16" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.16" add
ENDIF
IF COND ($x17 .GT. 5)
  $x = $x17 / $a
  $y = INT($x) * 4
  edge mesh "edge.17" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.17" add
ELSE
  edge mesh "edge.17" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.17" add
ENDIF
face mesh "face.5" pave
physics create "blades" btype "WALL" edge "edge.9" "edge.10" "edge.11" \
  "edge.12" "edge.14" "edge.15" "edge.16" "edge.17"
physics create "interface_rotor" btype "INTERFACE" edge "edge.13"
physics create "rotor" ctype "FLUID" face "face.5"
$F = ENTITYATTR(a_mesh,"face.5",t_fa)
IF COND ($F .eq. 1)
  export fluent5 "mesh.msh" nozval
ELSE
  edge delete "edge.11" "edge.10" "edge.16" "edge.15" "edge.17" "edge.14" \
```

```
"edge.12" "edge.9" lowertopology onlymesh
$a = 2.75 * 4
IF COND ($x9 .GT. 5)
  $x = $x9 / $a
  $y = INT($x) * 4
  edge mesh "edge.9" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.9" add
ELSE
  edge mesh "edge.9" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.9" add
ENDIF
IF COND ($x10 .GT. 5)
  $x = $x10 / $a
  $y = INT($x) * 4
  edge mesh "edge.10" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.10" add
ELSE
  edge mesh "edge.10" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.10" add
ENDIF
IF COND ($x11 .GT. 5)
  $x = $x11 / $a
  $y = INT($x) * 4
  edge mesh "edge.11" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.11" add
ELSE
  edge mesh "edge.11" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.11" add
ENDIF
IF COND ($x12 .GT. 5)
  $x = $x12 / $a
  $y = INT($x) * 4
  edge mesh "edge.12" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.12" add
ELSE
  edge mesh "edge.12" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.12" add
ENDIF
IF COND ($x14 .GT. 5)
  $x = $x14 / $a
  $y = INT($x) * 4
  edge mesh "edge.14" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.14" add
ELSE
  edge mesh "edge.14" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.14" add
ENDIF
IF COND ($x15 .GT. 5)
  $x = $x15 / $a
  $y = INT($x) * 4
  edge mesh "edge.15" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.15" add
ELSE
  edge mesh "edge.15" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.15" add
ENDIF
IF COND ($x16 .GT. 5)
  $x = $x16 / $a
  $y = INT($x) * 4
  edge mesh "edge.16" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.16" add
ELSE
  edge mesh "edge.16" successive ratio1 1 intervals $b
  blayer attach "curved" face "face.5" edge "edge.16" add
ENDIF
IF COND ($x17 .GT. 5)
  $x = $x17 / $a
  $y = INT($x) * 4
  edge mesh "edge.17" successive ratio1 1 intervals $y
  blayer attach "straight" face "face.5" edge "edge.17" add
ELSE
  edge mesh "edge.17" successive ratio1 1 intervals $b
```

```
      blayer attach "curved" face "face.5" edge "edge.17" add
    ENDIF
    face mesh "face.5" pave
    $FF = ENTITYATTR(a_mesh,"face.5",t_fa)
    IF COND ($FF .eq. 1)
      export fluent5 "mesh.msh" nozval
    ENDIF
  ENDIF
```

In order to execute the journal inside GAMBIT using a DOS batch, the following code must be used. To complete the journal, the files MESH.dbs and rotor.x_t must be in the specified paths because the journal will use them to create the mesh.

```
gambit -inputfile MESHING.jou
```

3.1.3. CFD

The main propose of the task is to obtain the C_P for any design iteration. In order to achieve that, a CFD analysis was defined using a commercial software called FLUENT 6.3.26.

The analysis was defined as unsteady due to the nature of the ciclic performance of the Savonius rotor and the setup of the analysis was made as follows:

- Selection of the solver: It was selected a 2D analysis, with an absolute formulation of the velocity, based on the pressure and with a 2nd order discretization of the time. The turbulence model was selected as k-ε Realizable because of the characteristics of this kind of fluid flow. On the other hand, for the discretization of the pressure momentum and turbulence equations it was selected a 2nd order approach. Finally for the pressure-velocity coupling it was selected a coupled scheme.
- Operating conditions: In this section the gravity was selected to act in the Z axis, and the density was established at 1.225 kg/m^3 for the air.
- Boundary conditions: As they were defined on the mesh file, now it is needed to select only the values of those boundary conditions. For the inlet a velocity of the wind of 10m/s was initially defined in order to compare the CFD results with tunnel tests results made at that wind velocity. For the outlet, a value for the pressure condition equal to zero was defined. And finally, the rotation of the rotor was set. As this rotation velocity depends on the diameter and the TSR, if one of those variables are being optimized, the MDO software will be forced to edit this value on every design iteration.
- Initial conditions: As an initial guess, an interpolation file named INTERPOLATION was created from an analysis previously performed in order to decrease the analysis time. On the Figure 34 is shown a comparison of an analysis made with and without

```
      blayer attach "curved" face "face.5" edge "edge.17" add
    ENDIF
    face mesh "face.5" pave
    $FF = ENTITYATTR(a_mesh,"face.5",t_fa)
    IF COND ($FF .eq. 1)
      export fluent5 "mesh.msh" nozval
    ENDIF
  ENDIF
```

In order to execute the journal inside GAMBIT using a DOS batch, the following code must be used. To complete the journal, the files MESH.dbs and rotor.x_t must be in the specified paths because the journal will use them to create the mesh.

```
gambit -inputfile MESHING.jou
```

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- Initial conditions: As an initial guess, an interpolation file named INTERPOLATION was created from an analysis previously performed in order to decrease the analysis time. On the Figure 34 is shown a comparison of an analysis made with and without

interpolation. The dotted curve in red which is the one revolution average C_P for the analysis that used interpolation reaches the convergence before the end of the second revolution of the rotor. On the other hand, the other analysis reaches the convergence until the third and a half revolution. It is important to mention that as the rotor has two blades, two cycles of the curves represents one revolution and it needs approximately 11 minutes to be computed, so the reduction in time is relevant. Figure 35 shows some examples of the interpolation of the Benesh 1988 results to other rotors to be used as an initial guess.

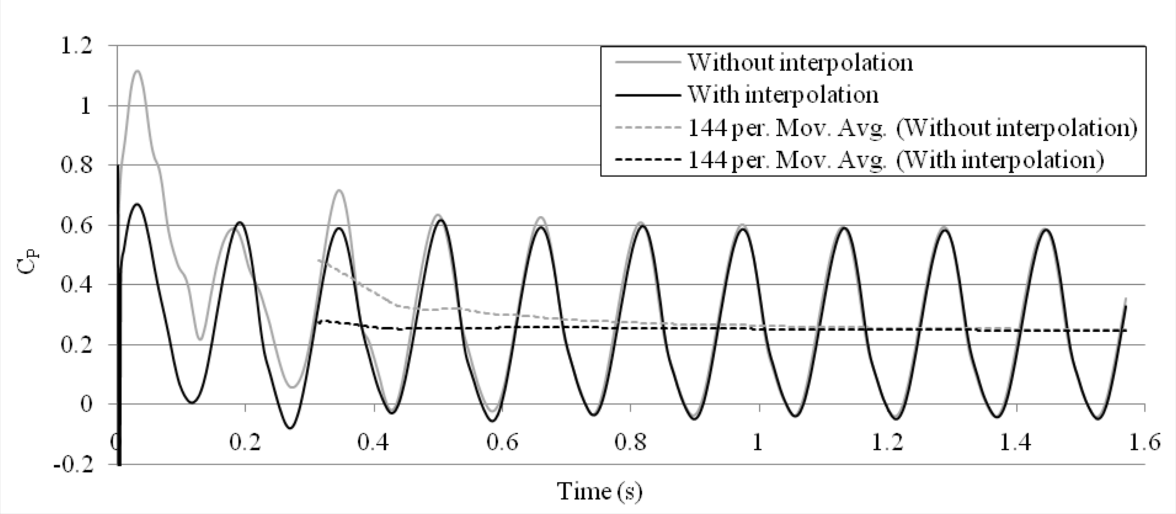


Figure 34. C_P convergence analyzing with and without interpolation.

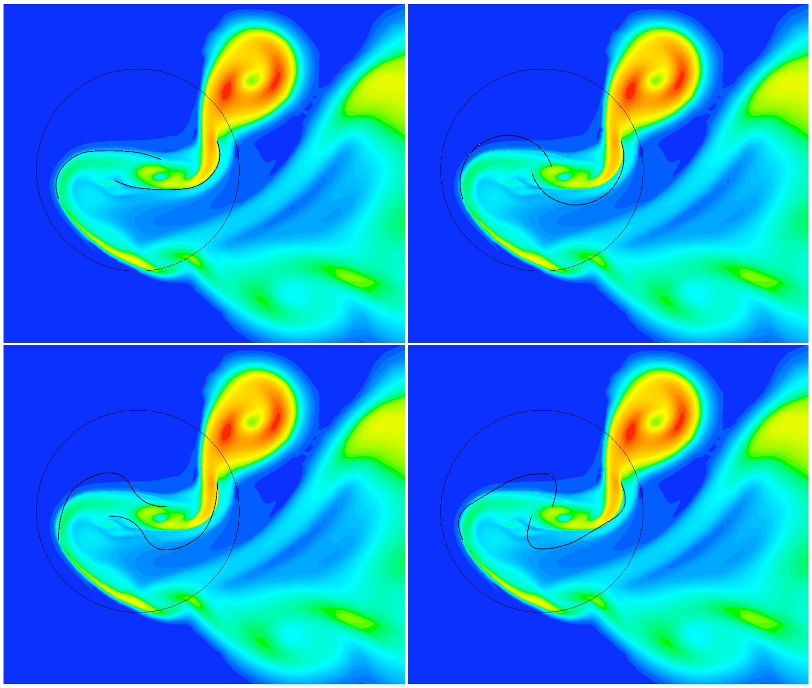


Figure 35. Examples of interpolation of the Benesh 1988 results to other rotors.

- Residuals: The residuals used in the analysis were 0.0001.
- Reference values: Because Fluent doesn't calculate the C_P, it is needed to compute the C_Q (Torque coefficient). Fluent is capable of computing this parameter using the equation 11. In order to achieve this, the CFD software needs the values for the variables of the equation. This values can be defined as reference values and they include the radius (in Fluent is is defined as length) and sweep area of the rotor , the wind velocity, and as this is a 2D analysis, a height must be defined for the rotor.

$$C_Q = \frac{Q}{\frac{1}{2}\rho \cdot V^2 \cdot r \cdot A} \tag{11}$$

- Solve: As the analysis is unsteady, to solve it, it is needed to assigned the time step size, the number of time steps and the number of iterations per time step. The number of time steps should be enough to complete two revolutions because on that moment is approximately when the C_P converges. In the case of the iterations per time step, Fluent (2006) affirms that a value of 5 to 10 is ideal, so 10 was selected. Finally in the case of the time step size, Fluent (2006) mentioned that if the analysis needs only a few iterations per time step it should be increased until it needs between 5 and 10 iterations. After testing the Savonius CFD analysis it was concluded that a time step, every 2.5 degrees of rotation needs that number of iterations. Because of that, the value of the time step size must be calculated according to the rotation velocity. This parameter, according to the equation 7, depends on the diameter of the rotor, wind velocity and the TSR. So if the diameter is a variable of the GA this value must be referenced and edited by the MDO software on every iteration of the design.
- Results: As Fluent doesn't calculate the C_P it must be calculated from the C_Q. In order to do that, a relation of the equations 6 and 11 can be done to obtain the equation 12. This equation then can be related with the equation 7 to obtain the equation 13, which is used to calculate the C_P.

$$\frac{C_P}{C_Q} = \frac{r \cdot \omega}{V} \tag{12}$$

$$C_P = \lambda \cdot C_Q \tag{13}$$

In order to validate the results of the CFD analysis proposed, the most important rotors were analyzed and compared with their respective wind tunnel tests. As those test were carried out at 10m/s this analysis is done at that velocity.

The first analysis was performed for the Savonius rotor with a ratio overlap/diameter of 0.125. This analysis was made at different TSR's to complete a curve and compare it with the curves presented by Blackwell for a rotor with a ratio height/diameter of 1 and 1.5 and also it was compared with the curve made by Moutsoglou. This comparison can be seen on the Figure 36 were the CFD analysis curve is very close to the ones calculated with wind tunnels.

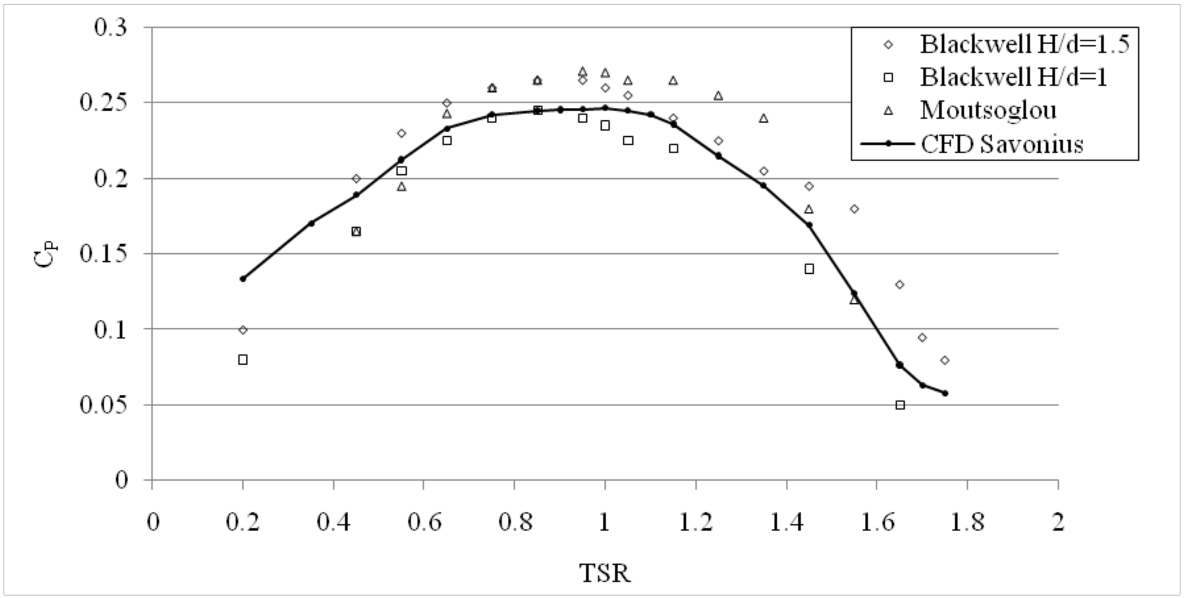


Figure 36. Comparison between wind tunnel tests and CFD analysis of a Savonius WT.

The next analysis were made only at a few different TSR's to the Benesh 1988, 1996 and Rahai rotors. The C_P results for those analysis are shown in the Table 4. On the other hand in the Figure 37 can be observed the convergence of the C_P variation over the time for the analysis made to the Savonius, Benesh 1988 and 1996 at a TSR=1, while the same C_P convergence of the Rahai rotor at TSR=1.5 can be seen in the next figure.

Finally on the Figure 39 a turbulence intensity contour of the rotors Savonius, Benesh 1998 and 1996 and the Rahai are illustrated.

Table 4. C_P at different TSR calculated using CFD.

Rotor	TSR = 0.85	TSR = 1	TSR = 1.25	TSR = 1.5
Savonius	0.242	0.246	-	-
Benesh 1988	0.243	0.2601	-	-
Benesh 1996	0.269	0.272	-	-
Rahai	-	0.183	0.202	0.1114

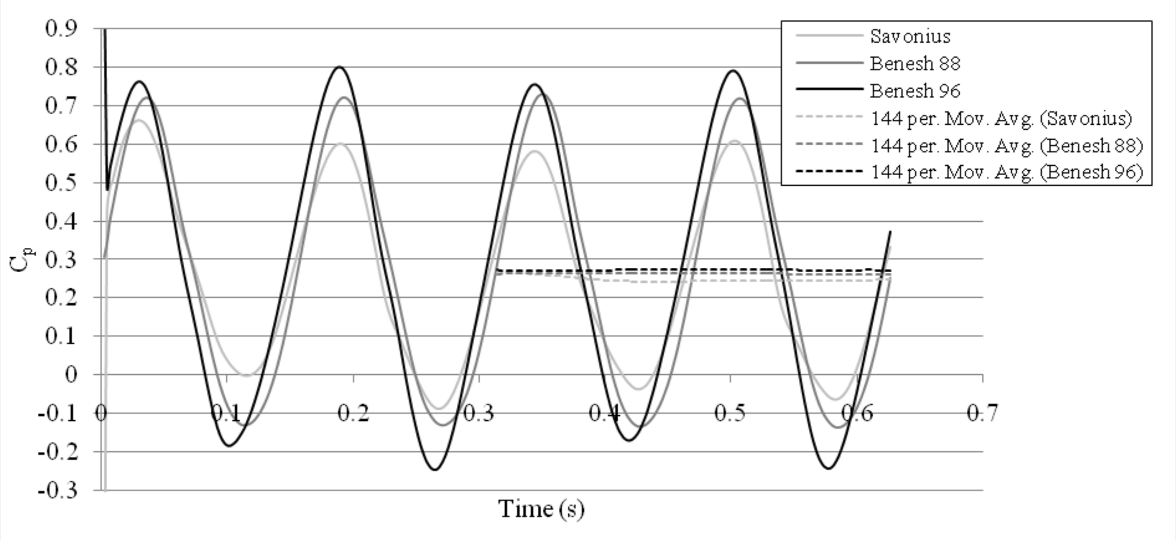


Figure 37. C_P convergence for the Savonius, Benesh 1988 and Benesh 1996 rotors at TSR=1.

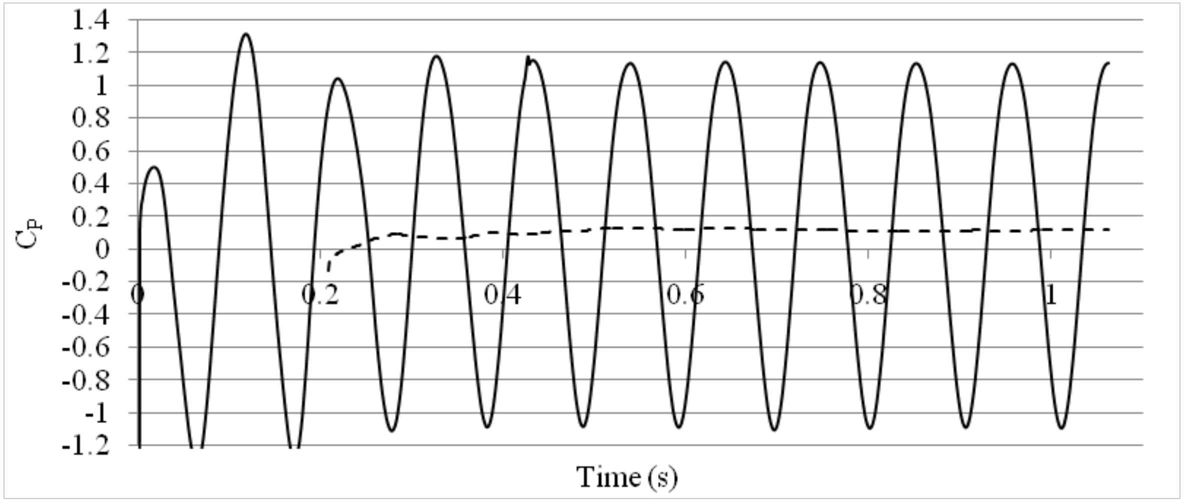


Figure 38. C_P convergence for the Rahai rotor at TSR=1.5.

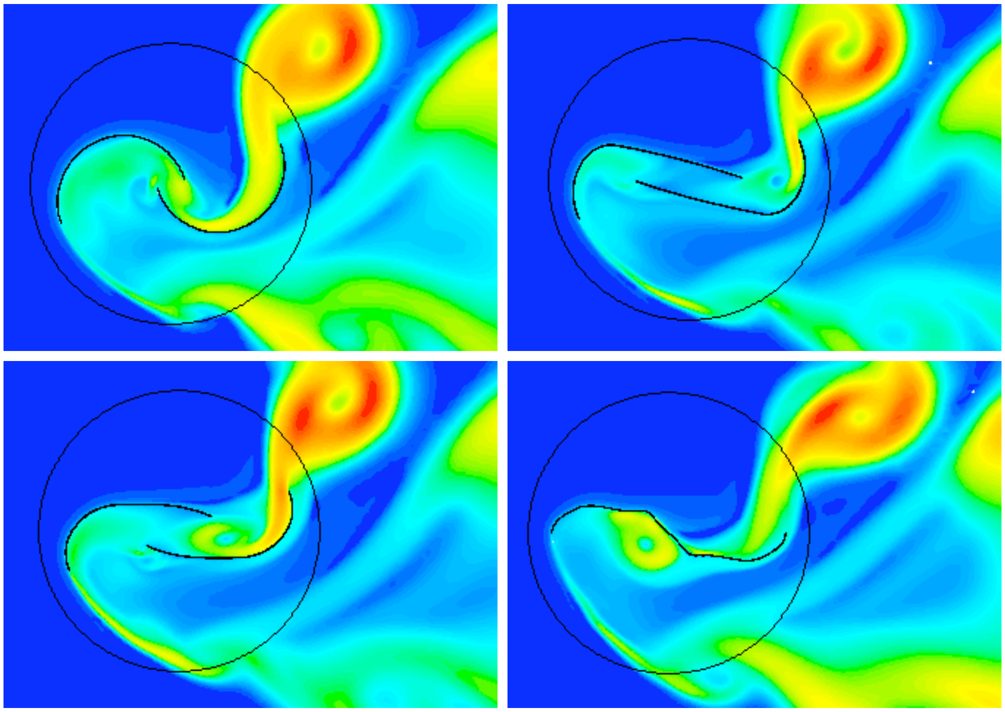


Figure 39. Turbulent intensity contour for the Savonius, Benesh 1988 and Benesh 1996 and Rahai rotors at TSR=1.

At first these CFD results seem to be different with the C_P's presented on the Table 1, but when it is determined which of them were analyzed with a wind tunnel the only trustable results to compare are the Savonius and the Benesh 1988. For these rotors the relation between the results of the wind turbine tests and the CFD analysis is detailed in the Table 5. This results show that the C_P calculated by CFD analysis for the Savonius was approx. 7% lower than the wind tunnel test. On the other hand, the Benesh 1996 CFD results are almost 12% lower than the tunnel test.

Table 5. C_P differences between wind tunnel tests and CFD analysis.

Rotor	Wind tunnel	CFD	CFD/wind tunnel
Savonius	0.265	0.246	0.928
Benesh 1988	0.295	0.2601	0.882

For the automation of this task, a journal was created. This journal imports the mesh created on the meshing process called mesh.msh, then it configures the solver and operation conditions.

After that, for the boundary conditions, the MDO software add the velocity of the wind and the velocity of rotation to the journal on every design iteration. It is true that the wind velocity isn’t a variable, but it was added to the MDO software as a constant in order to be able of changing its value for different tests without the necessity of editing any journal or macro. In the case of the velocity of rotation, according to the equation 7, it depends on the TSR, radius of the rotor and velocity of the wind, so it can be expressed as the equation 14 and the resultant dimensions are rad/s. Because of the diameter variation, this variable needs to be calculated and edited every design iteration.

$$\omega = \frac{V\cdot\lambda}{\frac{d}{2}} \tag{14}$$

The next step is the reference values. Here the journal needs to have the height, radius and wind velocity. As all the design iterations are calculated as having an area of $1m^2$, the height depends on the diameter (equation 15), also the radius (equation 16) depends on the same variable. On the other hand, the wind velocity is a constant inside the MDO software as mentioned on the las step.

$$H = \frac{A}{d} \tag{15}$$

$$r = \frac{d}{2} \tag{16}$$

The initial conditions are interpolated using a file named INTERPOLATION which was created once to be used on every design iteration.

For the solution propose, the residuals are defined and then the time step size (TSS) and number of time steps (NTS) are defined and the iterations begins. For the time step size (TSS) it is needed to divide the degrees per time step (DTS) over the rotational velocity. As mentioned earlier this DTS are the degrees that the WT will rotate after another time step is calculated, and it was defined to be 2.5 degrees. As the relation must be consistent in dimensions, the DTS is changed from degrees to radians.

$$TSS = \frac{DTS\cdot\frac{\pi}{180}}{\omega} \tag{17}$$

On the other hand, to calculate the number of time steps (NTS), it is defined in the equation 18 as the degrees of rotation (DS) that are going to be analyzed (e.g. for a two revolutions analysis, it will be 720) divided over the degrees per time step (DTS).

$$NTS = \frac{DS}{DTS} \qquad 18$$

The solution process is divided in two parts, the first calculates one revolution of the rotor without writing the results in a text file and in the second revolution the results starts to be written in a file called rotor-COUNTER-CQ, it is done like that because the results of the second revolution are more accurate.

Next the journal reads a predefined view contained in the file VIEW-FLUENT. After this, fluent creates an image of the analyzed rotor and saves it as rotor-COUNTER-CFD.tiff. Then the final step is to save the analysis as rotor-COUNTER-CFD.

It is worth to mention that the word COUNTER is replaced as on the CAD macro with the design iteration number by the MDO software. With this replacement, Fluent is able of creating a list of files for every design iteration. This files are stored and can be analyzed at any time.

As the journal file must be edited on every design iteration it is called template_CFD.jou and after it is modified the file will be called CFD.jou and positioned in the folder Analysis.

- File: template_CFD.jou

```
file/
        read-case/
        "mesh.msh"
q
define/
        grid-interfaces/
                create
                        interface
                        interface_rotor

                        interface_fluid

                        no
                        no
        q
q
grid/
        check
        smooth-grid
                "skewness"
                4
                0.4
        scale
                0.001
                0.001
q
define/
        models/
                solver/
                        pressure-based
                                yes
                q
                unsteady-2nd-order?
```

```
                        yes
                viscous/
                        ke-realizable?
                                yes
                q
        q
        boundary-conditions/
*                       INLET
                velocity-inlet
                inlet
                no
                no
                yes
                yes
                no
                WINDVELOCITY
                no
                no
                yes
                1
                1
*                       OUTLET
                pressure-outlet
                9
                no
                0
                no
                yes
                no
                no
                yes
                1
                1
                no
*                       BLADES
                wall
                blades
                yes
                motion-bc-moving
                no
                yes
                yes
                no
                no
                0
                no
                0.5
                0
                0
                0
*                       ROTOR
                fluid
                rotor
                no
                no
                no
                no
                no
                yes
                0
                0
                -ROTATIONALVELOCITY
                0
                0
                no
                no
                no
        q
        operating-conditions
                operating-pressure
                0
        q
```

```
q
report/
        reference-values
                area
                1
                depth
                HEIGHT
                length
                -RADIUS
                velocity
                WINDVELOCITY
        q
q
solve/
        set/
                p-v-coupling
                        24
                p-v-controls
                        100
                        0.6
                        0.6
                discretization-scheme/
                        pressure
                        12
                        mom
                        1
                        k
                        1
                        epsilon
                        1
                q
                under-relaxation
                        body-force
                        0.6
                        density
                        0.6
                        epsilon
                        0.6
                        k
                        0.6
                        turb-viscosity
                        0.6
                q
        q
q
file/
        interpolate/
                read-data
                "INTERPOLATION"
        q
q
grid/
        scale
                DIAMETER
                DIAMETER
solve/
        monitors/
                residual/
                        convergence-criteria
                                0.0001
                                0.0001
                                0.0001
                                0.0001
                                0.0001
                        plot
                                no
                        print
                                no
                        window
                                0
                q
                force/
```

```
                        moment-coefficient
                                yes
                                blades

                                yes
                                no
                                no
                                no
                                0
                                0
                        monitor-unsteady-iters
                                no
                q
        q
        set/
                time-step
                        TSS
        q
        dual-time-iterate
                NTS
                10
        monitors/
                force/
                        clear-moment-monitor-data
                                yes
                                yes
                        moment-coefficient
                                yes
                                blades

                                yes
                                yes
                                "rotor-COUNTER-CQ"
                                yes
                                1
                                no
                                0
                                0
                        monitor-unsteady-iters
                                no
                q
        q
        set/
                time-step
                        TSS
        q
        dual-time-iterate
                NTS
                10
q
display/
        set-window
        5
        view/
                read-views
                "VIEW-FLUENT"
                restore-view
                view-0
        q
        set/
                contours/
                        n-contour
                        50
                        filled-contours?
                        yes
                q
                hard-copy/
                        color-mode/
                                color
                        q
                        driver/
                                tiff
```

```
                      q
              q
       q
       contour
              turb-intensity
              0

       hard-copy
              "rotor-COUNTER-CFD.tiff"
q
file/
       write-case-data
       "rotor-COUNTER-CFD"
       write-case
       "kill"
q
exit
yes
```

In order to execute the journal inside FLUENT using a DOS batch, the following code must be used. To complete the journal, the files mesh.msh, INTERPOLATION and VIEW-FLUENT must be in the specified paths because the journal will use them to setup the analysis.

```
fluent.exe 2d -i CFD.jou
```

As this is an unsteady analysis one image isn’t the best way to describe it. Although a set of images as shown in Figure 40 can be more useful, a video its the most proper way. For that reason the videos created were uploaded in youtube.com and can be found searching for “Savonius CFD”.

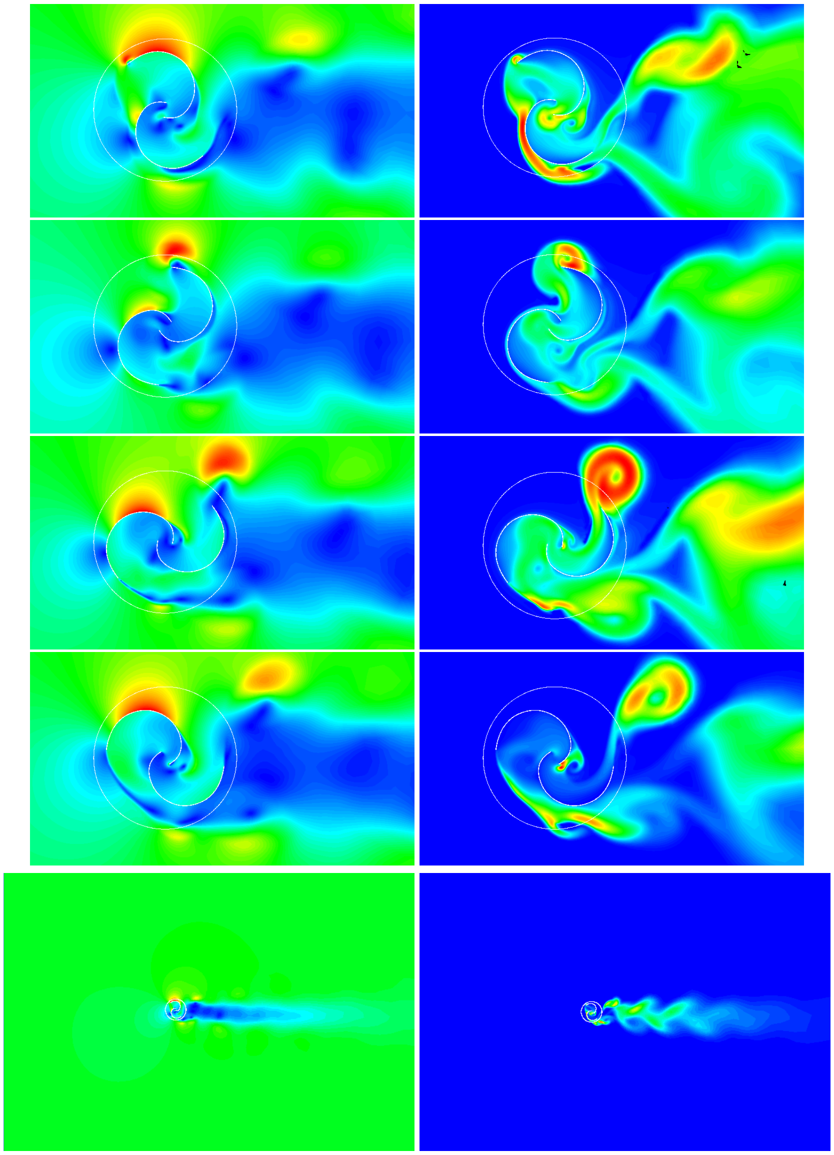
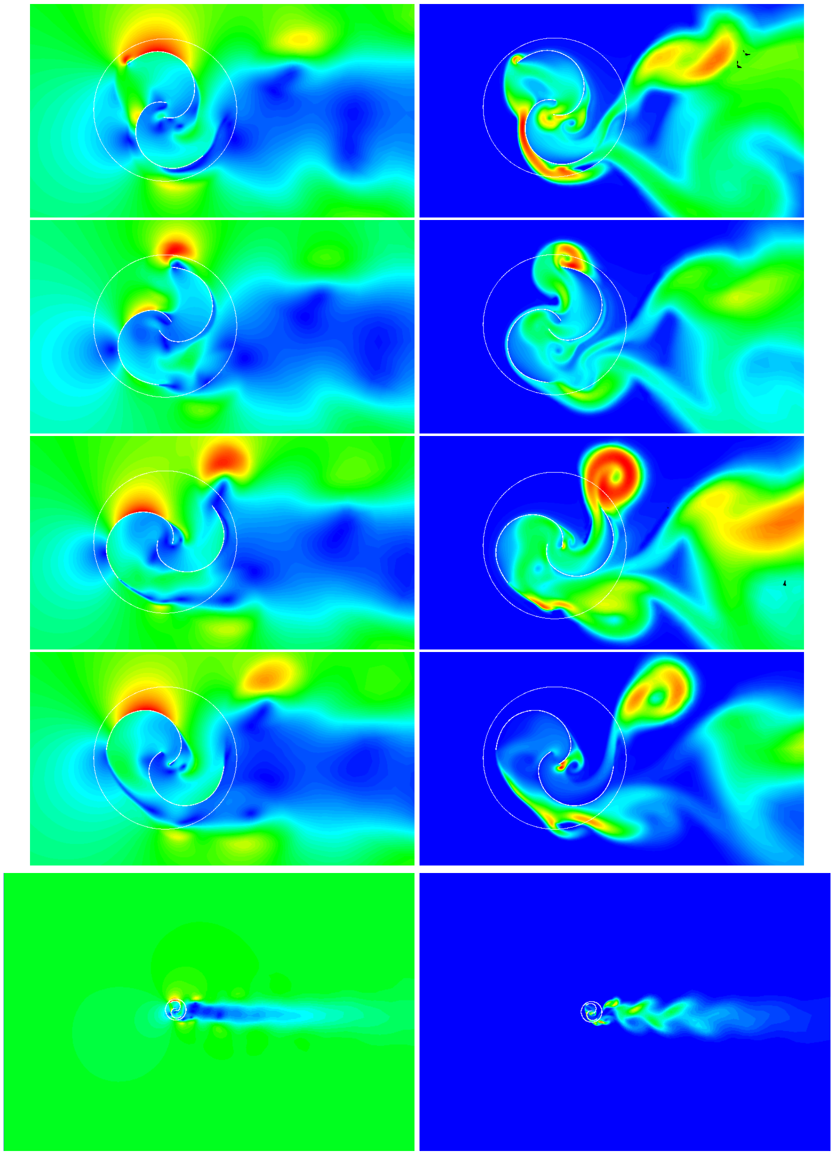


Figure 40. Velocity magnitude (left) and Turbulence intensity (right) contours at different angles.

3.1.4. Reading the results

As the CFD analysis generates a result that is a variation of the C_Q over the time, it must be averaged and the C_P needs to be calculated using the equation 13 that relates the C_Q and the TSR. To achieve this, an empty file was created using the commercial spreadsheet software Excel. Inside this file a macro called RESULTS was defined. This macro has the objective of calculating the average and the difference between the maximum and minimum C_P values using the TSR value. In order to do that the MDO software introduces the TSR value into the cell A1 and then executes the macro which calculates the C_P and C_{Pdif} and places



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- Macro inside Excel

```
Sub RESULTS()
'
' RESULTS Macro
'
    With ActiveSheet.QueryTables.Add(Connection:= _
        "TEXT;C:\MDO\Analysis\cq-savonius.", Destination:=Range("$A$1"))
        .Name = "cq-savonius."
        .FieldNames = True
        .RowNumbers = False
        .FillAdjacentFormulas = False
        .PreserveFormatting = True
        .RefreshOnFileOpen = False
        .RefreshStyle = xlInsertDeleteCells
        .SavePassword = False
        .SaveData = True
        .AdjustColumnWidth = True
        .RefreshPeriod = 0
        .TextFilePromptOnRefresh = False
        .TextFilePlatform = 437
        .TextFileStartRow = 1
        .TextFileParseType = xlDelimited
        .TextFileTextQualifier = xlTextQualifierDoubleQuote
        .TextFileConsecutiveDelimiter = False
        .TextFileTabDelimiter = True
        .TextFileSemicolonDelimiter = False
        .TextFileCommaDelimiter = False
        .TextFileSpaceDelimiter = False
        .TextFileColumnDataTypes = Array(1, 1, 1)
        .TextFileTrailingMinusNumbers = True
        .Refresh BackgroundQuery:=False
    End With
    Range("C3").Select
    ActiveCell.FormulaR1C1 = "=R[-2]C[1]*AVERAGE(RC[-1]:R[10000]C[-1])"
    Range("C4").Select
          ActiveCell.FormulaR1C1  =  "=R[-3]C[1]*(MAX(R[-1]C[-1]:R[9999]C[-1])-
MIN(R[-1]C[-1]:R[9999]C[-1]))"
    Range("C6").Select
    ActiveWindow.SmallScroll Down:=-6
End Sub
```

3.1.5. Optimization algorithm

The MDO software used was iSIGHT 8. In it, different kinds of optimization tools can be used such as optimization algorithms, design of experiments (DOE), quality engineering methods (as Monte Carlo simulation and Taguchi robust design), multi-criteria trade-off analysis, approximations and knowledge rules. Between the algorithms, iSIGHT 8 have 16 predefined and they can be found in the following list.

- Adaptive Simulated Annealing
- Directed Heuristic Search (DHS)
- Exterior Penalty
- Generalized Reduced Gradient - LSGRG2

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- Macro inside Excel

```
Sub RESULTS()
'
' RESULTS Macro
'
    With ActiveSheet.QueryTables.Add(Connection:= _
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        .Name = "cq-savonius."
        .FieldNames = True
        .RowNumbers = False
        .FillAdjacentFormulas = False
        .PreserveFormatting = True
        .RefreshOnFileOpen = False
        .RefreshStyle = xlInsertDeleteCells
        .SavePassword = False
        .SaveData = True
        .AdjustColumnWidth = True
        .RefreshPeriod = 0
        .TextFilePromptOnRefresh = False
        .TextFilePlatform = 437
        .TextFileStartRow = 1
        .TextFileParseType = xlDelimited
        .TextFileTextQualifier = xlTextQualifierDoubleQuote
        .TextFileConsecutiveDelimiter = False
        .TextFileTabDelimiter = True
        .TextFileSemicolonDelimiter = False
        .TextFileCommaDelimiter = False
        .TextFileSpaceDelimiter = False
        .TextFileColumnDataTypes = Array(1, 1, 1)
        .TextFileTrailingMinusNumbers = True
        .Refresh BackgroundQuery:=False
    End With
    Range("C3").Select
    ActiveCell.FormulaR1C1 = "=R[-2]C[1]*AVERAGE(RC[-1]:R[10000]C[-1])"
    Range("C4").Select
          ActiveCell.FormulaR1C1  =  "=R[-3]C[1]*(MAX(R[-1]C[-1]:R[9999]C[-1])-
MIN(R[-1]C[-1]:R[9999]C[-1]))"
    Range("C6").Select
    ActiveWindow.SmallScroll Down:=-6
End Sub
```

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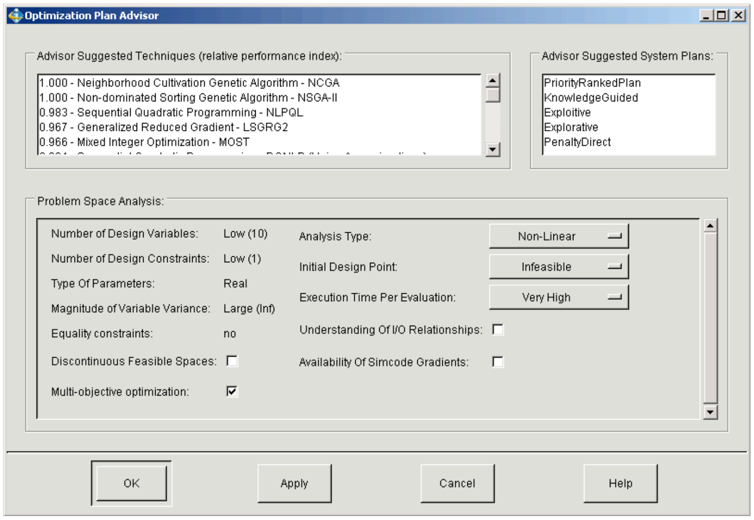
- Adaptive Simulated Annealing
- Directed Heuristic Search (DHS)
- Exterior Penalty
- Generalized Reduced Gradient - LSGRG2

- Hooke-Jeeves Direct Search
- Method of Feasible Directions - CONMIN
- Mixed Integer Optimization - MOST
- Modified Method of Feasible Directions
- Multi-Island Genetic Algorithm
- Neighborhood Cultivation Genetic Algorithm - NCGA
- Non-dominated Sorting Genetic Algorithm - NSGA-II
- Satisficing Trade-off Analysis
- Sequential Linear Programming
- Sequential Quadratic Programming - DONLP
- Sequential Quadratic Programming - NLPQL
- Successive Approximation Method

This MDO software also includes an optimization plan advisor which can define the best optimization techniques depending on the problem characteristics. For a multi-objective optimization this advisor positions the GA's in the first place and for single objective it selects the some others algorithms in addition to the GA's. On Figure 41 can be seen a plan advisor that selects the neighborhood cultivation genetic algorithm as the first choice when the multi-objective optimization check point is selected.



Optimization Plan Advisor

Advisor Suggested Techniques (relative performance index):

1.000 - Neighborhood Cultivation Genetic Algorithm - NCGA
1.000 - Non-dominated Sorting Genetic Algorithm - NSGA-II
0.983 - Sequential Quadratic Programming - NLPQL
0.967 - Generalized Reduced Gradient - LSGRG2
0.966 - Mixed Integer Optimization - MOST

Advisor Suggested System Plans:

PriorityRankedPlan
KnowledgeGuided
Exploitive
Explorative
PenaltyDirect

Problem Space Analysis:

Number of Design Variables: Low (10)
Number of Design Constraints: Low (1)
Type Of Parameters: Real
Magnitude of Variable Variance: Large (Inf)
Equality constraints: no
Discontinuous Feasible Spaces: ☐
Multi-objective optimization: ☑
Analysis Type: Non-Linear
Initial Design Point: Infeasible
Execution Time Per Evaluation: Very High
Understanding Of I/O Relationships: ☐
Availability Of Simcode Gradients: ☐

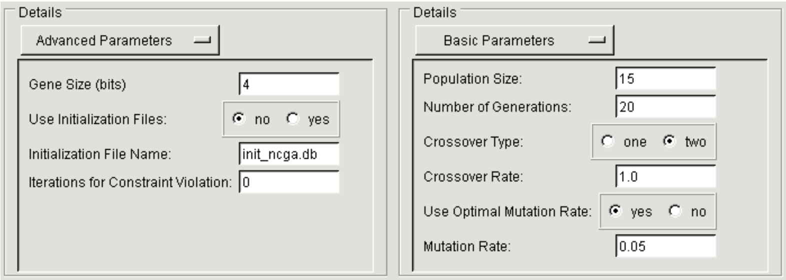
Figure 41. Optimization plan advisor inside iSIGHT 8.

For the optimization task in this investigation the following genetic algorithms were analyzed in order to select one.

- Multi-Island Genetic Algorithm: According to Engineous Software (2003), the main feature of this algorithm that distinguishes it from traditional genetic algorithms is the fact that each population of individuals is divided into several sub-populations called "islands." All traditional genetic operations are performed separately on each sub-population. Some individuals are then selected from each island and migrated to different islands periodically. This operation is called "migration." Two parameters control the migration process: migration interval, which is the number of generations between each migration, and migration rate, which is the percentage of individuals migrated from each island at the time of migration. This algorithm can be used only in multi-objective design optimization.

  The parameters for this algorithm are size of sub-population (greater than 1, default 10), number of islands (greater than 1, default 10), number of generations (greater than 1, default 10), gene size (1 to 32, default 32), rate of crossover (0 to 1, default 1), rate of mutation (0 to 1, default 0.1), rate of migration (0 to 0.5, default 0.5), interval of migration (greater than 1, default 5) and elite size (greater or equal to 0, default 1). This elite size is the number of parents that are carried to the child's generation.

- Neighborhood Cultivation Genetic Algorithm (NCGA): According to Engineous Software (2003), in this algorithm each objective parameter is treated separately. Standard genetic operation of mutation and crossover are performed on the designs. The crossover process is based on the "neighborhood cultivation" mechanism, where the crossover is performed mostly between individuals with values close to one of the objectives. By the end of the optimization run, a pareto set is constructed where each design has the "best" combination of objective values, and improving one objective is impossible without sacrificing one or more of other objectives. As the crossover is carried with the best individuals of every objective, this algorithm can be used only in multi-objective design optimizations.
  The parameters for his algorithm are population size (greater than 1, default 10), number of generations (greater than 1, default 20), crossover type (1 or 2 point crossover, default 1), crossover rate (0 to 1, default 1), use optimal mutation (yes or no, default no), mutation rate (0 to 1, default 0.01), gene size (1 to 63, default 20), use of an initialization file (initial generation) and iterations for constraint violation (0 and more, default 0). This last parameter specifies the number of attempts that the algorithms will make when an individual violates a predefined constraint.

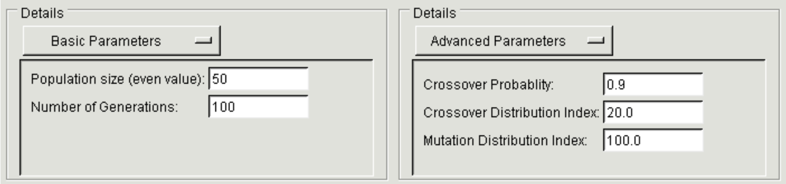


Gene Size (bits): 4
Use Initialization Files: ● no ○ yes
Initialization File Name: init_ncga.db
Iterations for Constraint Violation: 0

Population Size: 15
Number of Generations: 20
Crossover Type: ○ one ● two
Crossover Rate: 1.0
Use Optimal Mutation Rate: ● yes ○ no
Mutation Rate: 0.05

Figure 42. Parameters for the neighborhood cultivation genetic algorithm.

- Non-dominated Sorting Genetic Algorithm (NSGA II): According to Engineous Software (2003), in this algorithm each objective parameter is treated separately. Standard genetic operation of mutation and crossover are performed on the designs. The selection process is based on two main mechanisms, "non-dominated sorting" and "crowding distance sorting". According to Deb *et al* (2002), these two mechanisms offers a selection of the individuals with an uniformly spread out in the pareto front. Although this algorithm was developed by the authors mentioned above as a multi-objective technique, it also has been used as a single-objective algorithm using MDO software as iSIGHT by other authors (Sharma, Deb and Kishore, 2008).
- This algorithm can be used on single objective design optimizations.
  The parameters for this algorithm are population size (6 to 100, default 50), number of generations (1 to 100, default 100), crossover probability (0.5 to 1, default 0.9), crossover distribution (0.5 to 100, default 20), and mutation distribution (0.5 to 500, default 100). With the distribution parameters can be specified how close to or different to his parents will be the child's. A bigger value will result in child's close to their parents.



Population size (even value): 50
Number of Generations: 100

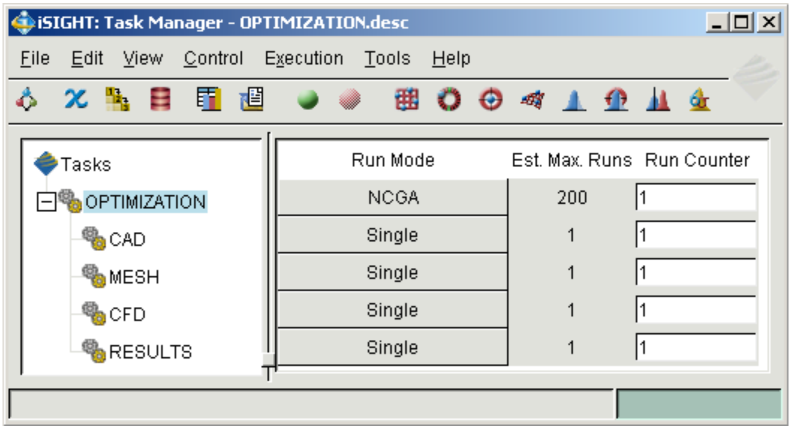
Crossover Probablity: 0.9
Crossover Distribution Index: 20.0
Mutation Distribution Index: 100.0

Figure 43. Parameters for the non-dominated sorting genetic algorithm.

From those, the neighborhood cultivation genetic algorithm (NCGA) was selected for the multi-objective optimization and the non-dominated sorting genetic algorithm(NSGA II) was selected for single objective optimizations.

3.1.6. Integration in MDO software

The integration of all the tasks was made using a commercial software named iSIGHT 8. This process consisted in the automation of the CAD, meshing, CFD and results reading for several design iterations of the Savonius rotor.



Run Mode	Est. Max. Runs	Run Counter
NCGA	200	1
Single	1	1
Single	1	1
Single	1	1
Single	1	1

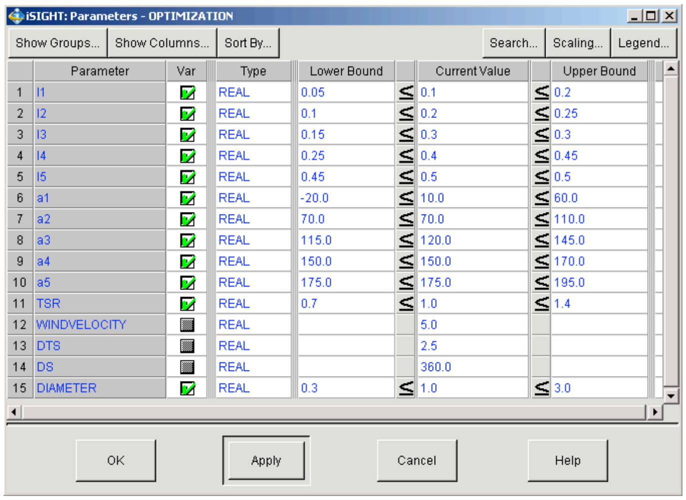
Figure 44. iSIGHT 8 user interface.

The optimization process integration file made in iSIGHT was named OPTIMIZATION.desc. This file contains a task called OPTIMIZATION, which controls four tasks defined as CAD, MESH, CFD and RESULTS.

In the OPTIMIZATION task were added the 10 variables that define the rotor's shape (a1...a5 and l1...l5), the diameter and TSR. This results in a 12 variables optimization process.

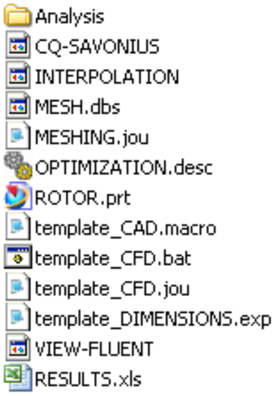
For testing proposes, 3 parameters, that stay constant, but can be modified in any design optimization process, were defined. This parameters are the wind velocity (WINDVELOCITY), degrees per time step (DTS) and degrees of simulation (DS). On Figure 45 can be seen the panel were those parameters are included and can be edited.

To start the optimization process, first the files shown in the Figure 46 must be positioned in the same folder than the iSIGHT optimization file. Then the process can be started and it follows the steps observed on the figure 47. All of this are going to be explained next.



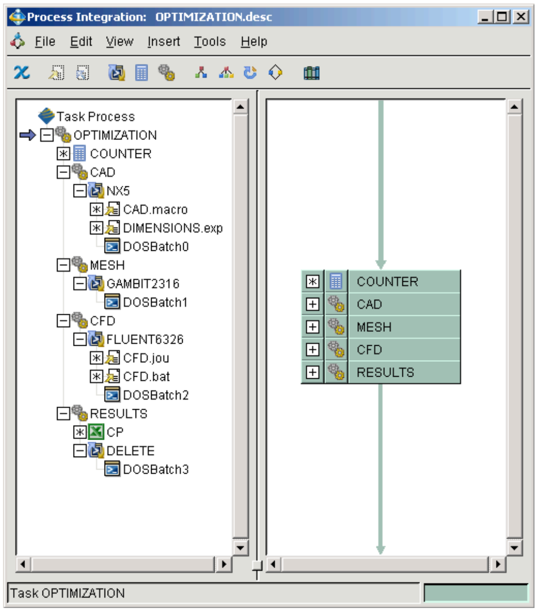
	Parameter	Var	Type	Lower Bound		Current Value		Upper Bound
1	l1	☑	REAL	0.05	≤	0.1	≤	0.2
2	l2	☑	REAL	0.1	≤	0.2	≤	0.25
3	l3	☑	REAL	0.15	≤	0.3	≤	0.3
4	l4	☑	REAL	0.25	≤	0.4	≤	0.45
5	l5	☑	REAL	0.45	≤	0.5	≤	0.5
6	a1	☑	REAL	-20.0	≤	10.0	≤	60.0
7	a2	☑	REAL	70.0	≤	70.0	≤	110.0
8	a3	☑	REAL	115.0	≤	120.0	≤	145.0
9	a4	☑	REAL	150.0	≤	150.0	≤	170.0
10	a5	☑	REAL	175.0	≤	175.0	≤	195.0
11	TSR	☑	REAL	0.7	≤	1.0	≤	1.4
12	WINDVELOCITY	☐	REAL			5.0		
13	DTS	☐	REAL			2.5		
14	DS	☐	REAL			360.0		
15	DIAMETER	☑	REAL	0.3	≤	1.0	≤	3.0

Figure 45. Variables and constants.



- Analysis
- CQ-SAVONIUS
- INTERPOLATION
- MESH.dbs
- MESHING.jou
- OPTIMIZATION.desc
- ROTOR.prt
- template_CAD.macro
- template_CFD.bat
- template_CFD.jou
- template_DIMENSIONS.exp
- VIEW-FLUENT
- RESULTS.xls

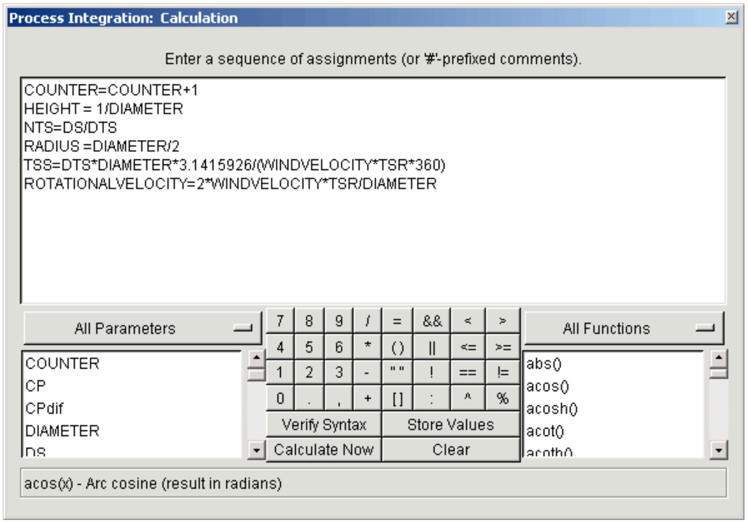
Figure 46. Files needed in order to start the optimization process.



- Task Process
  - OPTIMIZATION
    - COUNTER
    - CAD
      - NX5
        - CAD.macro
        - DIMENSIONS.exp
        - DOSBatch0
    - MESH
      - GAMBIT2316
        - DOSBatch1
    - CFD
      - FLUENT6326
        - CFD.jou
        - CFD.bat
        - DOSBatch2
    - RESULTS
      - CP
      - DELETE
        - DOSBatch3

Figure 47. iSIGHT 8 process integration.

First in the COUNTER section, 6 parameters are calculated. The first was named COUNTER and it has the objective of counting every design iteration. This number then is positioned on all of the created files on every design iteration. Using this technique all the files of the design iterations will be stored. The second parameter was the rotational velocity which was defined as ROTATIONALVELOCITY and it was determined on the equation 14. For the third parameter, the equation 15 was used to define the height of the rotor and it was named HEIGHT. The forth parameter defined is the radius which was named as RADIUS. The next two parameters created were the time step size (TSS) and the number of time steps (NTS), those variables were defined as the equations 17 and 18. On the next Figure can be observed those 6 variables positioned inside the COUNTER panel.



Enter a sequence of assignments (or '#'-prefixed comments).

```
COUNTER=COUNTER+1
HEIGHT = 1/DIAMETER
NTS=DS/DTS
RADIUS =DIAMETER/2
TSS=DTS*DIAMETER*3.1415926/(WINDVELOCITY*TSR*360)
ROTATIONALVELOCITY=2*WINDVELOCITY*TSR/DIAMETER
```

acos(x) - Arc cosine (result in radians)

Figure 48. COUNTER panel.

Then in the CAD section, first the file template_CAD.macro is modified replacing all the COUNTER strings with the parameter COUNTER. Then it is saved as \Analysis \CAD.macro. Then the template of the variables file named template_DIMENSIONS.exp is edited adding the 10 variables for the length and angle and the file is saved as \Analysis \DIMENSIONS.exp. After that, the DOSBatch0 is executed, which contains the following code:

```
cd Analysis
ugraf.exe -key:CAD.macro
```

This script fist positions the path in the Analysis folder and then executes the CAD.macro file created before.

In the MESH task. As no file needs to be edited, the only process it the execution of the DOSBatch1, which contains the following code:

```
copy MESH.dbs .\Analysis
copy MESHING.jou .\Analysis
cd Analysis
gambit -inputfile MESHING.jou
```

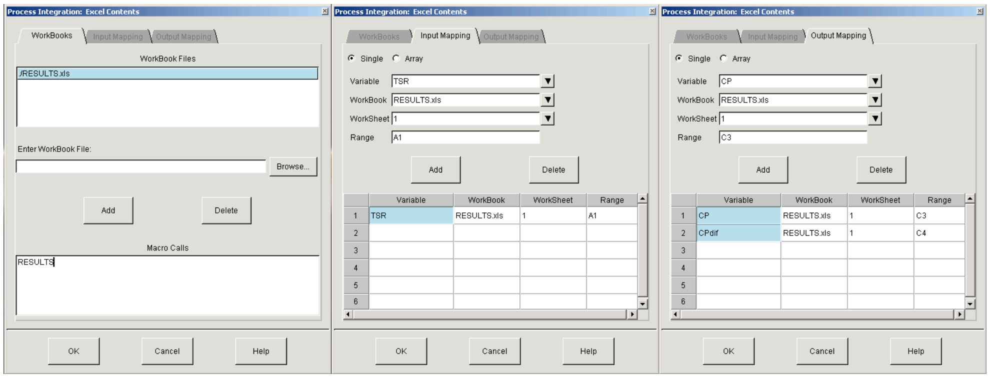
In this script, the files MESH.dbs and MESHING.jou are copied inside the folder Analysis. Then the path is changed to that folder and the journal MESHING.jou is executed inside GAMBIT.

Then in the CFD section. The variables DIAMETER and TSR and the parameters ROTATIONALVELOCITY, HEIGHT, RADIUS, TSS and NTS are introduced to the journal template_CFD.jou. Then this file is saved as \Analysis\CFD.jou. After this, the file template_CFD.bat is modified replacing the string COUNTER, then it is saved as \Analysis \CFD.bat. This file is shown next:

```
cd..
copy CQ-SAVONIUS .\Analysis\cq-savonius
cd Analysis
if not exist mesh.msh goto :FAIL
cd..
copy INTERPOLATION .\Analysis\INTERPOLATION
copy VIEW-FLUENT .\Analysis\VIEW-FLUENT
cd Analysis
fluent.exe 2d -i CFD.jou
:LOOP
call wait 5
if not exist .\kill* goto LOOP
copy rotor-COUNTER-CQ cq-savonius
:FAIL
```

After this DOS batch is edited and saved, iSIGHT executes it with the DOSBatch2. This batch code basically copies an empties CFD analysis results (cq-savonius) inside the folder Analysis. Then it looks for the mesh file and if it is not there (because of a meshing error), the script finishes without executing the CFD analysis, so this will result in a C_P result of zero. On the other hand if the mesh was successfully created, the CFD process will proceed and the files needed (INTERPOLATION and VIEW-FLUENT) will be copied to the folder Analysis. Then the CFD analysis will be executed and a loop will start to look for a file kill* every 5 seconds, this loop will finished until the file is founded. The file kill* is created at the end of the CFD process, so when it finishes the loop will ends and the DOS batch will continue with the next line. That line will copy the CFD result rotor-COUNTER-CQ as cq-savonius. This file names allows the storing of results of every design iteration (rotor-COUNTER-CQ) and also allows the reading of results because the Excel macro (will be explained next) needs a file named cq-savonius.

The next step is the CP task in which iSIGHT opens the file RESULTS.xls, then introduces the value of the TSR inside the cell A1. After this, iSIGHT executes the macro contained inside the file. This macro will import the values contained in the file cq-savonius which are the C_Q unsteady results of the CFD analysis. Then the macro calculates the CP and CPdif using the equation 13, which needs the TSR value. On the Figure 49 can be seen the CP task panel in which the instructions were introduced.



WorkBook Files: ./RESULTS.xls

Enter WorkBook File:

Macro Calls: RESULTS

● Single ○ Array

Variable: TSR
WorkBook: RESULTS.xls
WorkSheet: 1
Range: A1

	Variable	WorkBook	WorkSheet	Range
1	TSR	RESULTS.xls	1	A1
2				
3				
4				
5				
6				

● Single ○ Array

Variable: CP
WorkBook: RESULTS.xls
WorkSheet: 1
Range: C3

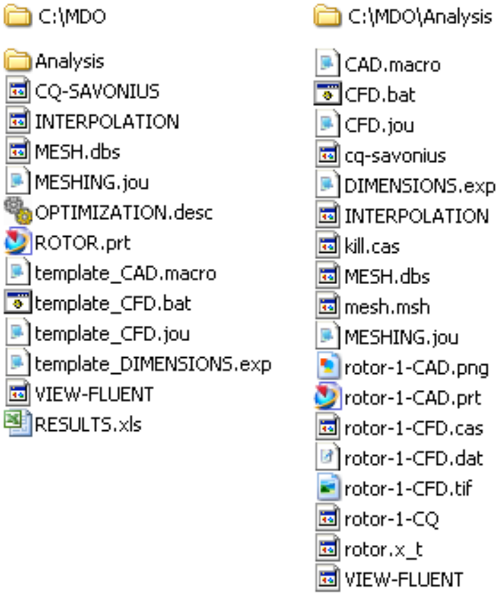
	Variable	WorkBook	WorkSheet	Range
1	CP	RESULTS.xls	1	C3
2	CPdif	RESULTS.xls	1	C4
3				
4				
5				
6				

Figure 49. Integration of Excel in iSIGHT 8.

After this task is done, the process DELETE will execute the DOSbatch3 code. This code will delete all of the temporal files created in the process. If this code is not executed, the next design iteration will fail due to file name duplications. This code first positions the path in the folder Analysis and then deletes all the files shown in the following code:

```
cd Analysis
del *.x_t c* d* m* i* v* k*
```

To illustrate the whole process explained before, on the Figure 50, are observed the files created on the iteration 1 before the DELETE task is executed.

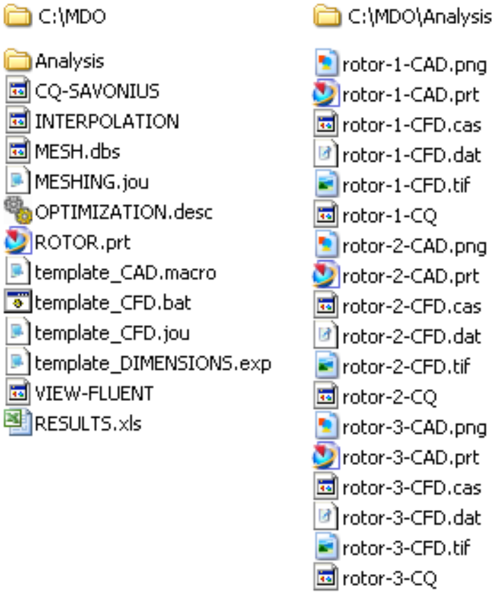


C:\MDO
Analysis
CQ-SAVONIUS
INTERPOLATION
MESH.dbs
MESHING.jou
OPTIMIZATION.desc
ROTOR.prt
template_CAD.macro
template_CFD.bat
template_CFD.jou
template_DIMENSIONS.exp
VIEW-FLUENT
RESULTS.xls

C:\MDO\Analysis
CAD.macro
CFD.bat
CFD.jou
cq-savonius
DIMENSIONS.exp
INTERPOLATION
kill.cas
MESH.dbs
mesh.msh
MESHING.jou
rotor-1-CAD.png
rotor-1-CAD.prt
rotor-1-CFD.cas
rotor-1-CFD.dat
rotor-1-CFD.tif
rotor-1-CQ
rotor.x_t
VIEW-FLUENT

Figure 50. Files created on the iteration 1 before the DELETE task.

On the other hand, as shown in the Figure 51, at the end of the third iteration, the files stored for every iteration will be an image of the CAD model (.png), the CAD file (.prt), the files of the CFD analysis (.cas and .dat), an image of the CFD analysis (.tif) and the C_Q unsteady results.



C:\MDO
Analysis
CQ-SAVONIUS
INTERPOLATION
MESH.dbs
MESHING.jou
OPTIMIZATION.desc
ROTOR.prt
template_CAD.macro
template_CFD.bat
template_CFD.jou
template_DIMENSIONS.exp
VIEW-FLUENT
RESULTS.xls

C:\MDO\Analysis
rotor-1-CAD.png
rotor-1-CAD.prt
rotor-1-CFD.cas
rotor-1-CFD.dat
rotor-1-CFD.tif
rotor-1-CQ
rotor-2-CAD.png
rotor-2-CAD.prt
rotor-2-CFD.cas
rotor-2-CFD.dat
rotor-2-CFD.tif
rotor-2-CQ
rotor-3-CAD.png
rotor-3-CAD.prt
rotor-3-CFD.cas
rotor-3-CFD.dat
rotor-3-CFD.tif
rotor-3-CQ

Figure 51. Files created at the end of the iteration 3.

Chapter 4
Results

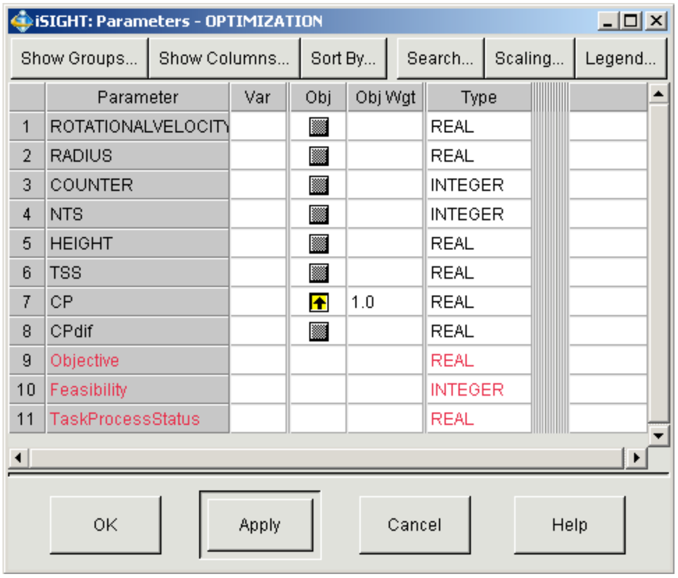
This Chapter presents the optimization processes carried out in order to improve the performance of the Savonius wind turbine. This improvement is based on the maximization of the C_P and the minimization of the variation of C_P (C_{Pdif}) in the unsteady CFD analysis explained in the last Chapter. The maximization of the C_P is needed in order to improve the capacity of converting the wind energy into mechanical energy. Also, the minimization of the C_{Pdif} could improve the WT stability by decreasing the generation of vibrations.

The optimizations were defined as single-objective (only maximization of the C_P) and multi-objective, and they include variables to modify the rotor shape (a1 to a5 and l1 to l5), size (diameter), and TSR.

The next sections describe the objectives, variables and algorithms parameters used in the optimizations. Also, the results of each design optimization process are shown and discussed.

4.1. Single-objective shape optimization

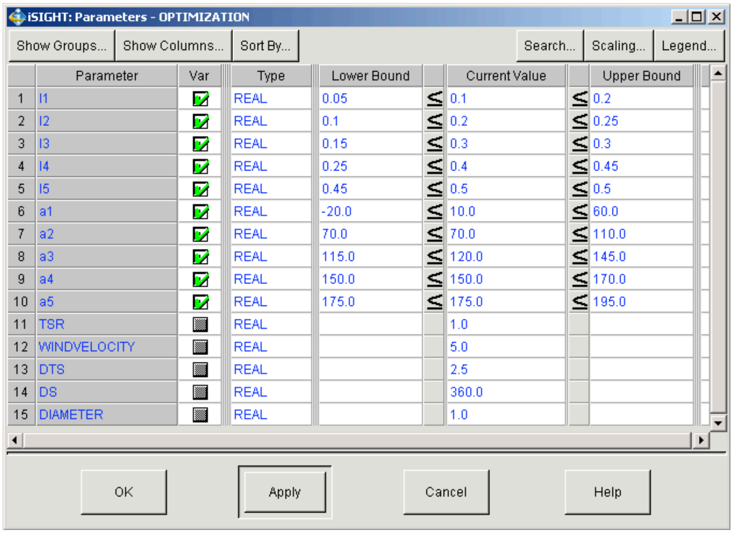
This design optimization was done in order to maximize the C_P modifying only the shape of the rotor. In Figure 52 it is observed the panel inside iSIGHT where the objectives were set.



	Parameter	Var	Obj	Obj Wgt	Type
1	ROTATIONALVELOCITY		▨		REAL
2	RADIUS		▨		REAL
3	COUNTER		▨		INTEGER
4	NTS		▨		INTEGER
5	HEIGHT		▨		REAL
6	TSS		▨		REAL
7	CP		↑	1.0	REAL
8	CPdif		▨		REAL
9	Objective				REAL
10	Feasibility				INTEGER
11	TaskProcessStatus				REAL

Figure 52. First optimization objective.

As mentioned earlier, the rotor profile shape is defined by 10 variables (a1 to a5 and l1 to l5). In this particular optimization the range of those variables were defined as illustrated in Figure 30. The next Figure shows how this variables and ranges were introduced into iSIGHT. Also it is observed that the diameter used was 1m and the TSR stayed constant at a value of 1.



	Parameter	Var	Type	Lower Bound		Current Value		Upper Bound
1	l1	☑	REAL	0.05	≤	0.1	≤	0.2
2	l2	☑	REAL	0.1	≤	0.2	≤	0.25
3	l3	☑	REAL	0.15	≤	0.3	≤	0.3
4	l4	☑	REAL	0.25	≤	0.4	≤	0.45
5	l5	☑	REAL	0.45	≤	0.5	≤	0.5
6	a1	☑	REAL	-20.0	≤	10.0	≤	60.0
7	a2	☑	REAL	70.0	≤	70.0	≤	110.0
8	a3	☑	REAL	115.0	≤	120.0	≤	145.0
9	a4	☑	REAL	150.0	≤	150.0	≤	170.0
10	a5	☑	REAL	175.0	≤	175.0	≤	195.0
11	TSR	▨	REAL			1.0		
12	WINDVELOCITY	▨	REAL			5.0		
13	DTS	▨	REAL			2.5		
14	DS	▨	REAL			360.0		
15	DIAMETER	▨	REAL			1.0		

Figure 53. First optimization variables (10) with their ranges.

As this is a single objective optimization, the non-dominated sorting genetic algorithm (NSGA II) was used. The next list presents the parameters used. From those, the crossover and mutation distribution were defined as the default values. This values are commonly used, as it is the case of the investigations of Tong (2003) and Chase (2008).

- Population size: 20
- Number of generations: 20
- Crossover probability: 1
- Crossover distribution: 20
- Mutation distribution: 100

In order to complete this task there were needed 420 iterations. From these, 400 were generated by the population created in each generation, and the other 20 were created as an initial population. All this process was computed in approximately 174.5 hrs, without counting a system failure that stopped the process at the 149th design iteration and required a re initialization of the process.

The C_P´s of the 420 individuals created in the current design optimization are presented in the following Figure. From it, it is clear that the C_P value was getting higher as the DI's were performed, and approximately after the iteration 200 the values continued growing but at a slower rate. In fact the individuals fitness started to stabilize in a value close to 0.3. This phenomena is called convergence.

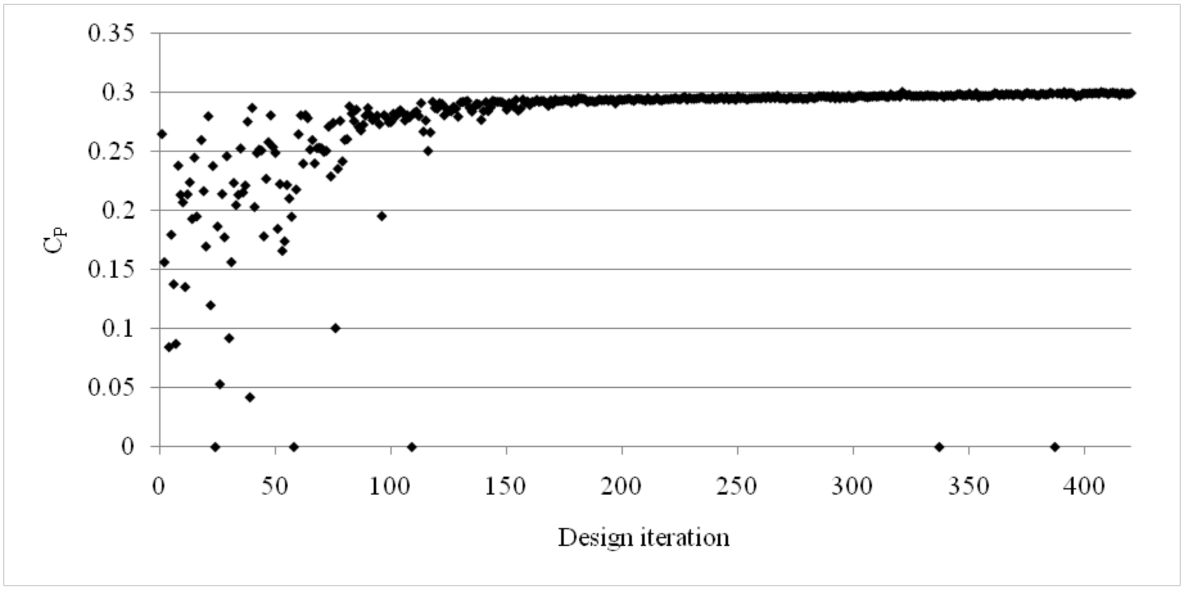


Figure 54. C_P convergence on the first optimization.

The results of this single objective optimization reached a maximum C_P of 0.301 found in the design iteration 321 (DI321). Table 6 presents individuals with the best fitnesses, while

Appendix B exposes all the iterations variables and results. Figure 55 illustrates the rotor shape of the DI 321, 407, 412 and 385.

Table 6. Best performance individuals of the first optimization.

DI	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	C_P	C_{Pdif}
321	0.13915	0.110314	0.26076	0.384695	0.474808	-18.9248	100.8004	128.2909	150.0876	187.2184	0.300872	0.734204
391	0.13915	0.110313	0.26076	0.384695	0.474808	-18.9248	100.8004	128.2909	150.0876	187.2184	0.300834	0.735141
407	0.14034	0.110301	0.255944	0.38764	0.473434	-18.926	100.8004	126.6676	150.1977	187.2138	0.300825	0.738301
412	0.13914	0.109035	0.255923	0.387662	0.476792	-18.9139	100.8004	126.6501	150.1977	187.2128	0.300349	0.737557
385	0.13743	0.110334	0.255987	0.387642	0.476791	-19.9599	100.8004	126.6135	150.1977	187.217	0.300201	0.734967

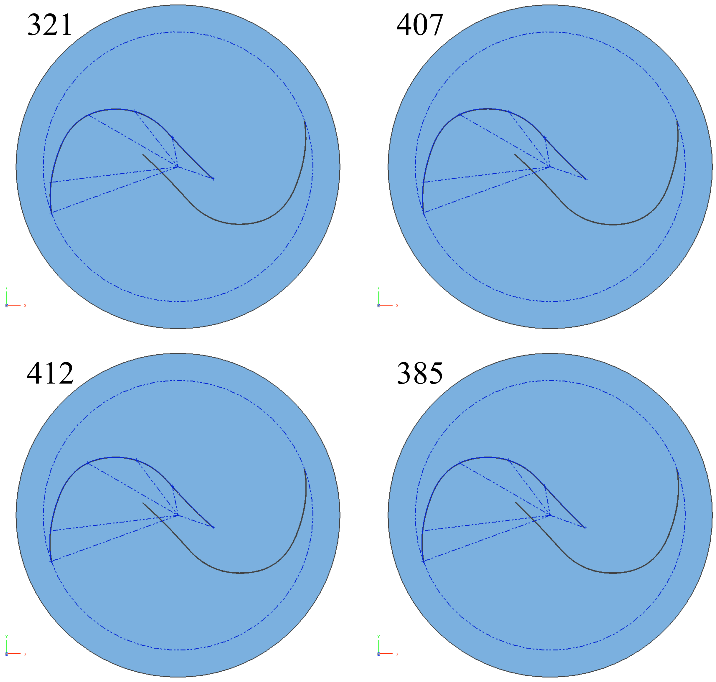


Figure 55. Best performance rotors profiles of the first optimization

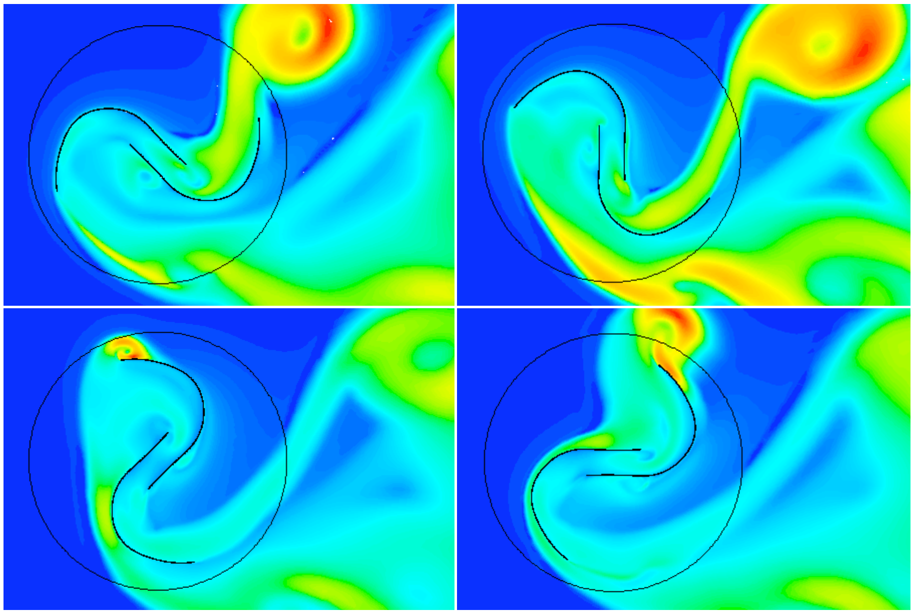


Figure 56. Turbulence intensity contours for the DI321.

Between the DI 321 and 391 there is only a difference of 0.000001 in their variable l2. Because of this, it can be thought that it is impossible to manufacture a rotor with that kind of dimensions because the tolerances needed would increase the cost of its production. But analyzing the data of the C_P convergence it can be noticed that after the iteration 200, the value of the C_P has a variation from 0.2933 to 0.3008, this is about a 0.0075 of the efficiency of the rotor. Also, the variables presented a considerable variation that it is shown in Table 7. This considerable variation in the shape and the minimal variation in C_P indicate that the design of the Savonius is robust and if the manufacturing process is controlled within those variations, the efficiency will be decreased at a maximum of 0.75%.

Table 7. Values of the variables between the iteration 200 to 420.

Variable	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	C_P
Maximum	0.1545	0.1314	0.2713	0.4006	0.4801	-17.96	102.59	128.39	153.08	188.05	0.300872
Minimum	0.1312	0.1028	0.2533	0.3817	0.4720	-19.97	97.84	125.69	150.00	184.44	0.293324
Variation	0.0233	0.0286	0.0181	0.0189	0.0081	2.01	4.75	2.70	3.08	3.61	0.0075

To exemplify the variation that can be acceptable, first the meaning of the variables must be understood. As the length variables (l1 to l5) are related to the rotor diameter, if a 1m diameter rotor is used, the variation values are represented as meters. According to that, the variable l1 can have a value between 13.1 cm and 15.4 cm without modifying the C_P in more than 0.75%. Also, the angles are represented as degrees, so the permissible angle for a1 is between -17.96 to -19.97 degrees.

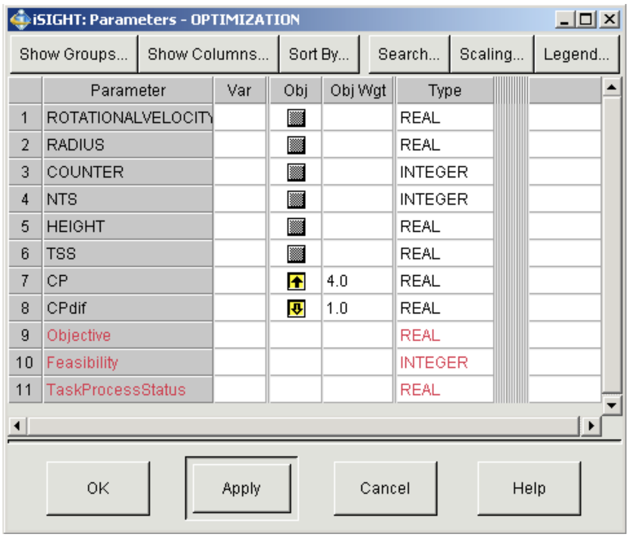
In Figure 54 some designs have a zero C_P. This results are because the mesh task failed. As only 5 mesh errors occurred in the 420 iterations, the total meshing error was about 1.2% in this optimization process.

This process leads to the conclusion that the ranges of the variables need to be modified. If the best individuals are analyzed, it can be seen that the variables a1, a4 and l2 are in their lower limit. For this reason, in the next optimization the ranges of those variables will be increased in their lower limit.

4.2. Multi-objective shape, diameter and TSR optimization

In this optimization the minimization of the C_{Pdif} was added as an objective. Also, the diameter and the TSR were added as variables in order to explore their potential.

In order to start this optimization, as it is shown in Figure 57, a weight must be determined for both objectives. In order to decide this value, a pareto front of the last single objective optimization was made. This front is shown in Figure 58 and it has four different lines that represent the zone were all the individuals have the same objective value using different weights for the C_P objective (the weight for C_{Pdif} is 1). In the Figure can be determined that if a weight of 1 is used, a design iteration with a C_P of 0.25 and with a C_{Pdif} of 0.63 can have a better fitness than the DI321 with a C_P of 0.301. To change this behavior, the weight for the C_P variable can be increased or decreased in order to search in the desired space. For this optimization a weight of 4 was added to the C_P variable.



	Parameter	Var	Obj	Obj Wgt	Type
1	ROTATIONALVELOCITY		▨		REAL
2	RADIUS		▨		REAL
3	COUNTER		▨		INTEGER
4	NTS		▨		INTEGER
5	HEIGHT		▨		REAL
6	TSS		▨		REAL
7	CP		⬆	4.0	REAL
8	CPdif		⬇	1.0	REAL
9	Objective				REAL
10	Feasibility				INTEGER
11	TaskProcessStatus				REAL

Figure 57. Second optimization objectives with weight.

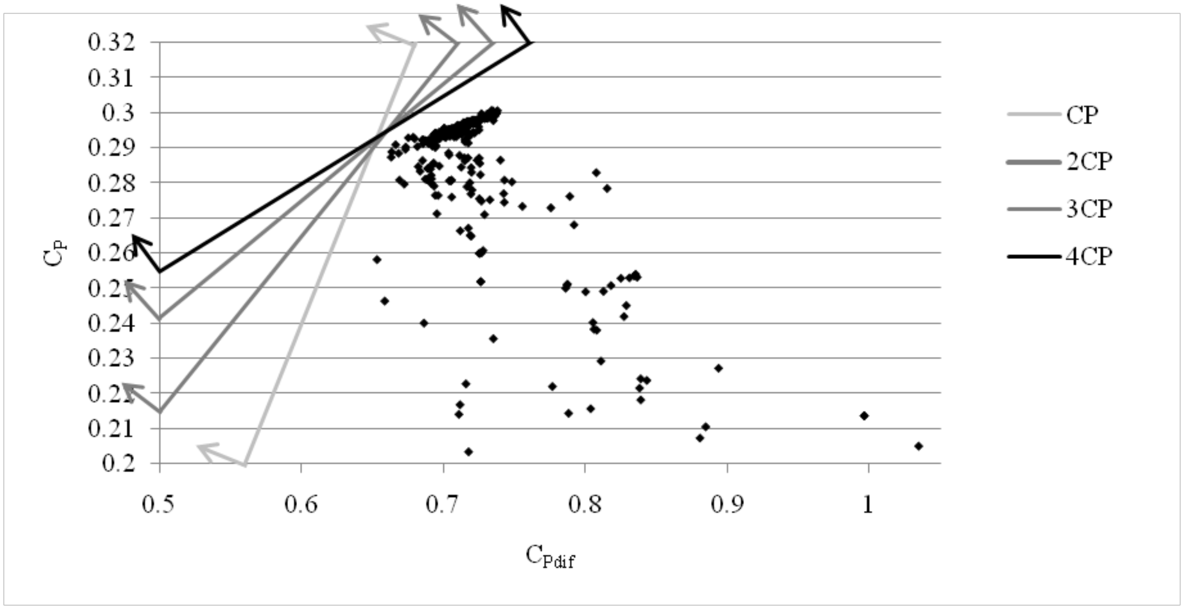


Figure 58. Pareto front with different weight for the variable C_P.

If in the last single objective optimization a weight of 4 were used, the DI197 would be the best individual with a C_P of 0.2911 and a C_{Pdif} of 0.6667. In Figure 59 can be observed the average and unsteady C_P of the DI's 197 and 321. Those curves show that the DI197 has a lower variation with a considerable good C_P. In this multi-objective optimization it was tried to find an individual with a greater C_P performance but with a smaller variation of the same parameter.

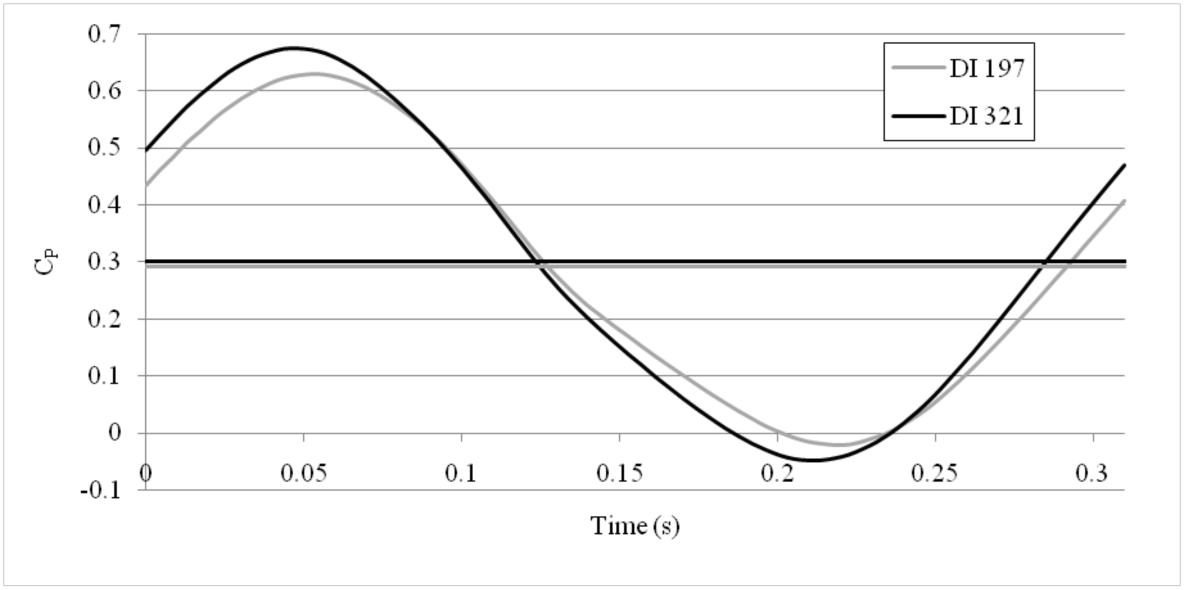


Figure 59. Average and unsteady C_P for the first optimization's DI's 197 and 321.

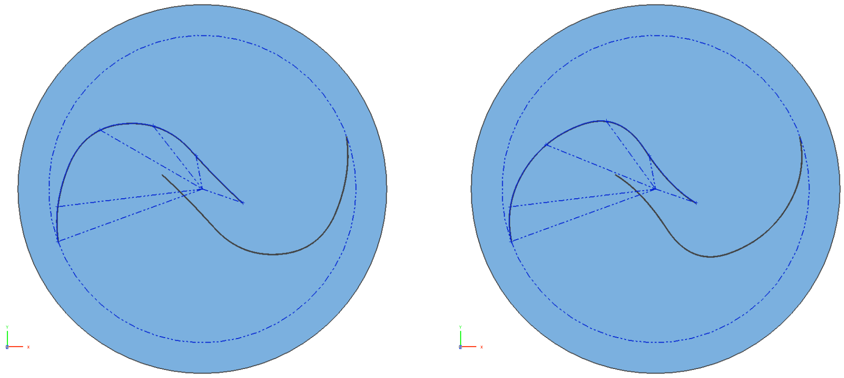


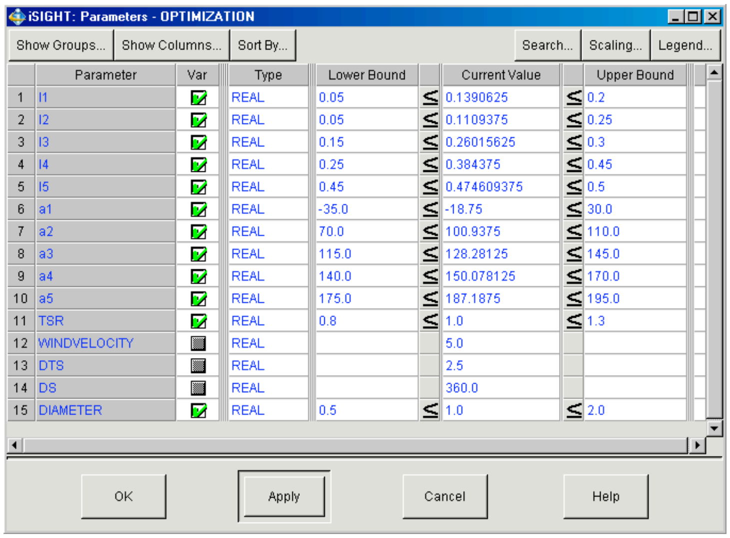
Figure 60. Comparison of rotor's profile for the DI 321 (left) and 197 (right).

In this optimization, the neighborhood cultivation genetic algorithm (NCGA) was used. The parameters selected for this multi-objective optimization were the following:

- Population size: 16
- Number of generations: 25
- Crossover type: 1 point.
- Crossover rate: 1
- Use optimal mutation: No
- Mutation rate: 0.05
- Gene size: 6
- Use initialization file: No
- Iterations for constraint violation: 0

In this process it was tried to use an initialization population taking some of the best individuals of the last single objective optimization. As it wasn't possible, only the initial individual was defined on the variables panel (see Figure 61) as the DI321 of the last optimization.

Another change made in this process was the modification of the ranges of the variables a1, a4 and l2. The value for those variables can be observed in the next Figure. It must be clarified that the lower limit of the variable a1 was also modified in order to avoid a search space that didn't show any potential in the last optimization, so it was reduced from 70 to 30 degrees. On the other hand, for the new variables the range defined was a diameter between 0.5 and 2m and a minimum TSR of 0.8 and maximum of 1.3.



	Parameter	Var	Type	Lower Bound		Current Value		Upper Bound
1	l1	☑	REAL	0.05	≤	0.1390625	≤	0.2
2	l2	☑	REAL	0.05	≤	0.1109375	≤	0.25
3	l3	☑	REAL	0.15	≤	0.26015625	≤	0.3
4	l4	☑	REAL	0.25	≤	0.384375	≤	0.45
5	l5	☑	REAL	0.45	≤	0.474609375	≤	0.5
6	a1	☑	REAL	-35.0	≤	-18.75	≤	30.0
7	a2	☑	REAL	70.0	≤	100.9375	≤	110.0
8	a3	☑	REAL	115.0	≤	128.28125	≤	145.0
9	a4	☑	REAL	140.0	≤	150.078125	≤	170.0
10	a5	☑	REAL	175.0	≤	187.1875	≤	195.0
11	TSR	☑	REAL	0.8	≤	1.0	≤	1.3
12	WINDVELOCITY	▨	REAL			5.0		
13	DTS	▨	REAL			2.5		
14	DS	▨	REAL			360.0		
15	DIAMETER	☑	REAL	0.5	≤	1.0	≤	2.0

Figure 61. Second optimization variables (12) with their ranges.

Figure 62 shows an illustration that compares the range of the last single objective optimization with the limits proposed for this multi objective optimization. Also, in the same Figure can be seen that the DI 321 values for a1, a4 and l1 were set close to their limits on the fist optimization.

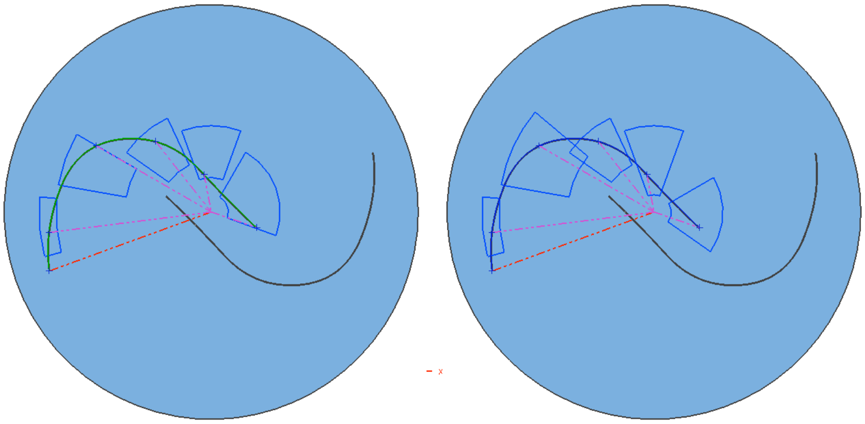


Figure 62. Ranges for the variables on the last (left) and present (right) optimization.

As this optimization was performed with a population of 16 individuals and 25 generations, the total number of iterations were 400. This iterations were performed in approx. 165 hours and the C_P variation over them is shown in the Figure 63.

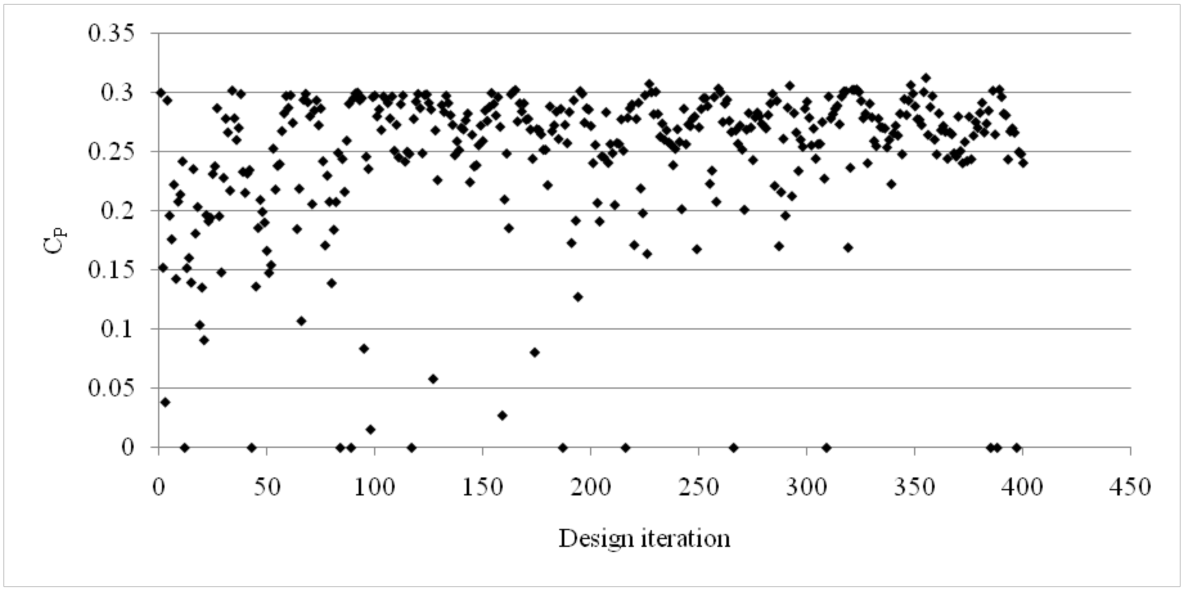


Figure 63. C_P obtained in every design iteration of the second optimization.

As this is a multi-objective optimization, there is a function that relates all the objectives. This function is called the Objective and penalty (see equation 19). In this function the C_P and C_{Pdif} are related to their weight and a penalty is added. The penalty value is zero when the design iteration evaluation completes successfully or a very high value when the design iteration evaluation fails.

$$\textit{Objective and Penalty} = 4 \cdot C_P - C_{Pdif} - \textit{Penalty} \qquad 19$$

The next Figure plots the Objective and Penalty function over the design iterations. In it can be seen that the values are getting higher as the iterations are performed, but there is no convergence. It is possible that 400 iterations were not enough to reach convergence. Due to the time needed for every design iteration evaluation, it is difficult to perform an optimization process with more than that number of iterations.

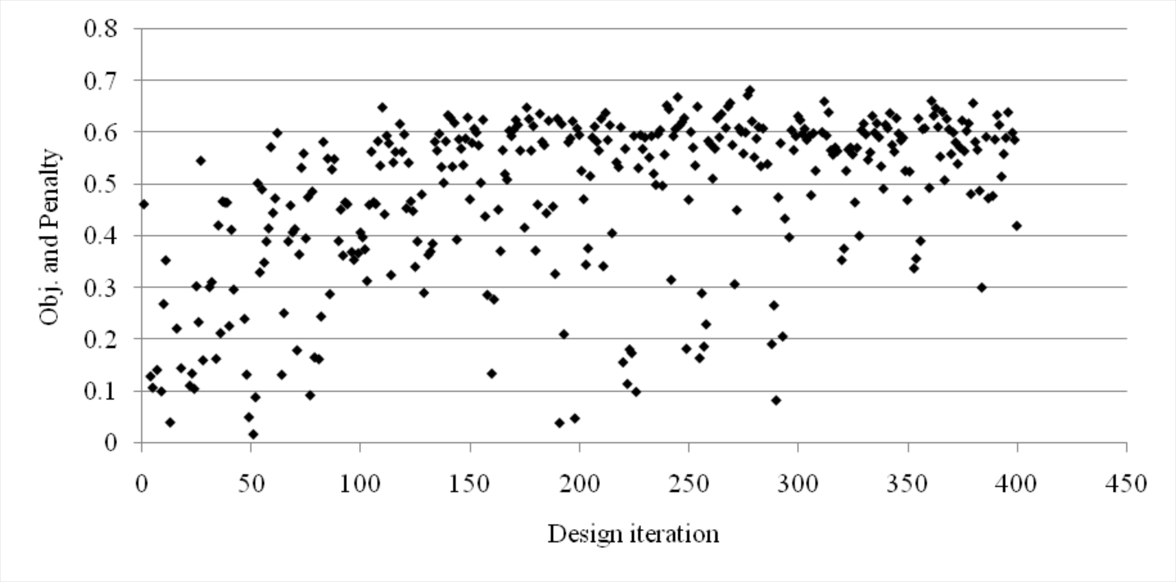


Figure 64. Objective and penalty for every design iteration of the second optimization.

On the next Figure it is observed the pareto front for the current optimization. In it can be observed that if a higher value of C_P is wanted, the variation of it will be increased. This improvement of one objective and worsening of the other its a tradeoff that its defined by the weight of every objective. Using the weight of 4 for the C_P objective, the best individuals can be detected. In Table 8 the best individuals according to the Objective and penalty function are presented, then each of those individuals shapes are represented on Figure 66. On the other hand the individuals with the higher values of C_P are presented on Table 9 and their shapes are shown in Figure 67.

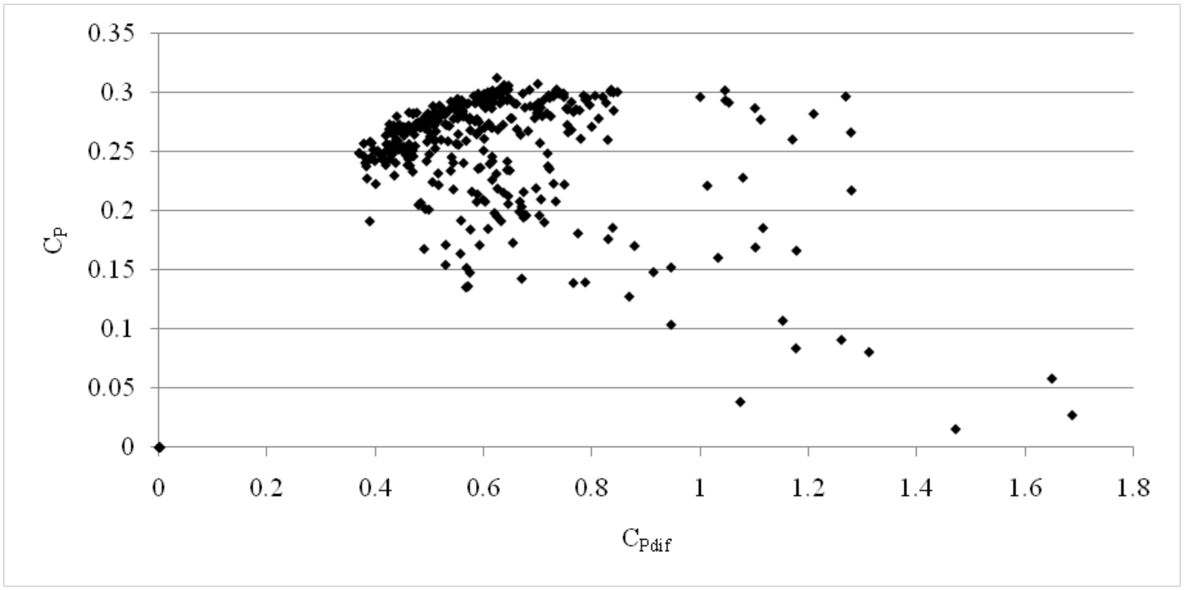


Figure 65. Pareto front of the second optimization.

Table 8. Best performance individuals of the second optimization.

DI	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5
278	0.1390625	0.10625	0.2953125	0.371875	0.4734375	-18.75	104.375	128.125	141.875	190.625
277	0.1390625	0.115625	0.28125	0.384375	0.4617188	-16.71875	106.25	128.59375	150.3125	188.4375
245	0.1390625	0.10625	0.2976563	0.384375	0.4617188	-17.734375	106.25	128.59375	150.3125	188.4375
361	0.1390625	0.11875	0.28125	0.38125	0.4625	-18.75	106.25	128.125	151.25	186.5625
312	0.1273438	0.115625	0.28125	0.384375	0.4617188	-16.71875	106.25	128.59375	154.53125	186.25

DI	TSR	DIAMETER	C_P	C_{Pdif}	Obj. Penalty	Technique Data
278	0.8	1.2734375	0.28008762	0.43803291	0.68231756	Generation=18/Individual=5/Extra=0
277	0.8078125	1.25	0.28331592	0.46080187	0.67246181	Generation=18/Individual=4/Extra=0
245	0.8	1.203125	0.27333320	0.42455565	0.66877716	Generation=16/Individual=4/Extra=0
361	0.815625	1.4140625	0.28262394	0.46890363	0.66159213	Generation=23/Individual=8/Extra=0
312	0.815625	1.8359375	0.28210470	0.46796706	0.66045175	Generation=20/Individual=7/Extra=0

Table 9. Individuals with the highest C_P value.

DI	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5
355	0.171875	0.115625	0.225	0.35	0.4625	-18.75	108.125	129.0625	150.3125	186.5625
227	0.1789063	0.115625	0.2226563	0.371875	0.4804688	-18.75	106.25	128.125	150.3125	189.0625
348	0.1789063	0.115625	0.2320313	0.38125	0.4625	-18.75	108.125	129.0625	150.3125	186.5625
292	0.18125	0.10625	0.225	0.3625	0.4742188	-18.75	108.125	130.46875	154.0625	188.125
259	0.18125	0.10625	0.225	0.3625	0.4742188	-18.75	108.125	130	151.25	185.625

DI	TSR	DIAMETER	C_P	C_{Pdif}	Obj. Penalty	Technique Data
355	0.9015625	1.9765625	0.31263414	0.62307515	0.62746140	Generation=23/Individual=2/Extra=0
227	0.9484375	1.4140625	0.30756643	0.69845487	0.53181087	Generation=15/Individual=2/Extra=0
348	0.9015625	1.4140625	0.30662299	0.63625051	0.59024144	Generation=22/Individual=11/Extra=0
292	0.909375	1.4140625	0.30607150	0.64453818	0.57974781	Generation=19/Individual=3/Extra=0
259	0.9015625	1.4140625	0.30366842	0.63054404	0.58412966	Generation=17/Individual=2/Extra=0

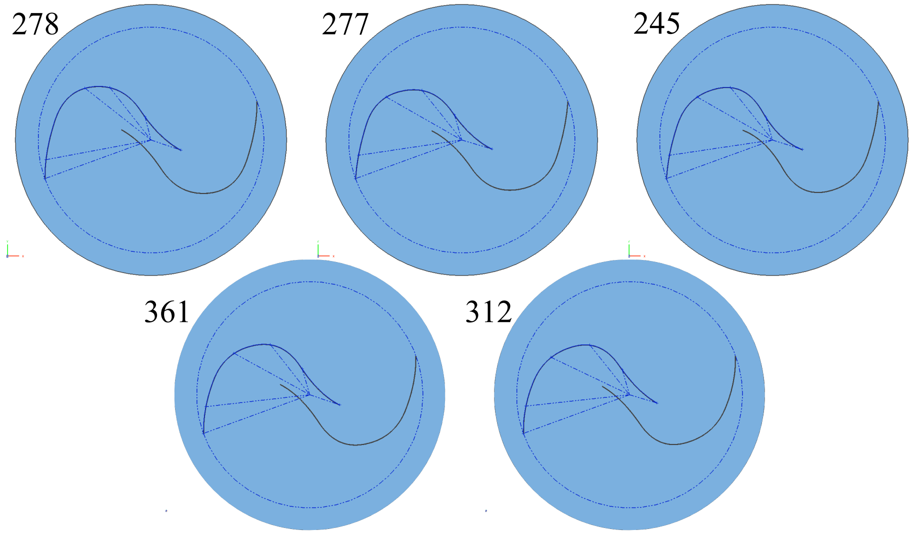


Figure 66. Best performance rotors profiles of the second optimization.

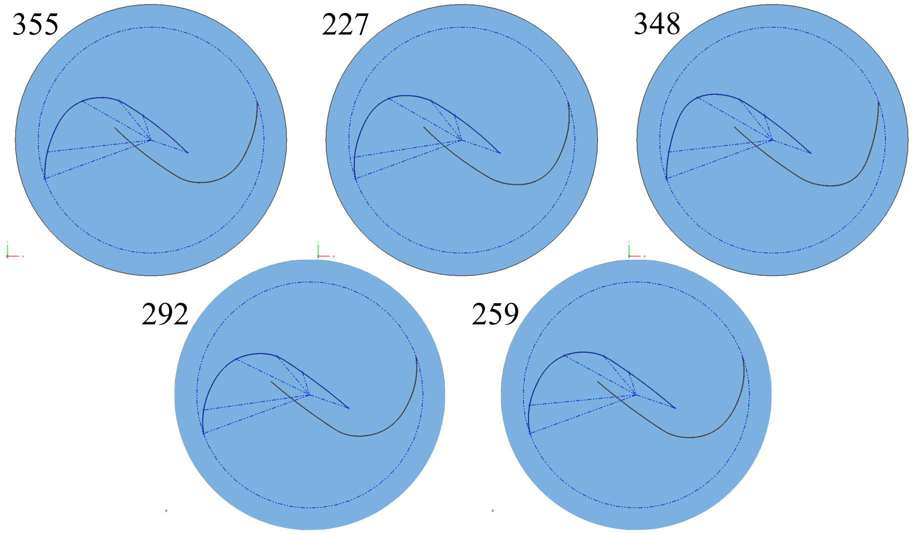


Figure 67. Rotor's profiles with the highest C_P values of the second optimization.

The shapes presented on the Figures 66 and 67 offer a graphic representation of the individuals. From those figures can be seen that the individuals with the best tradeoff performance between a good C_P and an acceptable C_{Pdif} seems to have a more curved shape with a small overlap. On the other hand, a more straight shape with a long overlap describes the rotors with the highest C_P's.

Analyzing the best individuals on Table 7, its observed that the values for the TSR are on their lower limit (around 0.8). In order to find the source of this behavior, the C_P and C_{Pdif} objectives were plotted according to the TSR (Figures 68 and 69). In the first Figure can be observed that the maximum value is positioned at a TSR of 0.9, which agrees with the C_P curve on Figure 3 that positions the best performance Savonius WT at a TSR around 0.75

and 1. The second Figure presents a very clear relation between the C_{Pdif} and the TSR. With it, it can be concluded that at a lower working velocity, the variation of the C_P over the time (C_{Pdif}) is diminished. This gives the individuals with lower TSR a better fitness.

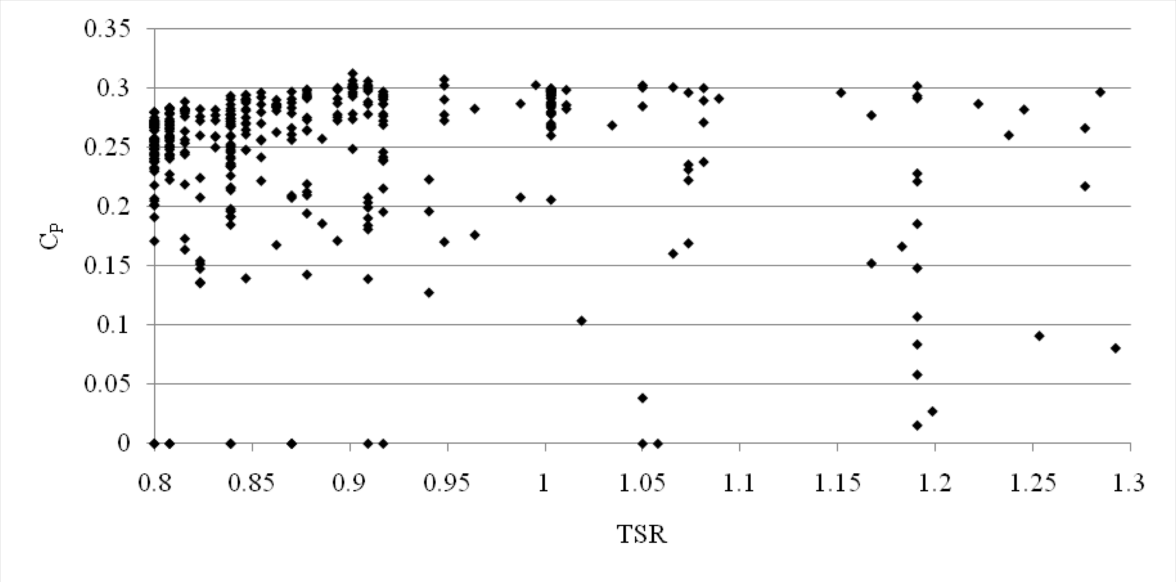


Figure 68. C_P variation over the TSR on the second optimization.

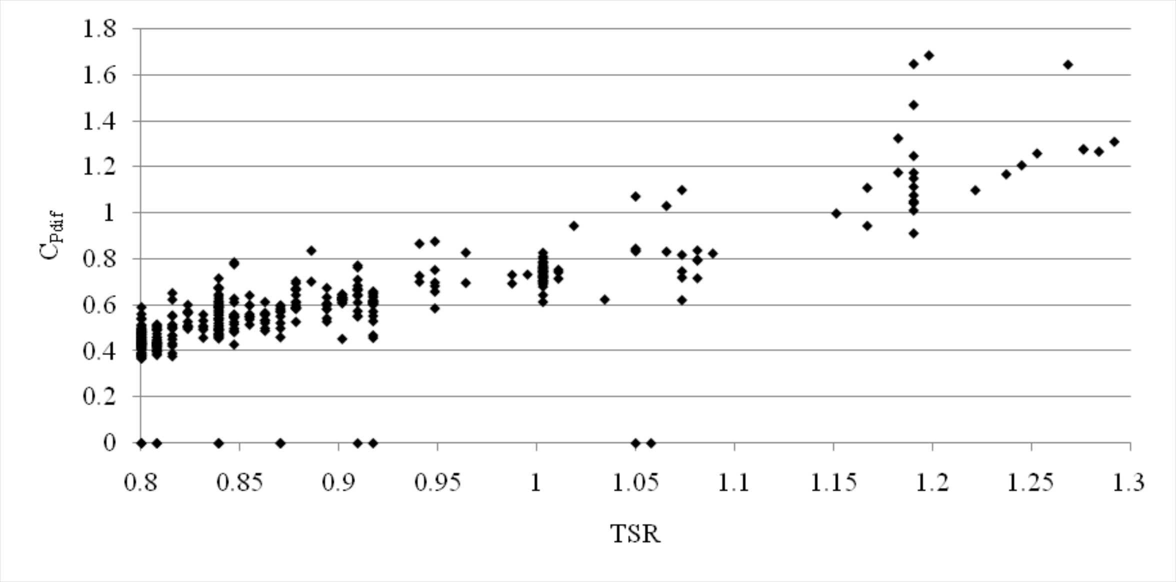


Figure 69. C_{Pdif} according to the TSR on the second optimization.

Meanwhile, the diameter variable its around the values of 1.2 and 1.8. In order to detect a relation of this variable with the higher performance individuals, the C_P and C_{Pdif} variables were plotted according to this variable (Figures 70 and 71). In both Figures, a relation cant be detected and more iterations will be needed in order to conclude if a higher or lower value of this variable is better or not.

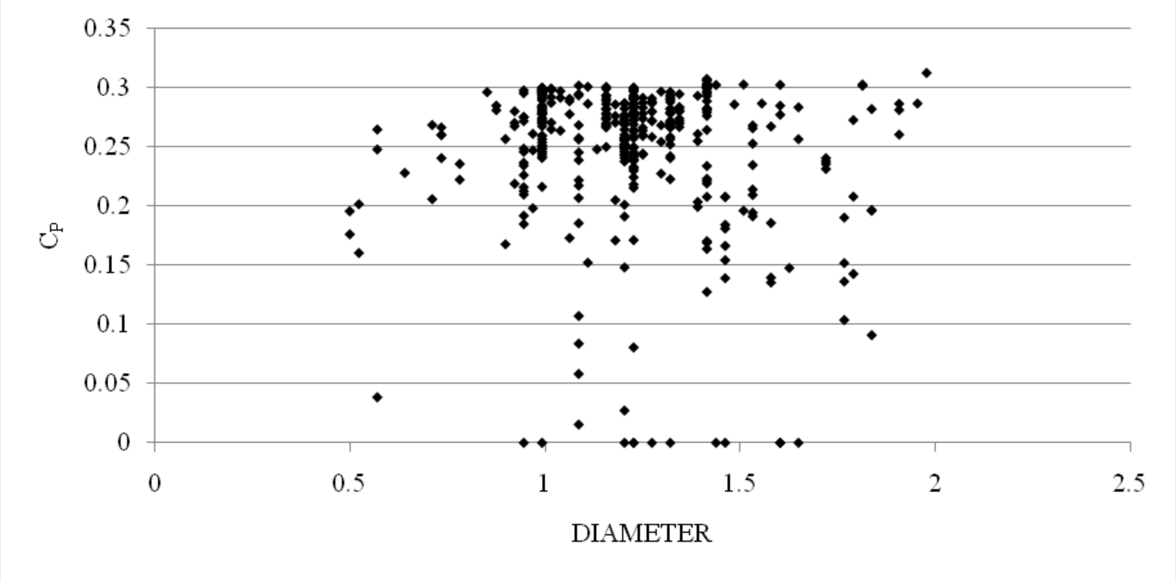


Figure 70. C_P variation over the diameter variable on the second optimization.

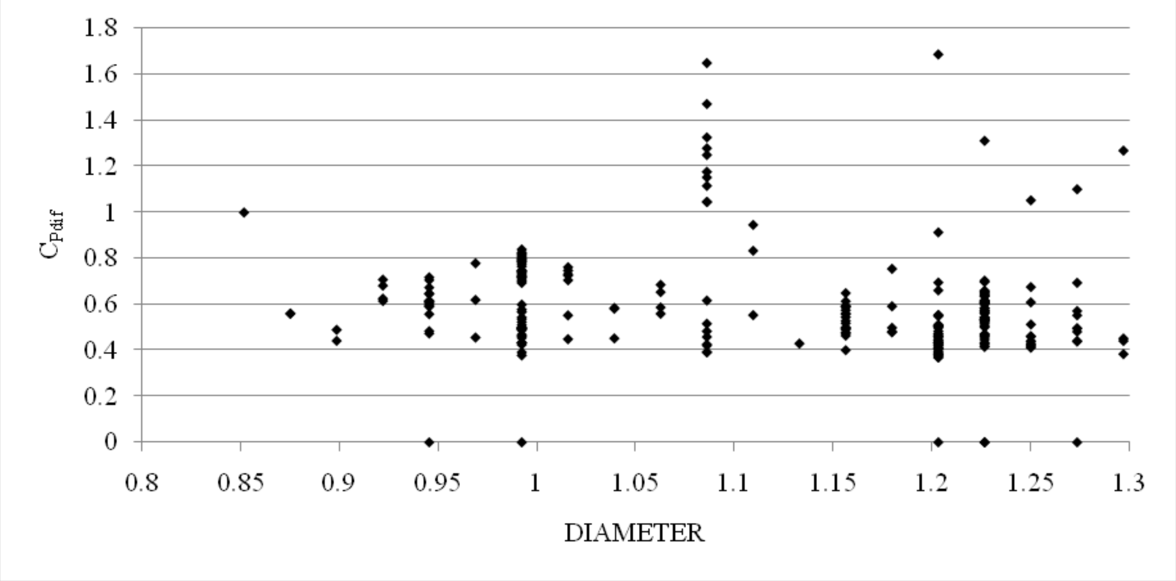


Figure 71. C_{Pdif} according to the diameter on the second optimization.

Although this is an optimization that involves two objectives, the individuals with the highest C_P values (Table 8) will be analyzed too. According to the TSR, this individuals shows a value close to 0.9. As told before, it agrees the C_P curve on Figure 3. As for the diameter variable, the best individual has a value close to 1.9 and the next 4 individuals a value close to 1.4. This values seem to have a relation of better C_P performance for a bigger diameter rotor (see Figure 70), but more iterations are needed to make a conclusion.

On the Figure 72 it is shown a comparison of the best individual (DI278) according to the objective function (equation 19) and the individual with the higher C_P value (DI355). In that comparison can be seen that the variation of the C_P is lower than the best individuals of the first optimization (see Figure 59). This was improved by using the minimization of C_{Pdif} objective.

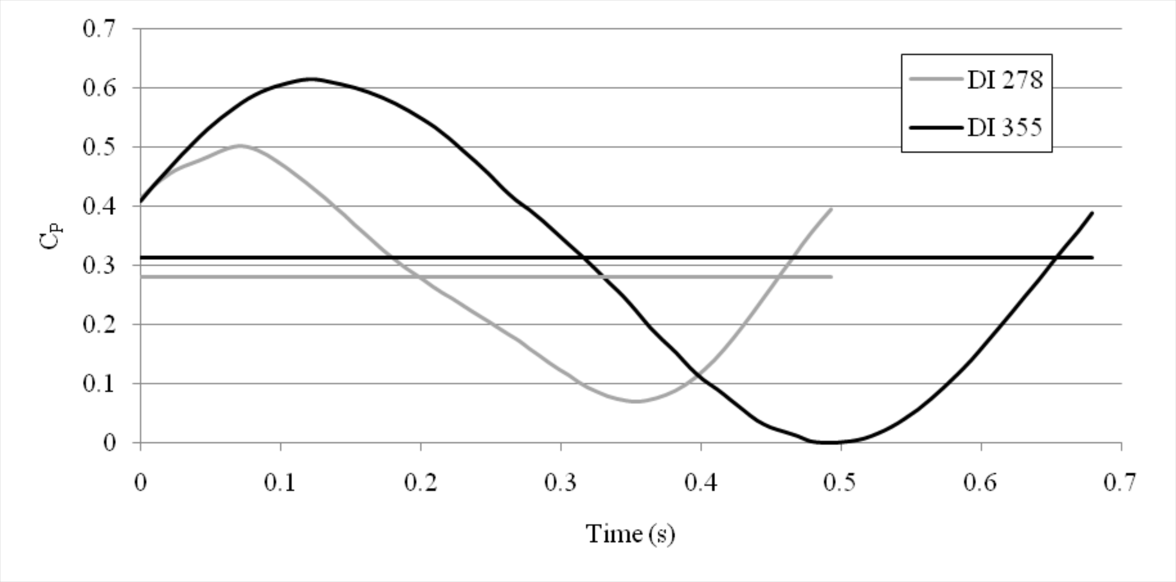


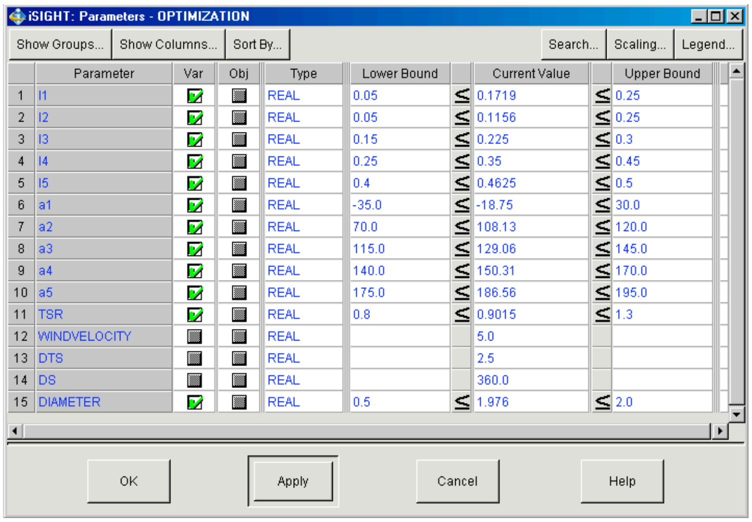
Figure 72. Average and unsteady C_P for the second optimization's DI's 278 and 355.

In the last Figure can be observed that the cycle time is different in both DI's. This difference is because of its different TSR and diameter, which determine the rotational velocity (see equation 7).

4.3. Single-objective shape, diameter and TSR optimization

As it was noticed that the TSR and diameter has a potential of increasing the C_P, another single-objective optimization was performed including these variables. As in the first optimization presented in this investigation the only objective in it was the maximization of the C_P.

The ranges of the variables for this optimization were modified according to the values presented on Figure 73. On the other hand, the initial individual used for this optimization was the individual with the highest Cp of the second optimization process. This individual (DI 355) is represented in Figure 74 with the range of variation for each variable.



	Parameter	Var	Obj	Type	Lower Bound		Current Value		Upper Bound
1	l1	☑	▨	REAL	0.05	≤	0.1719	≤	0.25
2	l2	☑	▨	REAL	0.05	≤	0.1156	≤	0.25
3	l3	☑	▨	REAL	0.15	≤	0.225	≤	0.3
4	l4	☑	▨	REAL	0.25	≤	0.35	≤	0.45
5	l5	☑	▨	REAL	0.4	≤	0.4625	≤	0.5
6	a1	☑	▨	REAL	-35.0	≤	-18.75	≤	30.0
7	a2	☑	▨	REAL	70.0	≤	108.13	≤	120.0
8	a3	☑	▨	REAL	115.0	≤	129.06	≤	145.0
9	a4	☑	▨	REAL	140.0	≤	150.31	≤	170.0
10	a5	☑	▨	REAL	175.0	≤	186.56	≤	195.0
11	TSR	☑	▨	REAL	0.8	≤	0.9015	≤	1.3
12	WINDVELOCITY	▨	▨	REAL			5.0		
13	DTS	▨	▨	REAL			2.5		
14	DS	▨	▨	REAL			360.0		
15	DIAMETER	☑	▨	REAL	0.5	≤	1.976	≤	2.0

Figure 73. Third optimization variables (12) with their ranges.

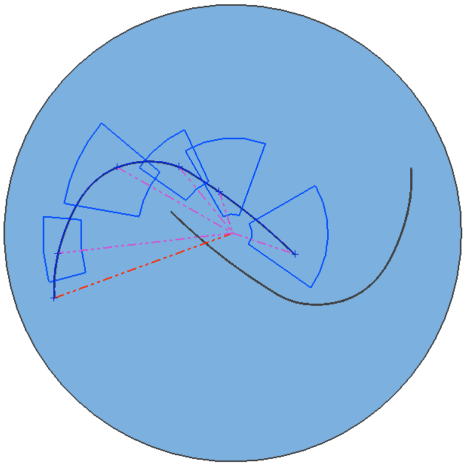


Figure 74. Ranges for the variables and initial individual used on the current optimization.

This process was performed using a non-dominated sorting genetic algorithm (NSGA II) using the same parameter as in the first optimization. Also as in the first optimization, 420 iterations were needed. The result of the Cp over the design iterations is shown in the following Figure. Also, in the Table 10 can be observed the best individuals for this process and in Figure 76 their shapes are presented.

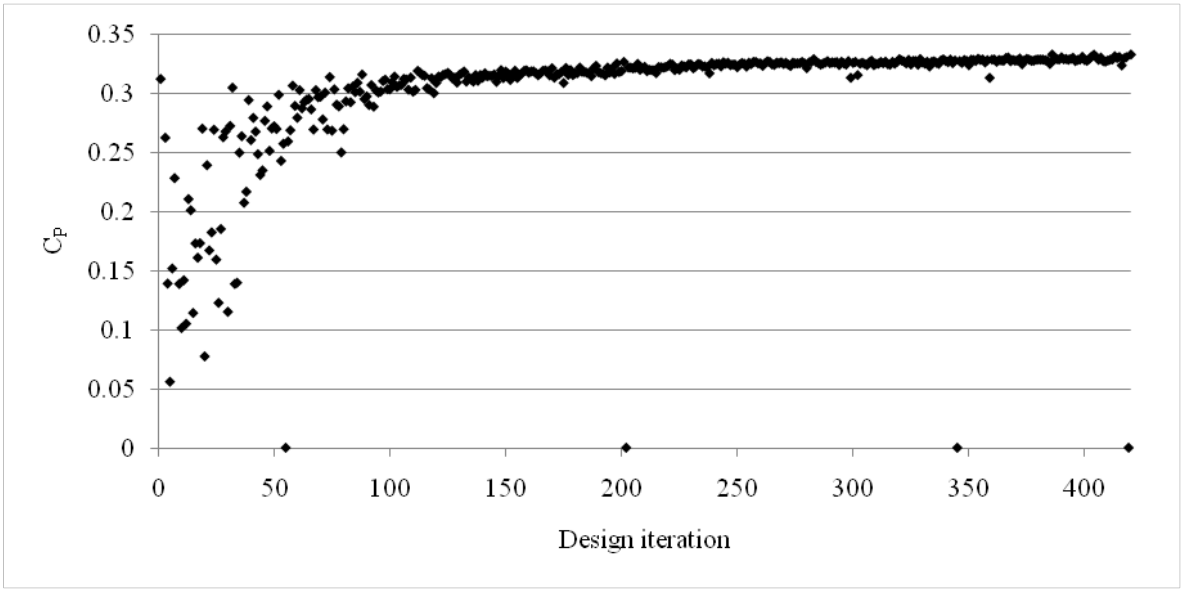


Figure 75. C_P obtained in every design iteration of the third optimization.

Table 10. Best performance individuals of the third optimization.

DI	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5
386	0.1750828	0.1056084	0.2146677	0.383315	0.469582	-18.833168	112.95172	130.43834	150.94864	185.87688
420	0.1750828	0.1056084	0.2146677	0.383315	0.469582	-18.833168	112.95172	130.43834	150.94864	185.87688
404	0.1750916	0.1098871	0.2155152	0.3834444	0.469582	-18.833168	112.95114	130.46481	150.8555	185.87688
413	0.1750828	0.1056084	0.2161256	0.3826697	0.469582	-18.833168	112.93968	130.20398	150.94864	185.87688
403	0.1748294	0.1056084	0.2160234	0.3824816	0.4700561	-18.833168	107.96403	130.20048	150.94864	185.87688

DI	TSR	DIAMETER	C_P	C_{Pdif}
386	1.06756836	1.972069186	0.33318457	0.90699001
420	1.06756836	1.972069186	0.33318457	0.90699001
404	1.06443306	1.992905378	0.33309531	0.90155893
413	1.06756836	1.972069186	0.33178122	0.90239430
403	1.06756836	1.972069186	0.33152674	0.89843304

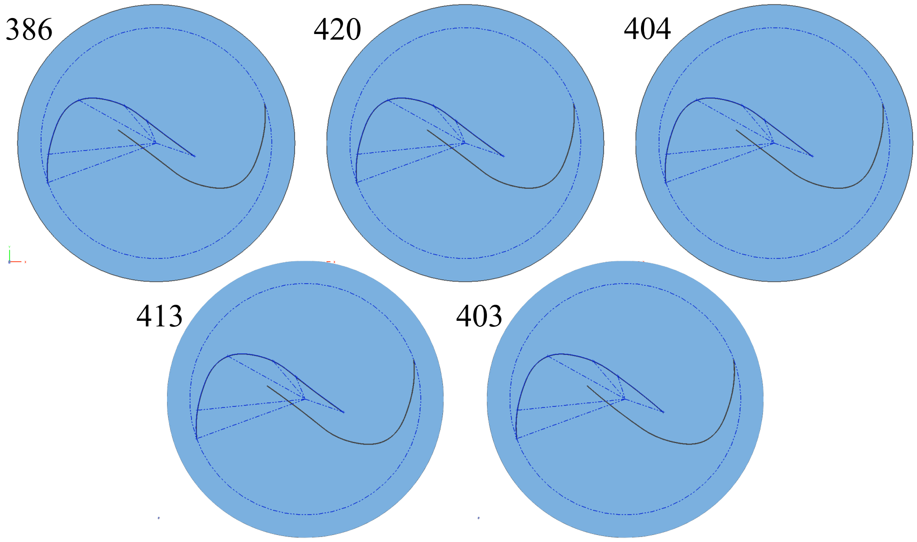


Figure 76. Best performance rotors profiles of the third optimization.

In this optimization, the best performance individual was found in the iteration 386. It reached a C_P of 0.333 with a C_{Pdif} of 0.9. In Figure 75, it can be seen that the C_P values are still increasing. For that reason, it is recommended to continue this optimization process in order to reach convergence.

In Figure 77, it is observed a plot of the C_P over the C_{Pdif}. In it, is clear that the values of the last mentioned variable have increased as the objective of minimizing was not set in this optimization process. This Figure shows that the C_P values are higher as the C_{Pdif} values increase, but there's no evidence of when the C_P value stops increasing and starts to decrease. This indicates that more iterations are needed in order to analyze if the C_P value can become higher with a higher C_{Pdif}.

As in Figure 68, it can be seen in Figure 78 that the C_P obtains the highest values close to a TSR of 1, and at higher TSR's this value starts to decrease.

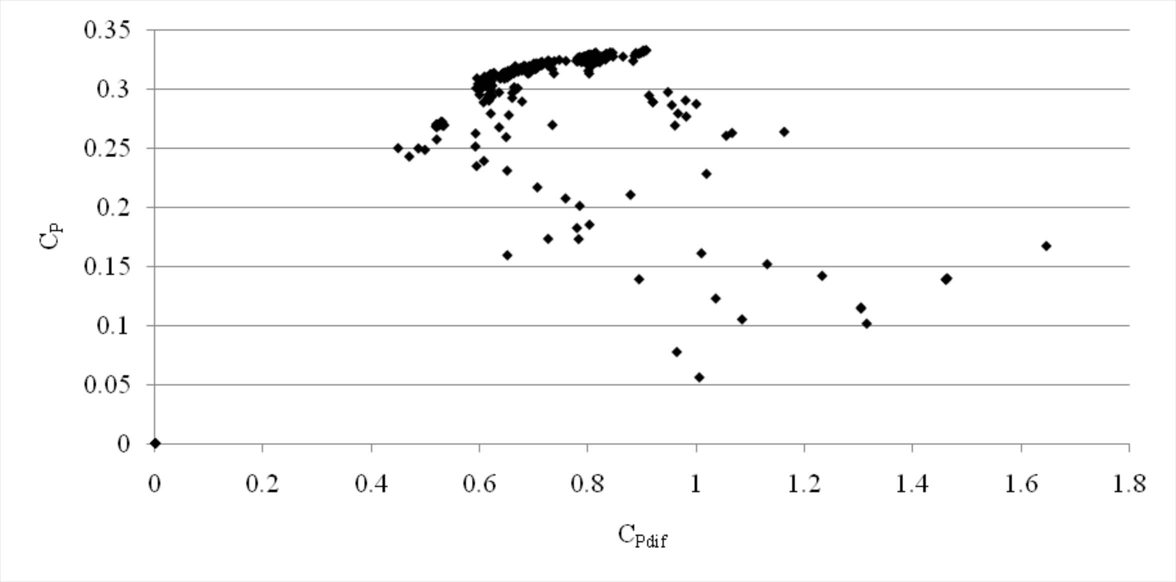


Figure 77. Pareto front of the third optimization.

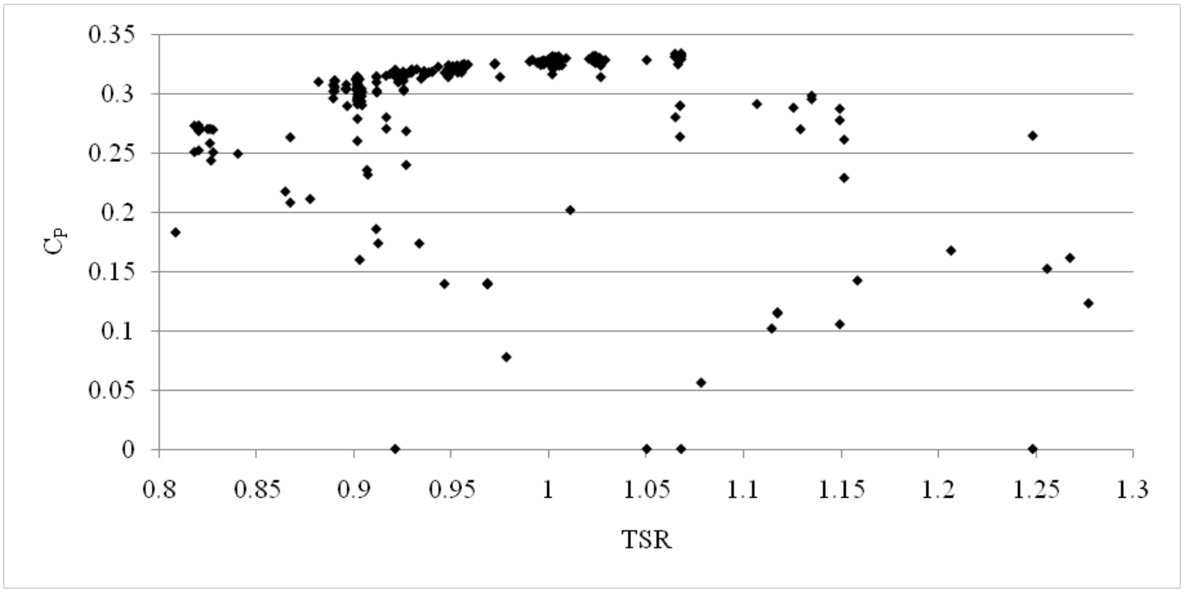


Figure 78. C_P variation over the TSR on the third optimization.

According to Figure 79, it is observed a tendency of obtaining higher C_P values as the diameter is increased. This relation must be analyzed with more detail and define at which value the C_P maximizes. In order to do that, another optimization must be done with a higher range for that variable.

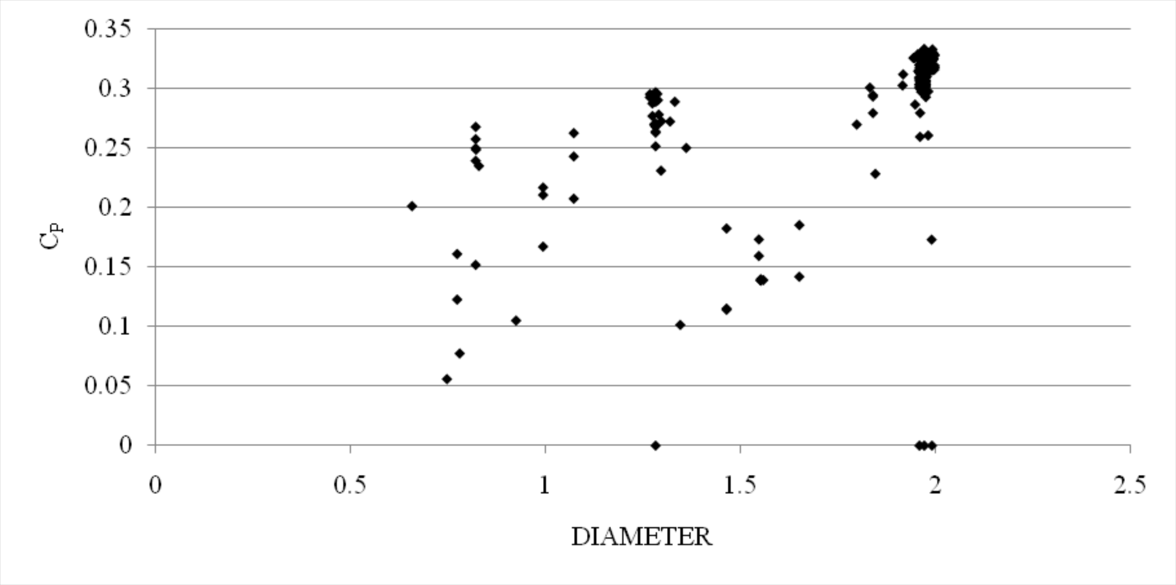


Figure 79. C_P variation over the diameter variable on the third optimization.

On the Figure 80 and 81 it is shown a comparison of the individual with the higher C_P of the current optimization (DI 386) and it is compared with the best individual of the second optimization (DI 278). It must be remembered that the DI 386 was obtained with the objective of maximizing the C_P, and the second design was obtained with the multi-objective criteria of maximizing the C_P and minimizing the C_{Pdif}.

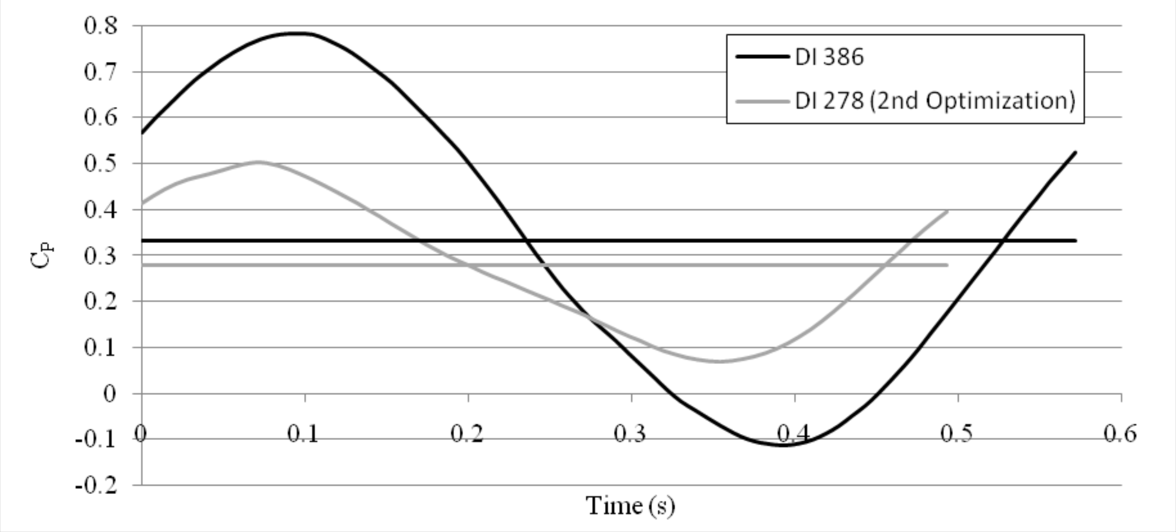
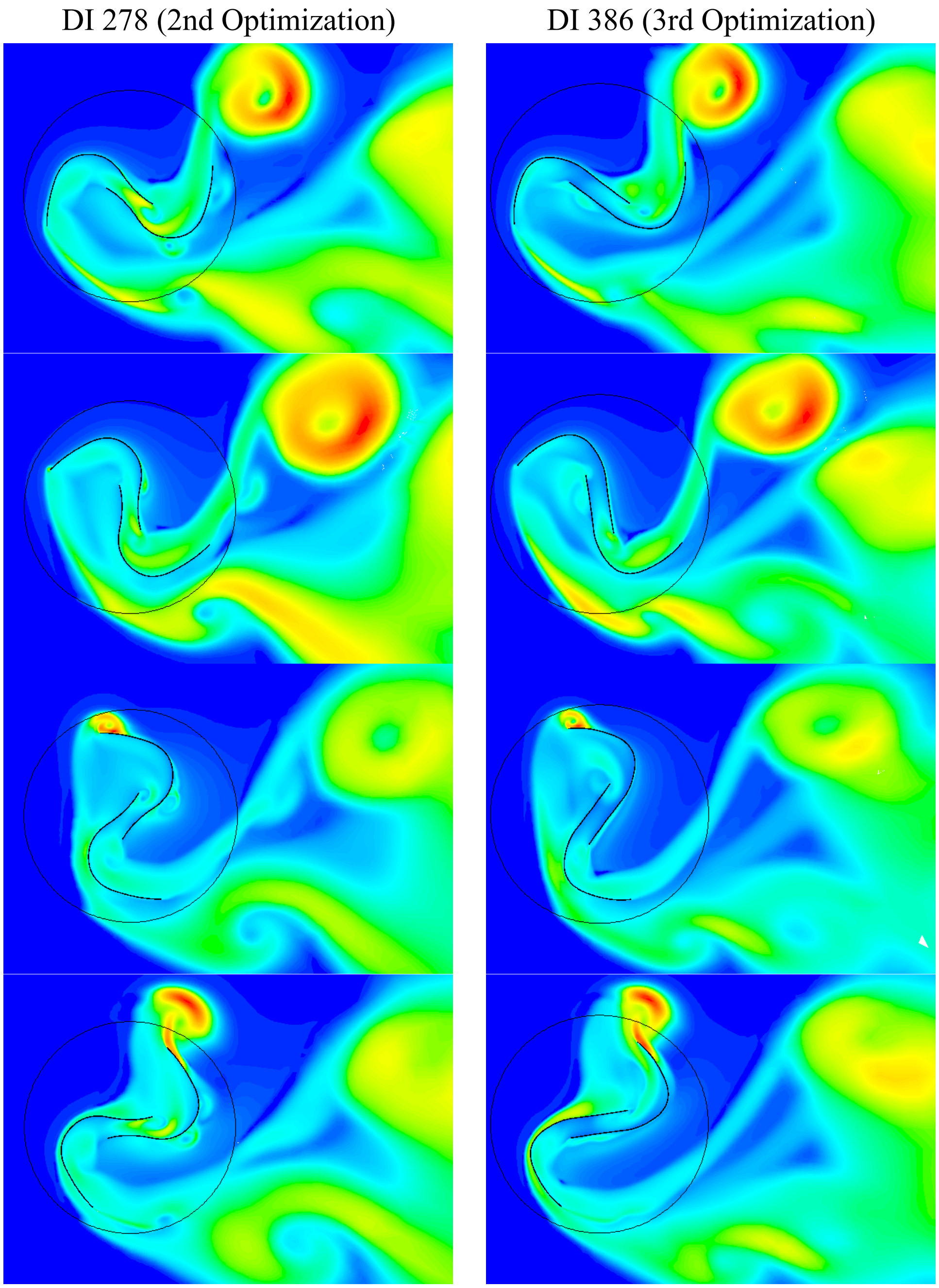


Figure 80. Average and unsteady C_P for the DI 386 (third optimization) and DI 278 (second optimization).

In order to decide which of those designs is better, it must be decided which parameter its more important, a high C_P or a low C_{Pdif}. In one hand, it is presented the individual 386 which has the highest C_P value found, nevertheless it also has a high value of C_{Pdif}, which can be the source of considerable vibration, wear and noise. Foremost, the individual 278 of the second optimization process has 5% less C_P but half the C_{Pdif} found in the individual 386. As the second mentioned design can reduce the negative impact of the vibration, both designs must be tested in order to analyze the value of the C_{Pdif} that can be acceptable. This value must be defined as a tradeoff of the power generation and the maintenance of the wind turbine due to the wear in its components generated by vibration.



DI 278 (2nd Optimization)

DI 386 (3rd Optimization)

Figure 81. Turbulence intensity contours for the DI's 278 (2nd Optimization) and 386 (3rd Optimization).

Chapter 5

Recommendations

In this Chapter, some additional ideas that due to time limitations weren't added to the design optimization process, are presented. Within this ideas, a potential innovative rotor with a greater performance can be found.

Also, at the end of this Chapter some recommendations regarding the optimization process integration are exposed and finally, recommendations about the computer hardware are discussed.

5.1. Further design optimizations.

Due that the time needed to complete the design optimizations required too many hours, it was not possible to experiment with different values for the variables and constants.

In the case of the constants, the three design optimization were performed with a constant wind speed of 5 m/s. It could be interesting to analyze the shapes obtained performing optimization processes using different wind speeds.

In case of the variables, the rotor diameter seems to have potential to improve the C_P of the WT rotor. In the optimizations presented in this investigation the rotor with the highest C_P had a diameter close to 2m, which was the upper limit of this variable. For this reason, it is needed to explore higher values for the diameter and analyze in which value the performance is maximized.

5.2. Optimization technique.

There are many optimization techniques available in the MDO software that can be used in order to improve the performance of designs. In the present investigation, two different genetic algorithms were used, but there are other techniques that can be applied in order to decrease the design iterations. As in this investigation each design iteration took about 22 minutes to be evaluated, the number of iterations must be minimized. In order to achieve this, there are two proposals that can be implemented.

The first is to create a fractional factorial design of experiments (DOE). This technique can be used as an initial exploratory approach. In order to implement this technique it is recommended to use a fractional DOE including the 12 variables used in this investigation with two levels for each one. To obtain accurate results, 32 runs will be needed (2^{12-7}) and a DOE of resolution IV will be completed. According to Box *et al* (2006), with this resolution it is possible to estimate the main effects of the variables. Using this approach an initial population for the genetic algorithm can be selected.

The second proposal is to use an initial population for the genetic algorithm. This population can be defined as the best individuals of another design optimization performed earlier or in the case of this investigation, the patented shapes could be used. This initial population could decrease the number of iterations by defining an initial guess that is known to have a good performance.

5.3. Additional profile variations.

The present investigation focused on a profile modeled using interpolation b-splines curves. This curves have a great flexibility to be modified in several forms but there are more shapes with a potential greater C_P performance that a spline cannot reach, or it needs a lot more control point in order to do that. Those forms, illustrated in the next Figure, include segmentations, variable thickness along the profile, the number of blades, non symmetric profile and different shapes at the tip of the blades.

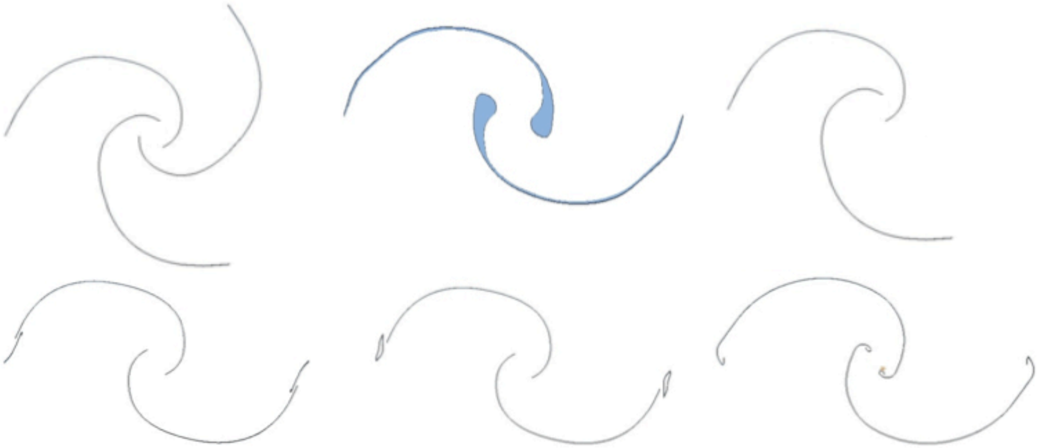


Figure 82. Proposed rotor profile variations.

This shape variations may be relatively easy to implement in the CAD process, but the mesh creation is a far more challenging task. If rotor's shapes are very different between the design iterations, the automation process becomes much more difficult and the mesh fail rate will be too high.

Another modification to the shape, that may not improve the C_P but it will look for a more realistic wind turbine profile, is the addition of a shaft at the center of the rotor. This shaft is present in some commercial Savonius WT's and it gives a greater strength and stability to the device.

5.4. Hybridization.

The hybridization between different kinds of VAWT's can be another way of creating a design optimization with a bigger diversity of individuals. Between the VAWT's that can be added to the Savonius WT are the Darrieus, Lenz and PacWind Alfa which are illustrated in the Figure 83.

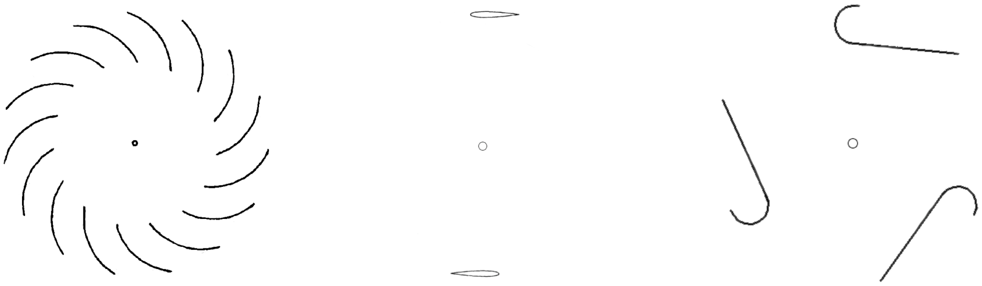


Figure 83. PacWind Alpha, Darrieus and Lenz rotor's profiles.

An hybridization of rotors can be illustrated as the Figure 84 but a simple union of two rotors couldn't offer a wide diversity of individuals. It is needed to search over all the possibilities inside the union of two rotors.

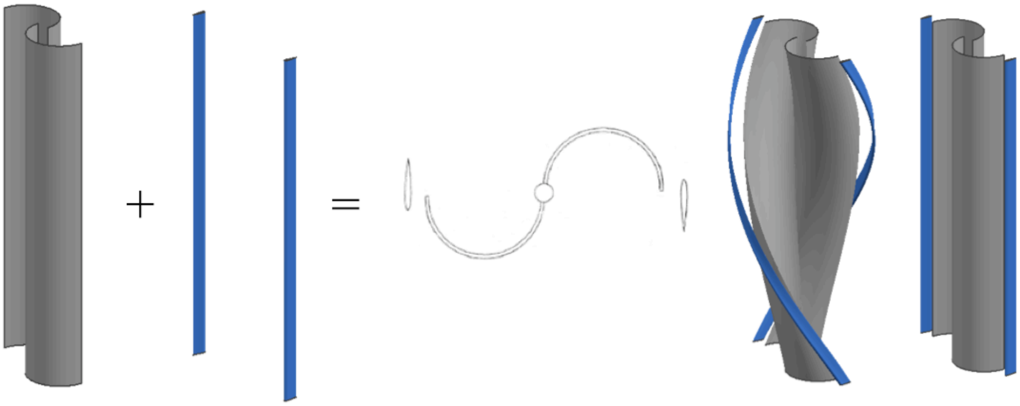


Figure 84. Hybridization of the Savonius and Darrieus rotors.

In order to search over all the possibilities of hybrid rotors, three variables are needed. The first two variables are the size of the Savonius and the added rotors given that both hybridized rotors cannot be interfering each other and the two rotors must be scaled. The third variable is the angle at which both rotors are going to be united. Figure 85 displays an example of a Savonius-Darrieus hybridization in which the three variables are shown with different values.

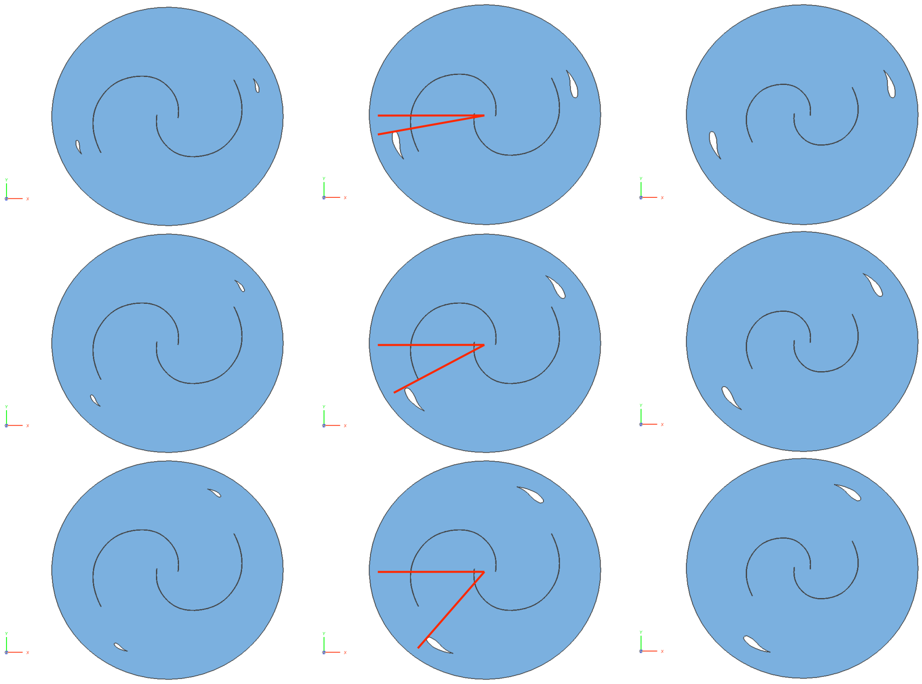


Figure 85. Example of a Savonius-Darrieus hybridization.

In order to implement the optimization process the TSR must be defined with a range much wider than the used on the present investigation. This is necessary because each rotor has its optimum performance at different values of TSR. In the Figure 3 it is observed that the Savonius has its optimum performance between a TSR of 0.8 and 1, the Darrieus works at approx. 5.5 and an hybrid Savonius-Darrieus is around 1.5 and 2.5.

5.5. Concentration stator.

Another optimization that can result in an innovative VAWT is the addition of a concentration stator (See Figure 86) to the Savonius WT. This stator stays fixed and generates a concentration effect which differs at different wind directions.

The stator and rotor could me modeled using splines and a design optimization could be defined to maximize the C_P modifying both shapes at the same time.

In order to calculate the C_P for this kind of rotor, different CFD analysis must be performed with different wind directions, because as mentioned, the concentration effect is different at different wind directions.

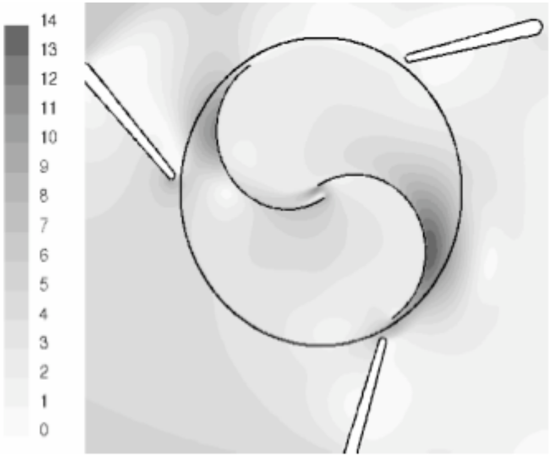


Figure 86. Concentration stator added to the Savonius rotor. [Cochran, 2004]

5.6. Multidisciplinary optimization.

The design optimization could include another kind of objectives that doesn’t include the efficiency of the rotor. Those objectives could be the blades strength, material costs or manufacturing process cost among others.

In order to implement that kind of objectives, another disciplines must be added which include: finite element analysis (FEM) and computer aided manufacturing (CAM).

The FEM analysis could be used to calculate stresses and deformations on the blades due to the wind force applied to them. On the other hand the CAM software could be used to calculate the time needed to manufacture an injection molding tooling in order to manufacture the rotor with plastics.

Using an MDO software amplifies the possibilities of generating a multi-objective process and it can be a useful tool to innovate products.

5.7. Optimization process integration.

There are more software options in order to integrate optimization processes. Among those, modeFRONTIER is another MDO software with a simpler and robust user interface. This software includes modules to synchronize several CAD and CAE software in an easier way. Also it includes several optimization techniques such as multi-objective genetic algorithms. This software includes very useful options such as the selection of number of intervals in which each variable is divided, similar to the gene size. So with it, it is possible to select 10 intervals for the TSR, 20 for the diameter and 100 for the variables of angle (a1 to a5) and length (l1 to l5). This is very useful when it is needed to have more resolution on a variable or when its range it to big and more intervals are needed. On the other hand iSIGHT doesn’t have that option, and every variable is defined with the same gene size. But iSIGHT has another characteristics that makes it a superior software, and it is the possibility of modifying templates using logical functions, the ability of programing your own algorithm and a wider selection or optimization techniques.

5.8. Hardware.

In order to perform an optimization process of this kind, it is recommended to have a computer with the best performance available connected to a no-break device. As this processes can take weeks to be completed, that kind of device can save the process from an electrical failure.

Another recommendation is to avoid the use of a wireless network if the licenses of the software are in a server. If this wireless network is weak, the connection can be lost and the process can break due to this failure. In order to avoid this, it can be used a reliable LAN network or licenses files inside the computer. Another way of avoiding this, is the use of open source software such as, OpenFOAM (CFD), DAKOTA (algorithms) and a programming language in order to integrate the process.

Chapter 6

Conclusions

The conclusions regarding this investigation can be divided in two main directions; the automated optimization process and the results obtained in the Savonius WT optimization.

For the automated optimization process integrated in the MDO software, it can be concluded that nevertheless it is difficult and time consuming to integrate, it is a powerful tool that can be used not only to optimize, but to innovate and to understand the products and/or systems behavior.

When this integration is performed by an experimented engineer it can be achieved in a couple of hours or days. But this time doesn't compare with the time that the computer can be working alone, day and night and performing repetitive tasks that aren't challenging at all.

The advantages and potential of the integration of genetic algorithms or any other optimization tool with a CAD and CAE systems are enormous wether for optimization and innovation or in the reduction of time and effort.

About the optimized shape for the Savonius WT, it is clear that a new and innovative shape was developed. This was possible using a rotor geometry created with splines, which generated a shape that would be impossible to create with lines and arcs. On the other hand, there are more possibilities of optimizing this WT, by applying the recommended shape modifications on Chapter 5.

Another conclusion regarding the Savonius WT behavior can be drawn from the second optimization processes. In it, it was observed that if the TSR is reduced, the C_{Pdif} will be reduced too. This reduction of the C_{Pdif} could also reduce the vibration while the reduction of the WT speed (TSR) can reduce the noise generation. Although this reduction decreases the C_P, the minimization of the C_{Pdif} could be a more important improvement for the straight Savonius WT design. Taking as an example the best individual of the second optimization, (whose C_P was around 0.28 and its C_{Pdif} was 0.438) and comparing it with the design iteration with the highest C_P found in the third optimization (which reached a C_P of 0.333 with a C_{Pdif} of 0.9), the first is more than 5% less efficient than the second, but it presents a smoother working condition.

These conditions forces to carry out a more detailed analysis about the effects of the vibration of this device. In order to do that, real size prototypes could offer an excellent field test to analyze the wear and fatigue generated by the vibration of both types of straight Savonius wind turbines.

As the helical Savonius WT doesn't generate vibrations, it can be concluded that for this kind of design the best individual of the third optimization (whose C_P was calculated as 0.3332) can be used without concerns about generating vibrations. This conclusion lead us to think that the optimization of the Savonius WT could be focused in the minimal electrical generation cost between the cheap straight Savonius with less C_P and C_{Pdif}, and the more expensive helical Savonius with higher C_P and C_{Pdif}.

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Appendix A - Files

OPTIMIZATION.desc

```
MDOLVersion: 8.0
CompilerOptions: warn

Task OPTIMIZATION

    TaskHeader OPTIMIZATION
        Version: 1.0
        Evaluation: single
        ControlMode: user
        RunCounter: 1
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader OPTIMIZATION

    Inputs OPTIMIZATION
        Parameter: l1 Type: real InitialValue: 0.1
        Parameter: l2 Type: real InitialValue: 0.2
        Parameter: l3 Type: real InitialValue: 0.3
        Parameter: l4 Type: real InitialValue: 0.4
        Parameter: l5 Type: real InitialValue: 0.5
        Parameter: a1 Type: real InitialValue: 10.0
        Parameter: a2 Type: real InitialValue: 70.0
        Parameter: a3 Type: real InitialValue: 120.0
        Parameter: a4 Type: real InitialValue: 150.0
        Parameter: a5 Type: real InitialValue: 175.0
        Parameter: TSR Type: real InitialValue: 1.0
        Parameter: WINDVELOCITY Type: real InitialValue: 5.0
        Parameter: DTS Type: real InitialValue: 2.5
        Parameter: DS Type: real InitialValue: 360.0
        Parameter: DIAMETER Type: real InitialValue: 1.0
    End Inputs OPTIMIZATION

    Outputs OPTIMIZATION
        Parameter: ROTATIONALVELOCITY Type: real
        Parameter: RADIUS Type: real
        Parameter: COUNTER Type: integer
        Parameter: NTS Type: integer
        Parameter: HEIGHT Type: real
        Parameter: TSS Type: real
        Parameter: CP Type: real
        Parameter: CPdif Type: real
    End Outputs OPTIMIZATION

    Calculations OPTIMIZATION
        Calculation COUNTER
            Parameters
                    TSR WINDVELOCITY DTS DS DIAMETER ROTATIONALVELOCITY RADIUS COUNTER NTS
HEIGHT
```

```
            TSS
        Statements
            COUNTER=COUNTER+1
            HEIGHT = 1/DIAMETER
            NTS=DS/DTS
            RADIUS =DIAMETER/2
            TSS=DTS*DIAMETER*3.1415926/(WINDVELOCITY*TSR*360)
            ROTATIONALVELOCITY=2*WINDVELOCITY*TSR/DIAMETER
        End Statements
    End Calculation COUNTER
End Calculations OPTIMIZATION

Task CAD

    TaskHeader CAD
        Version: 1.0
        Evaluation: single
        ControlMode: user
        RunCounter: 1
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader CAD

    Inputs CAD
        Parameter: l1 Type: real InitialValue: 0.1
        Parameter: l2 Type: real InitialValue: 0.2
        Parameter: l3 Type: real InitialValue: 0.3
        Parameter: l4 Type: real InitialValue: 0.4
        Parameter: l5 Type: real InitialValue: 0.5
        Parameter: a1 Type: real InitialValue: 10.0
        Parameter: a2 Type: real InitialValue: 70.0
        Parameter: a3 Type: real InitialValue: 120.0
        Parameter: a4 Type: real InitialValue: 150.0
        Parameter: a5 Type: real InitialValue: 175.0
        Parameter: COUNTER Type: integer InitialValue: 2
    End Inputs CAD

    Outputs CAD
    End Outputs CAD

    SimCode NX5
        InputFiles NX5
            FileDescription AnalysisCADmacro
                FileType: standard
                TemplateFile: "template_CAD.macro"
                InputFile: "Analysis/CAD.macro"
                Parameters
                    COUNTER
                Instructions
                    require COUNTER
                    preferences noreturn
                    replace "COUNTER" with $COUNTER occurrence all
                End Instructions
            End FileDescription AnalysisCADmacro

            FileDescription AnalysisDIMENSIONSexp
                FileType: standard
                TemplateFile: "template_DIMENSIONS.exp"
                InputFile: "Analysis/DIMENSIONS.exp"
                Parameters
                    l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
                Instructions
                    require l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
                    preferences noreturn
                    moveto $Line_End
                    write $l1
                    moveto line + 1
                    moveto $Line_End
                    write $l2
                    moveto line + 1
                    moveto $Line_End
                    write $l3
```

```
                moveto line + 1
                moveto $Line_End
                write $l4
                moveto line + 1
                moveto $Line_End
                write $l5
                moveto line + 1
                moveto $Line_End
                write $a1
                moveto line + 1
                moveto $Line_End
                write $a2
                moveto line + 1
                moveto $Line_End
                write $a3
                moveto line + 1
                moveto $Line_End
                write $a4
                moveto line + 1
                moveto $Line_End
                write $a5
            End Instructions
        End FileDescription AnalysisDIMENSIONSexp
    End InputFiles NX5

    SimCodeProcess NX5
        ScriptLanguage: DOSBatch
        Script
            cd Analysis
            ugraf.exe -key:CAD.macro
        End Script
        ProcessType: transient
        Environment: unrestored
        ElapseTime: 20s
        Prologue
            WriteInputSpecs: AnalysisCADmacro
                             AnalysisDIMENSIONSexp
    End SimCodeProcess NX5

End SimCode NX5

TaskProcess CAD
    Control: [
        NX5
    ]
End TaskProcess CAD

Optimization CAD
    PotentialVariables:
        l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
        COUNTER
    Variables: none
    VariableScaling
        Parameter: l1 ScaleFactor: 1.0
        Parameter: l2 ScaleFactor: 1.0
        Parameter: l3 ScaleFactor: 1.0
        Parameter: l4 ScaleFactor: 1.0
        Parameter: l5 ScaleFactor: 1.0
        Parameter: a1 ScaleFactor: 1.0
        Parameter: a2 ScaleFactor: 1.0
        Parameter: a3 ScaleFactor: 1.0
        Parameter: a4 ScaleFactor: 1.0
        Parameter: a5 ScaleFactor: 1.0
        Parameter: COUNTER ScaleFactor: 1.0
    PotentialObjectives:
        l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
        COUNTER

    # PLAN TO BE CONFIGURED BY ADVISOR:
    OptimizePlan PriorityRankedPlan
        Control: [
        ]
```

```
    End Optimization CAD

    TaskPlan CAD
        StopTaskPlanOnError: no
        Control: [
            PriorityRankedPlan
        ]
    End TaskPlan CAD

    DataStorage CAD
        Restore: no
        DataLog: "CAD.db" Mode: overwrite
        DataLookUp: "CAD.db"
        MatchMode: Exact
        Levels: all
        StoreGradRuns: yes
        StoreApproxRuns: yes
    End DataStorage CAD

End Task CAD


Task MESH

    TaskHeader MESH
        Version: 1.0
        Evaluation: single
        ControlMode: user
        RunCounter: 1
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader MESH

    Outputs MESH
    End Outputs MESH

    SimCode GAMBIT2316
        SimCodeProcess GAMBIT2316
            ScriptLanguage: DOSBatch
            Script
                copy MESH.dbs .\Analysis
                copy MESHING.jou .\Analysis
                cd Analysis
                gambit -inputfile MESHING.jou
            End Script
            ProcessType: transient
            Environment: unrestored
            ElapseTime: 4m
        End SimCodeProcess GAMBIT2316

    End SimCode GAMBIT2316

    TaskProcess MESH
        Control: [
            GAMBIT2316
        ]
    End TaskProcess MESH

    Optimization MESH
        Variables: none
        VariableScaling

        # PLAN TO BE CONFIGURED BY ADVISOR:
        OptimizePlan PriorityRankedPlan
            Control: [
            ]
    End Optimization MESH

    TaskPlan MESH
        StopTaskPlanOnError: no
        Control: [
            PriorityRankedPlan
```

```
            ]
        End TaskPlan MESH

        DataStorage MESH
            Restore: no
            DataLog: "MESH.db" Mode: overwrite
            DataLookUp: "MESH.db"
            MatchMode: Exact
            Levels: all
            StoreGradRuns: yes
            StoreApproxRuns: yes
        End DataStorage MESH

    End Task MESH


    Task CFD

        TaskHeader CFD
            Version: 1.0
            Evaluation: single
            ControlMode: user
            RunCounter: 1
            BoundsPolicy: adjustvalue
            CheckPoint: unknown
        End TaskHeader CFD

        Inputs CFD
            Parameter: COUNTER Type: integer InitialValue: 2
            Parameter: DIAMETER Type: real InitialValue: 0.75
            Parameter: WINDVELOCITY Type: real InitialValue: 5.0
            Parameter: ROTATIONALVELOCITY Type: real InitialValue: 11.3333333333333
            Parameter: HEIGHT Type: real InitialValue: 1.33333333333333
            Parameter: RADIUS Type: real InitialValue: 0.375
            Parameter: TSS Type: real InitialValue: 0.00384999093137255
            Parameter: NTS Type: integer InitialValue: 2
        End Inputs CFD

        Outputs CFD
        End Outputs CFD

        SimCode FLUENT6326
            InputFiles FLUENT6326
                FileDescription AnalysisCFDjou
                    FileType: standard
                    TemplateFile: "template_CFD.jou"
                    InputFile: "Analysis/CFD.jou"
                    Parameters
                          COUNTER DIAMETER WINDVELOCITY ROTATIONALVELOCITY HEIGHT RADIUS TSS
NTS
                    Instructions
                             require COUNTER DIAMETER WINDVELOCITY ROTATIONALVELOCITY HEIGHT
RADIUS TSS NTS
                        preferences noreturn
                        replace "DIAMETER" with $DIAMETER ignore occurrence all
                        replace "WINDVELOCITY" with $WINDVELOCITY ignore occurrence all
                               replace "ROTATIONALVELOCITY" with $ROTATIONALVELOCITY ignore
occurrence all
                        replace "HEIGHT" with $HEIGHT ignore occurrence all
                        replace "RADIUS" with $RADIUS ignore occurrence all
                        replace "TSS" with $TSS ignore occurrence all
                        replace "NTS" with $NTS ignore occurrence all
                        replace "COUNTER" with $COUNTER ignore occurrence all
                    End Instructions
                End FileDescription AnalysisCFDjou

                FileDescription AnalysisCFDbat
                    FileType: standard
                    TemplateFile: "template_CFD.bat"
                    InputFile: "Analysis/CFD.bat"
                    Parameters
                        COUNTER
```

```
                Instructions
                    require COUNTER
                    preferences noreturn
                    replace "COUNTER" with $COUNTER ignore occurrence all
                End Instructions
            End FileDescription AnalysisCFDbat
        End InputFiles FLUENT6326

        SimCodeProcess FLUENT6326
            ScriptLanguage: DOSBatch
            Script
                cd Analysis
                CFD.bat
            End Script
            ProcessType: transient
            Environment: unrestored
            ElapseTime: 25m
            Prologue
                WriteInputSpecs: AnalysisCFDjou
                                 AnalysisCFDbat
        End SimCodeProcess FLUENT6326

    End SimCode FLUENT6326

    TaskProcess CFD
        Control: [
            FLUENT6326
        ]
    End TaskProcess CFD

    Optimization CFD
        PotentialVariables:
            COUNTER DIAMETER WINDVELOCITY ROTATIONALVELOCITY HEIGHT RADIUS TSS NTS
        Variables:
            COUNTER DIAMETER WINDVELOCITY ROTATIONALVELOCITY HEIGHT RADIUS TSS NTS
        VariableScaling
            Parameter: COUNTER ScaleFactor: 1.0
            Parameter: DIAMETER ScaleFactor: 1.0
            Parameter: WINDVELOCITY ScaleFactor: 1.0
            Parameter: ROTATIONALVELOCITY ScaleFactor: 1.0
            Parameter: HEIGHT ScaleFactor: 1.0
            Parameter: RADIUS ScaleFactor: 1.0
            Parameter: TSS ScaleFactor: 1.0
            Parameter: NTS ScaleFactor: 1.0
        PotentialObjectives:
            COUNTER DIAMETER WINDVELOCITY ROTATIONALVELOCITY HEIGHT RADIUS TSS NTS

        # PLAN TO BE CONFIGURED BY ADVISOR:
        OptimizePlan PriorityRankedPlan
            Control: [
            ]
    End Optimization CFD

    TaskPlan CFD
        StopTaskPlanOnError: no
        Control: [
            PriorityRankedPlan
        ]
    End TaskPlan CFD

    DataStorage CFD
        Restore: no
        DataLog: "CFD.db" Mode: overwrite
        DataLookUp: "CFD.db"
        MatchMode: Exact
        Levels: all
        StoreGradRuns: yes
        StoreApproxRuns: yes
    End DataStorage CFD

End Task CFD
```

```
Task RESULTS

    TaskHeader RESULTS
        Version: 1.0
        Evaluation: single
        ControlMode: user
        RunCounter: 1
        BoundsPolicy: adjustvalue
        CheckPoint: unknown
    End TaskHeader RESULTS

    Inputs RESULTS
        Parameter: TSR Type: real InitialValue: 0.85
    End Inputs RESULTS

    Outputs RESULTS
        Parameter: CP Type: real
        Parameter: CPdif Type: real
    End Outputs RESULTS

    SimCode DELETE
        SimCodeProcess DELETE
            ScriptLanguage: DOSBatch
            Script
                cd Analysis
                del *.x_t c* d* m* i* v* k*
            End Script
            ProcessType: transient
            Environment: unrestored
            ElapseTime: 10s
        End SimCodeProcess DELETE

    End SimCode DELETE

    Excel CP
        WorkBooks
            WorkBookFile: "./RESULTS.xls"
            MacroCalls: RESULTS
        End WorkBooks
        ElapseTime: 30s
        Persistent: no
        Visible: no
        InputMapping
            Parameter: TSR WorkBook: "RESULTS.xls" Sheet: "1" Range: "A1"
        End InputMapping
        OutputMapping
            Parameter: CP WorkBook: "RESULTS.xls" Sheet: "1" Range: "C3"
            Parameter: CPdif WorkBook: "RESULTS.xls" Sheet: "1" Range: "C4"
        End OutputMapping
    End Excel CP

    TaskProcess RESULTS
        Control: [
            Sequential [
                CP
                DELETE
            ]
        ]
    End TaskProcess RESULTS

    Optimization RESULTS
        PotentialVariables:
            TSR
        Variables:
            TSR
        VariableScaling
            Parameter: TSR ScaleFactor: 1.0
        PotentialObjectives:
            TSR CP CPdif

        # PLAN TO BE CONFIGURED BY ADVISOR:
```

```
        OptimizePlan PriorityRankedPlan
            Control: [
            ]
    End Optimization RESULTS

    TaskPlan RESULTS
        StopTaskPlanOnError: no
        Control: [
            PriorityRankedPlan
        ]
    End TaskPlan RESULTS

    DataStorage RESULTS
        Restore: no
        DataLog: "RESULTS.db" Mode: overwrite
        DataLookUp: "RESULTS.db"
        MatchMode: Exact
        Levels: all
        StoreGradRuns: yes
        StoreApproxRuns: yes
    End DataStorage RESULTS

End Task RESULTS


TaskProcess OPTIMIZATION
    Control: [
        Sequential [
            COUNTER
            CAD
            MESH
            CFD
            RESULTS
        ]
    ]

    SubTask CAD
        InputToSubtask
            Send:
                COUNTER a1 a2 a3 a4 a5 l1 l2 l3 l4
                l5
        OutputFromSubtask
    End SubTask CAD

    SubTask MESH
        InputToSubtask
        OutputFromSubtask
    End SubTask MESH

    SubTask CFD
        InputToSubtask
            Send:
                COUNTER DIAMETER HEIGHT NTS RADIUS ROTATIONALVELOCITY TSS WINDVELOCITY
        OutputFromSubtask
    End SubTask CFD

    SubTask RESULTS
        InputToSubtask
            Send:
                TSR
        OutputFromSubtask
            Receive:
                CP CPdif
    End SubTask RESULTS

End TaskProcess OPTIMIZATION

Optimization OPTIMIZATION
    PotentialVariables:
        l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
        TSR WINDVELOCITY DTS DS DIAMETER
    Variables:
```

```
    l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
    TSR DIAMETER
VariableScaling
    Parameter: l1 ScaleFactor: 1.0
    Parameter: l2 ScaleFactor: 1.0
    Parameter: l3 ScaleFactor: 1.0
    Parameter: l4 ScaleFactor: 1.0
    Parameter: l5 ScaleFactor: 1.0
    Parameter: a1 ScaleFactor: 1.0
    Parameter: a2 ScaleFactor: 1.0
    Parameter: a3 ScaleFactor: 1.0
    Parameter: a4 ScaleFactor: 1.0
    Parameter: a5 ScaleFactor: 1.0
    Parameter: TSR ScaleFactor: 1.0
    Parameter: WINDVELOCITY ScaleFactor: 1.0
    Parameter: DTS ScaleFactor: 1.0
    Parameter: DS ScaleFactor: 1.0
    Parameter: DIAMETER ScaleFactor: 1.0
InputConstraints
    Parameter: l1 LowerBound: 0.05 UpperBound: 0.2
    Parameter: l2 LowerBound: 0.1 UpperBound: 0.25
    Parameter: l3 LowerBound: 0.15 UpperBound: 0.3
    Parameter: l4 LowerBound: 0.25 UpperBound: 0.45
    Parameter: l5 LowerBound: 0.45 UpperBound: 0.5
    Parameter: a1 LowerBound: -20.0 UpperBound: 60.0
    Parameter: a2 LowerBound: 70.0 UpperBound: 110.0
    Parameter: a3 LowerBound: 115.0 UpperBound: 145.0
    Parameter: a4 LowerBound: 150.0 UpperBound: 170.0
    Parameter: a5 LowerBound: 175.0 UpperBound: 195.0
    Parameter: TSR LowerBound: 0.7 UpperBound: 1.4
    Parameter: DIAMETER LowerBound: 0.3 UpperBound: 3.0
PotentialObjectives:
    l1 l2 l3 l4 l5 a1 a2 a3 a4 a5
    TSR WINDVELOCITY DTS DS DIAMETER ROTATIONALVELOCITY RADIUS COUNTER NTS HEIGHT
    TSS CP CPdif
Objectives
    Parameter: CPdif Direction: minimize Weight: 1.0 ScaleFactor: 1.0
    Parameter: CP Direction: maximize Weight: 3.0 ScaleFactor: 1.0

OptimizePlan NCGA
    DefaultUpperBound: 1.0E15
    UseScaling: yes
    OptimizeStep Step1
        Technique: "Neighborhood Cultivation Genetic Algorithm - NCGA"
        Prologue
            RestoreBestSolution: no
            RerunTask: no
        Epilogue
            RestoreBestSolution: yes
            RerunTask: no
        Options
            MutationRate: 0.05
            GeneSize: 6
    Control: [
        Step1
    ]

OptimizePlan NSGA
    DefaultUpperBound: 1.0E15
    UseScaling: yes
    OptimizeStep Step1
        Technique: "Non-dominated Sorting Genetic Algorithm - NSGA-II"
        Prologue
            RestoreBestSolution: no
            RerunTask: no
        Epilogue
            RestoreBestSolution: yes
            RerunTask: no
        Options
            PopulationSize: 20
            Generations: 20
    Control: [
```

```
            Step1
        ]

    # PLAN TO BE CONFIGURED BY ADVISOR:
    OptimizePlan PriorityRankedPlan
        Control: [
        ]
End Optimization OPTIMIZATION

TaskPlan OPTIMIZATION
    StopTaskPlanOnError: no
    Control: [
        PriorityRankedPlan
    ]
End TaskPlan OPTIMIZATION

DataStorage OPTIMIZATION
    Restore: no
    DataLog: "OPTIMIZATION.db" Mode: overwrite
    DataLookUp: "OPTIMIZATION.db"
    MatchMode: Exact
    Levels: all
    StoreGradRuns: yes
    StoreApproxRuns: yes
End DataStorage OPTIMIZATION

End Task OPTIMIZATION
```

CQ-SAVONIUS

```
"Moment Convergence"
"Flow Time" "Cm"
0       0
0       0
0       0
0       0
```

VIEW-FLUENT

```
(38 ((
(view-list (
(view-0  ((0.26020262  -0.033607658  5.0900846)  (0.26020262  -0.033607658  0.00022082753)
(1.2004173e-06 1.0000106 -1.7934138e-09) 2.0359454 2.0359454 "perspective") #(1 0 0 0 0 1 0
0 0 0 1 0 0 0 0 1))
)))))
```

Appendix B - Results

First optimization process

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
1	0.078125	0.128125	0.20625	0.3875	0.48125	0	92.5	120.625	160	188.75	0.2652040821	0.7190703
2	0.073170045	0.159637718	0.182116143	0.386812969	0.48869423	7.033069897	78.3594275	127.2438569	166.0221441	184.9797291	0.1565955217	0.8315679
3	0.191093218	0.128559821	0.154579725	0.378167104	0.478785295	58.11701417	91.65218038	120.0487622	152.0623537	189.7225993	-0.000858078	1.289675
4	0.152271392	0.190185914	0.155589354	0.419733611	0.455734387	57.03617673	94.86341728	132.4838152	154.3470476	176.9062356	0.0846499094	0.9072316
5	0.178683122	0.108681487	0.235294594	0.339231894	0.497309526	31.99675266	102.6957123	138.4958851	160.6511769	194.4820643	0.1799082316	1.00054
6	0.067773489	0.20265504	0.283246391	0.276312905	0.459735366	22.32394578	102.7327552	139.1096212	164.5866882	178.4587799	0.1379534023	0.6912274
7	0.190490688	0.209338365	0.153638526	0.389421538	0.489612647	8.900302686	72.18883377	123.3214613	169.4045793	184.4836768	0.0874366082	1.1566624
8	0.131385842	0.135323949	0.208705746	0.403816382	0.494536765	-5.42206645	85.14656997	130.1206717	155.0493362	184.2842518	0.2384019297	0.8063386
9	0.189861288	0.139328356	0.162643621	0.259080172	0.472653723	2.151822392	94.82572393	131.7230172	151.4703862	192.8073319	0.2136752833	0.9966469
10	0.186935998	0.148790162	0.200551847	0.434437847	0.457388797	-8.49962274	86.32871018	124.2133326	159.6139911	187.2615352	0.2073123474	0.8809991
11	0.17410538	0.214645997	0.201679163	0.398167155	0.479436576	43.36791992	98.78987238	122.1138622	169.0001931	185.5346676	0.1355588611	0.9090006
12	0.140274167	0.217727226	0.273236992	0.403669388	0.47828318	-18.5549406	104.0339472	127.001711	152.4985107	194.0813694	0.2140966504	0.7111884
13	0.121207641	0.127516918	0.166454564	0.297499928	0.454053409	43.55095679	73.0998299	119.1371599	160.0559534	185.4303677	0.2242505063	0.8393019
14	0.167200196	0.131380126	0.253353892	0.251626812	0.49989536	-15.649508	98.59768207	119.230285	153.010444	190.2456434	0.1932730774	0.6116589
15	0.169534327	0.152371572	0.212573255	0.357775676	0.460513708	13.66888456	99.7663206	129.020335	161.930461	175.7498017	0.2451621796	0.8290894
16	0.067508989	0.189796702	0.227625585	0.332239596	0.46323641	4.056082889	100.6670104	117.2403634	157.0952245	187.6919409	0.19534709	0.6977711
17	0.169647366	0.103922296	0.254937503	0.316448171	0.468133559	54.23907498	107.2298412	132.3330694	157.4364128	194.1197319	-0.00051965	1.1704938
18	0.069534158	0.132654784	0.234885495	0.43545197	0.461508336	35.84445685	102.6675514	123.4451367	168.6320167	186.6787973	0.2600826322	0.7255965
19	0.090171036	0.154207577	0.227266173	0.38156892	0.488155707	-1.25847464	83.46513986	128.1345561	158.9179697	190.635676	0.216844937	0.7119619
20	0.118538324	0.158716863	0.246505592	0.443427303	0.480370333	3.832220472	88.21038156	144.1305752	150.2772511	187.5595152	0.1699440692	0.9269841
21	0.140274167	0.129683287	0.273236992	0.403669388	0.47828318	-18.1359087	92.40866842	126.8414404	151.6752075	186.6877862	0.2802714691	0.7189255
22	0.078125	0.216168939	0.20625	0.3875	0.48125	-0.41903191	104.1252787	120.625	160.8233032	194.3404245	0.12011322	0.8225981
23	0.131385842	0.135323949	0.208420843	0.403816382	0.494536765	-5.35010055	85.43779187	130.3382867	155.0171964	184.2842518	0.23813617	0.8083197
24	0.067508989	0.189796702	0.227910488	0.332239596	0.46323641	3.98411699	100.3757885	117.2403634	157.1273643	187.6919409	0	0
25	0.117069108	0.127516918	0.166454564	0.251904356	0.455291387	-16.0823559	73.0998299	119.1316975	152.7932716	185.4303677	0.1868639829	0.9032933
26	0.169882357	0.131380126	0.250027565	0.298345578	0.498657382	43.98380469	98.59768207	119.2357474	160.2731258	190.2456434	0.0532353369	0.8227664
27	0.069534158	0.133463899	0.153296321	0.43545197	0.461508336	35.84445685	102.6675514	123.4451367	155.0122967	176.4638252	0.2143816888	0.7884891
28	0.152271392	0.190030564	0.237686728	0.419733611	0.455734387	57.03617673	94.86341728	132.4838152	167.9667675	187.1212078	0.1777235684	0.8911013
29	0.067508989	0.158717725	0.227625585	0.335086066	0.461773245	3.243748498	100.6670104	117.2403634	157.6435982	184.9132923	0.2464585214	0.6589524
30	0.073170045	0.190716696	0.182116143	0.383966498	0.490157395	7.033069897	78.3594275	127.2438569	166.0221441	187.7583777	0.092239251	0.9826667
31	0.078351035	0.148790162	0.182131122	0.434514297	0.457388797	-8.62527157	86.32871018	124.2915641	159.6139911	186.1552018	0.156656176	0.8806416
32	0.181755008	0.159637718	0.200536868	0.386812969	0.48869423	7.15871873	78.3594275	127.1656253	166.0221441	185.5593649	0.2237887142	0.8435321
33	0.189861288	0.139328356	0.161273606	0.259080172	0.472653723	1.985064248	94.82572393	131.7230172	151.4703862	193.5517089	0.2050011261	1.0350624
34	0.189861288	0.139328356	0.162643621	0.259080172	0.472653723	2.151822392	94.82572393	131.7230172	151.4703862	192.8073319	0.2136752833	0.9966469
35	0.169534327	0.135239452	0.208578855	0.356810107	0.460513708	13.66888456	99.7663206	125.9531482	161.930461	175.7498017	0.2529570309	0.8253383
36	0.131385842	0.152456069	0.212700147	0.409462634	0.494536765	-5.42206645	85.14656997	130.1206717	155.0493362	184.2842518	0.2156828197	0.8040725
37	0.167857531	0.131191521	0.202333132	0.25725028	0.455738827	-15.0983371	86.05375833	124.2133326	152.968134	187.2615352	0.2215819084	0.8384427
38	0.186278663	0.143284128	0.251572607	0.428218594	0.498990015	-9.05079362	97.85549104	119.230285	159.656301	190.2456434	0.2756821022	0.7255926
39	0.168501377	0.209338365	0.153638526	0.256829539	0.489746455	8.900302686	72.18883377	119.1866941	169.4045793	184.142546	0.0421163829	1.2154585
40	0.189189507	0.131380126	0.253353892	0.38421881	0.499761551	-15.649508	98.59768207	123.3650522	153.010444	190.5867742	0.2873524096	0.7151901
41	0.069534158	0.132268075	0.223921743	0.43545197	0.461508336	35.84445685	77.9853131	123.2086482	166.0894506	186.6787973	0.2033887399	0.7180063
42	0.181755008	0.160024427	0.200536868	0.386812969	0.48869423	7.15871873	103.1061931	126.168759	168.5647101	185.5593649	0.2490865995	0.8005077
43	0.078997996	0.128026741	0.206077268	0.389572453	0.48095372	-5.42206645	85.7729033	120.7444562	154.9161767	184.344395	0.2520082693	0.7265947
44	0.130512846	0.135422208	0.208878478	0.401743929	0.494833045	0	91.87366668	130.0596918	160.1331595	188.6898568	0.2512952454	0.7876795
45	0.090171036	0.154207577	0.208935793	0.355042114	0.459073857	-0.71414995	82.68503188	125.845215	158.9179697	190.635676	0.1785169689	0.8769644
46	0.169534327	0.135239452	0.226909235	0.383336914	0.489595558	13.66888456	100.5464286	128.2424894	162.4567557	175.6635581	0.2272578479	0.894126
47	0.067508989	0.130629845	0.227625585	0.335086066	0.462588602	-16.1169786	92.20815809	117.2403634	151.27576	184.9132923	0.258288747	0.6536029
48	0.138674716	0.157771167	0.273236992	0.399533755	0.477467823	1.22481837	100.8675208	126.8414404	158.0430457	186.6877862	0.2810269924	0.7059644
49	0.169534327	0.130524749	0.208659421	0.356852024	0.460513708	13.66888456	99.7663206	129.020335	161.930461	175.7498017	0.2541102816	0.835642

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
50	0.166693774	0.152431707	0.212492689	0.35773376	0.460513708	13.66888456	99.7663206	125.9531482	161.930461	175.7498017	0.2492248364	0.8130075
51	0.08081557	0.127516918	0.167268109	0.297499928	0.453322943	-0.02213925	73.0998299	117.9458192	160.0559534	185.4303677	0.1849151684	0.8452349
52	0.119283156	0.158717725	0.22681204	0.335086066	0.462503711	46.81684454	100.4568965	116.6309134	157.6435982	184.9132923	0.2227944523	0.7161494
53	0.081968298	0.139328356	0.162643621	0.259080172	0.46046462	2.582192784	94.82572393	122.7064429	151.4703862	192.8073319	0.1662240948	1.0204116
54	0.177427148	0.133463899	0.153296321	0.43545197	0.473697438	35.41408646	102.1236895	131.8950514	155.0122967	176.4638252	0.1742952808	0.9865257
55	0.131975666	0.152366352	0.212700147	0.358194914	0.461142696	-5.42206645	85.06161617	129.0546165	155.0493362	184.2842518	0.2220407347	0.7770364
56	0.168944503	0.15246129	0.212573255	0.409043396	0.493907777	13.66888456	99.8512744	128.7092183	161.930461	175.7498017	0.2105336258	0.8850653
57	0.131436935	0.139328356	0.162643621	0.259080172	0.47181892	-5.4003096	85.02440292	131.7230172	151.4703862	184.0169638	0.1951141858	0.8451201
58	0.189810195	0.152456069	0.212700147	0.409462634	0.493675103	2.130065541	94.94789099	130.1206717	155.0493362	193.0746199	0	0
59	0.121207641	0.130328083	0.166454564	0.297646092	0.4532711	43.55095679	73.0998299	119.1371599	160.0559534	185.4303677	0.2182169956	0.8392998
60	0.078125	0.128125	0.20625	0.387353836	0.481617044	0	92.50764263	120.625	160	188.75	0.2649913441	0.7198187
61	0.189189507	0.130572259	0.253353892	0.38421881	0.499761551	-15.649508	98.69971528	123.4200184	151.1082874	184.9767497	0.2810062846	0.7432201
62	0.067508989	0.131437712	0.227625585	0.335086066	0.462588602	-16.1169786	92.20815809	117.2403634	153.1779166	190.2632402	0.2401407083	0.6865963
63	0.140274167	0.133359284	0.273236992	0.354620165	0.461479481	-14.1503927	92.40866842	125.9926739	150.5652102	175.6005949	0.2813553081	0.6919356
64	0.169534327	0.134534436	0.208578855	0.405859329	0.475972647	10.1126384	99.77147947	126.5601113	163.0404584	186.8369929	0.2786115862	0.8155706
65	0.078997996	0.128026741	0.206077268	0.389572453	0.48095372	-5.42206645	85.94010598	120.7444562	154.9161767	184.344395	0.2520082693	0.7265947
66	0.069534158	0.132654784	0.234885495	0.43545197	0.461508336	35.84445685	102.5003487	123.4451367	168.6320167	186.6787973	0.2600826322	0.7255965
67	0.133708278	0.135323949	0.208647256	0.403816382	0.494536765	-5.42206645	85.14656997	129.0278799	154.5300886	184.2842518	0.240307724	0.8056117
68	0.167211891	0.130524749	0.206970142	0.356852024	0.460513708	13.66888456	99.7663206	130.1131267	162.4497086	175.7498017	0.2532634797	0.8367962
69	0.169534327	0.130524749	0.208577143	0.356852024	0.46054931	13.66888456	99.7663206	125.977876	161.930461	175.7498017	0.2536209973	0.8347168
70	0.169534327	0.135978852	0.209857495	0.356810107	0.460513708	13.66888456	99.7663206	128.9956073	161.930461	175.7498017	0.2530739607	0.8313215
71	0.128541049	0.135422208	0.208878478	0.401743929	0.495896643	0	91.87366668	130.0596918	160.1331595	188.6898568	0.2501220069	0.7863614
72	0.130512846	0.135422208	0.208878478	0.401743929	0.495722259	0	91.87366668	130.0596918	160.1331595	188.6898568	0.2510028511	0.7872754
73	0.065387487	0.13264982	0.237009471	0.399533755	0.477467823	2.245250146	100.8675208	123.4798523	157.4766406	186.6786196	0.2714094721	0.6956953
74	0.142821387	0.157776132	0.271113016	0.43545197	0.461508336	34.82402508	102.6675514	126.8067248	169.1984217	186.6879638	0.2293067734	0.8112322
75	0.069534158	0.132654784	0.232340257	0.43545197	0.461508336	-18.2939936	101.9553054	123.3662152	168.6320167	186.8127132	0.2746674721	0.7431593
76	0.189112193	0.131380126	0.25589913	0.38421881	0.499761551	38.48894241	98.59768207	123.4439737	153.010444	190.4528582	0.1006973231	0.9707562
77	0.07922734	0.127025981	0.206091808	0.357423455	0.461092534	13.66888456	86.01673084	120.4184437	162.2615903	175.7498017	0.2357076028	0.7355065
78	0.169304983	0.130405659	0.20864488	0.389001021	0.480374894	-5.42206645	99.52249306	129.3463475	154.9161767	184.344395	0.2763486833	0.7893655
79	0.166693774	0.152431707	0.212492689	0.35773376	0.460439549	14.68886813	100.0456073	125.9531482	162.0327968	175.2464929	0.2420285835	0.8275433
80	0.069534158	0.132654784	0.233639114	0.43545197	0.461582495	34.82447328	102.3882647	123.4451367	168.5296809	187.1821061	0.260198335	0.7270534
81	0.073979717	0.128125874	0.20625	0.3875	0.481856023	0	92.5	120.625	153.137126	188.7321246	0.260882704	0.7282466
82	0.192848309	0.130521248	0.252286282	0.390335525	0.499155528	-15.649508	98.59768207	123.3650522	159.873318	190.6046496	0.2887460697	0.7039526
83	0.140274167	0.129646629	0.273236992	0.404500362	0.462586291	-17.5165116	92.89878345	126.8414404	151.6752075	186.6902717	0.2825339886	0.7263241
84	0.069534158	0.130292198	0.232340257	0.434620996	0.477205225	-18.1477963	101.4651904	123.3662152	168.6320167	186.8102277	0.2761570781	0.7061264
85	0.140274167	0.129683287	0.273236992	0.403669388	0.461588937	-18.1359087	94.14058306	123.3329537	151.8024153	186.6877862	0.2858760492	0.693445
86	0.069534158	0.132654784	0.232340257	0.43545197	0.478081145	-18.4276875	101.1674905	126.8747019	168.5048089	186.8127132	0.2711351669	0.7292235
87	0.189189507	0.130432163	0.203897406	0.38421881	0.499761551	-15.9336208	98.69075229	123.2366375	151.1082874	184.9767497	0.268225465	0.7922975
88	0.169534327	0.134674531	0.252645183	0.405859329	0.475972647	10.1126384	99.78044246	126.7434923	163.0404584	186.8369929	0.2730928082	0.7760033
89	0.138674716	0.157771167	0.257502886	0.399533755	0.477728935	1.22481837	100.8675208	123.3509954	158.0430457	187.0648159	0.2808156256	0.7044343
90	0.189189507	0.131380126	0.269087998	0.38421881	0.499500439	-15.649508	98.59768207	126.8554972	152.8804117	190.2097445	0.287239336	0.7254347
91	0.140274167	0.129857884	0.274237036	0.354620165	0.461479481	-18.7396039	92.40866842	125.9926739	150.5652102	175.6005949	0.2811650833	0.6887705
92	0.140336358	0.135175207	0.273236992	0.403669388	0.47828318	-14.1940789	92.40866842	126.8414404	151.6752075	186.6877862	0.2770362392	0.7196893
93	0.138720925	0.129671695	0.273236992	0.403669388	0.47747477	-18.1359087	92.40866842	126.5280972	151.4443179	186.6877862	0.2781781548	0.7204832
94	0.140227957	0.157771167	0.273236992	0.399533755	0.478276233	1.22481837	100.8675208	126.8414404	158.2739353	186.6877862	0.2807674492	0.7055846
95	0.076357542	0.130418418	0.208853229	0.391395717	0.463872342	-5.39531993	99.60097924	123.4451367	154.4224605	186.6787973	0.273495525	0.755948
96	0.165474118	0.132642026	0.234677147	0.433057275	0.478010888	36.20320386	102.4218625	129.3463475	169.1257329	184.344395	0.1956593491	0.9013585
97	0.140274167	0.129557551	0.273236992	0.350978765	0.460526971	-18.617181	92.40866842	125.9926739	150.5502	175.8099488	0.2812843179	0.6875352
98	0.140274167	0.13348502	0.273236992	0.402056041	0.479235689	-13.6691204	92.51910961	126.8414404	151.6902177	186.4784323	0.2791253358	0.7169157
99	0.069534158	0.132660244	0.232483845	0.428049458	0.461493281	-17.7348515	101.9553054	123.3662152	168.6320167	186.8127132	0.2750024364	0.7271101
100	0.186278663	0.143278668	0.25142902	0.435621106	0.498189018	-9.60993566	97.85549104	119.004106	159.656301	190.1960311	0.2753890227	0.7330182
101	0.142924087	0.128507381	0.273236992	0.354620165	0.461479481	-14.1503927	92.40866842	125.9926739	150.5652102	175.6005949	0.2823889008	0.6917001
102	0.140274167	0.133359284	0.27274916	0.354620165	0.461479481	-14.1503927	92.40866842	125.9926739	150.5652102	175.6005949	0.2800384054	0.6917849
103	0.140274167	0.129697158	0.273236992	0.35373926	0.461479481	-17.962109	92.40866842	125.9926739	150.5652102	177.4184424	0.2835288667	0.6839122
104	0.140274167	0.133345412	0.273236992	0.404550293	0.461588937	-14.3241924	94.14058306	123.3329537	151.8024153	184.8699387	0.2853849673	0.6924498
105	0.169534327	0.133057003	0.208578855	0.407342836	0.47597756	1.458552345	99.77147947	126.549707	158.2473724	187.0049579	0.2831430262	0.8080107
106	0.140227957	0.1592486	0.273236992	0.399533755	0.478271319	9.878904423	100.8675208	126.8518447	163.0670213	186.6877862	0.2766692584	0.6945994
107	0.140274167	0.129857884	0.274237036	0.354620165	0.461479481	-18.7396039	92.40866842	125.9926739	150.5652102	175.6005949	0.2811650833	0.6887705
108	0.140274167	0.129857884	0.274237036	0.354620165	0.461479481	-18.7396039	92.40866842	125.9926739	150.5652102	175.1443651	0.2793078294	0.6936978
109	0.141588386	0.129923542	0.252796606	0.382526265	0.466245402	-18.0656504	93.99674942	123.3323317	153.010444	190.5867742	0	0
110	0.187875287	0.132222675	0.273794278	0.405361933	0.495105087	-15.7197664	98.74151572	123.3656742	151.5899178	186.6877862	0.283226611	0.7201092
111	0.134187408	0.128530457	0.25397509	0.38421881	0.478240101	-18.1365871	92.00237028	123.4331407	153.010444	187.0720196	0.2843460551	0.6893664
112	0.186726912	0.131381366	0.271785031	0.40907911	0.498374395	-15.6488296	98.38738565	126.4600088	151.4443179	190.2025407	0.2804908199	0.7486156
113	0.138674716	0.129516844	0.267863216	0.399457643	0.477281843	-18.7004101	100.8675208	123.3160257	151.7032011	186.7692212	0.2913772579	0.6918288
114	0.140274167	0.157937609	0.273236992	0.4037455	0.461588937	1.789319758	94.14058306	126.8583684	158.1422599	186.6877862	0.2672696865	0.7178271
115	0.139463815	0.130521248	0.252286282	0.338603539	0.463056075	-15.649508	98.59768207	123.3650522	151.3121083	190.6046496	0.2766343757	0.6966217
116	0.19365866	0.133359284	0.273236992	0.390235018	0.497578934	-14.1503927	92.40866842	125.9926739	159.1264198	175.6005949	0.2508774823	0.8182837
117	0.130776929	0.157771167	0.273236992	0.35102165	0.461174955	1.22481837	92.50145875	126.8414404	150.3700049	175.129526	0.2665287218	0.712135
118	0.139159191	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	125.9926739	158.2232407	187.368209	0.292425305	0.6856873
119	0.189189507	0.131380126	0.269087998	0.38421881	0.499500439	-15.649508	98.59768207	126.8951912	153.0001235	190.2097445	0.287239336	0.7254347
120	0.183142875	0.131380126	0.269087998	0.38421881	0.499500439	-15.649508	98.59768207	126.8554972	152.8804117	190.2097445	0.2866583887	0.7239348
121	0.138674716	0.130332805	0.267863216	0.394620367	0.477281843	-18.7004101	100.8675208	123.3160257	151.7032011	186.7692212	0.2913905646	0.6859562
122	0.138674716	0.129516844	0.267863216	0.399457643	0.479554183	-19.2111944	100.8675208	122.858498	151.7032011	186.7692212	0.2907533352	0.6923893
123	0.140274167	0.129559669	0.273236992	0.357130645	0.460526971	-18.617181	92.14136592	123.3096192	150.5347981	176.3801047	0.2810380647	0.6693956
124	0.140274167	0.129681168	0.273236992	0.402712853	0.461588937	-18.1359087	94.40788556	126.0160084	151.8178172	186.1176302	0.2865260369	0.71534
125	0.134187408	0.128530457	0.25397509	0.38421881	0.478240101	-18.1365871	92.00237028	122.3211751	152.812178	187.0720196	0.2848747229	0.6825769
126	0.134187408	0.128530457	0.25397509	0.38421881	0.478240101	-18.1365871	92.00237028	123.4331407	153.010444	187.0720196	0.2843460551	0.6893664

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
127	0.139630272	0.131380126	0.252306862	0.38421881	0.464186523	-17.7142251	98.59768207	123.3650522	153.010444	177.3603667	0.2881512627	0.7043946
128	0.189833401	0.129697158	0.274284023	0.35373926	0.497054509	-15.897392	92.40866842	125.9926739	150.5629034	190.6448498	0.2866010563	0.6856243
129	0.138619671	0.128480624	0.267624787	0.353166034	0.461179338	-18.9326628	92.40866842	121.8232094	150.5652102	175.6005949	0.2798621242	0.6727153
130	0.142979131	0.129543601	0.273475421	0.400911774	0.477581986	-13.91814	100.8675208	125.8702085	151.7032011	186.7692212	0.2919183673	0.7155486
131	0.139159191	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	125.9926739	158.2232407	187.368209	0.292425305	0.6856873
132	0.139159191	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	101.0989697	125.9926739	158.2232407	187.368209	0.292425305	0.6856873
133	0.139159191	0.110297412	0.269219328	0.384383907	0.476783175	-18.9261929	100.8007026	125.993161	153.0248586	187.2571191	0.2932557455	0.6961145
134	0.189189507	0.131380126	0.273105662	0.399325774	0.499537103	-15.4769663	98.59768207	126.8947041	158.1985056	190.3208344	0.2873294171	0.717576
135	0.135325299	0.128530457	0.25397509	0.38421881	0.479399798	-18.2637623	92.03683663	122.8237075	153.010444	187.1089936	0.2842089643	0.6912279
136	0.188051616	0.131380126	0.253353892	0.38421881	0.498601855	-16.3574725	98.56321573	123.4319005	153.010444	190.5498002	0.2880629913	0.7117325
137	0.138674716	0.131790659	0.267863216	0.399457643	0.477281843	-17.8073467	100.8675208	123.3160257	151.7032011	186.7692212	0.2908708301	0.694918
138	0.138674716	0.129516844	0.267863216	0.399457643	0.477281843	-18.7004101	100.8675208	123.3160257	151.7032011	184.2708062	0.2903333331	0.6945633
139	0.189189507	0.131380126	0.254695615	0.38385384	0.499761551	-13.0537876	94.34214044	123.3650522	151.8128476	185.0158273	0.2771433061	0.7426993
140	0.140274167	0.133345412	0.27189527	0.404915263	0.461588937	-14.3283533	98.3961247	123.3329537	153.0000116	190.4408857	0.2846867039	0.7129551
141	0.146347788	0.129643697	0.252279899	0.390335525	0.477029871	-18.6381598	98.61244216	124.1406744	159.873318	190.6046496	0.2922904501	0.6934694
142	0.184053825	0.130435102	0.274200902	0.39949087	0.498945497	-15.6285292	100.7859425	125.9926739	158.2232407	187.368209	0.2845819272	0.7198433
143	0.13868506	0.110630872	0.269219328	0.384383907	0.476783175	-19.217836	100.8007026	122.7499091	153.0248586	186.7625829	0.2875479845	0.663507
144	0.139148847	0.129183384	0.267863216	0.399457643	0.479554183	-18.9195512	100.8675208	126.1017499	151.7032011	187.2637573	0.2934227828	0.7181218
145	0.139159191	0.110297412	0.269434053	0.384235798	0.476918118	-18.9189394	100.8007026	125.993161	153.5144947	187.2571191	0.2926014201	0.6920029
146	0.139159191	0.129624022	0.273022268	0.39963898	0.476820911	-18.6244345	100.8007026	125.9926739	157.7336046	187.368209	0.2923978557	0.687253
147	0.146977511	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	127.1925957	158.2232407	187.368209	0.2924929308	0.6913326
148	0.141219322	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	125.9926739	158.2232407	187.368209	0.2922258784	0.6881158
149	0.138493583	0.130332805	0.267863216	0.384209733	0.477281843	-18.7004101	100.8675208	123.3160257	151.6967289	186.7692212	0.2904779921	0.6738075
150	0.189370639	0.131380126	0.253353892	0.394629445	0.499761551	-15.649508	98.59768207	123.3650522	153.0169161	190.5867742	0.2857632326	0.7259403
151	0.138674716	0.129516844	0.267863216	0.399457643	0.477281843	-18.7004101	100.8675208	123.3160257	151.7032011	186.7692212	0.2913772579	0.6918288
152	0.138674716	0.131790659	0.267863216	0.399457643	0.477281843	-17.8073467	100.8675208	123.3160257	151.7032011	186.7692212	0.2908708301	0.694918
153	0.138411376	0.112440033	0.267928019	0.383479711	0.476766348	-18.7004101	100.8015078	123.0967014	151.7032011	186.7692212	0.2886666989	0.66875
154	0.139159191	0.130590993	0.269154526	0.39478202	0.477298669	-18.9261929	100.8667156	126.2124853	153.0248586	187.0120845	0.2941890795	0.7072275
155	0.189189507	0.131380126	0.269087998	0.38421881	0.49859168	-15.649508	98.55505378	123.4490728	152.8928532	190.202807	0.2850245944	0.6974279
156	0.188051616	0.131380126	0.253353892	0.38421881	0.499510614	-16.3574725	98.60584402	126.9980991	152.9980025	190.5567376	0.2867136746	0.7404419
157	0.139159191	0.129557551	0.267843668	0.38370279	0.476819839	-18.9265971	100.8108496	125.9926264	153.0292977	187.368209	0.2944454715	0.6946756
158	0.139159191	0.110297412	0.272831016	0.400171987	0.476783175	-18.6167768	101.0888228	125.9932086	158.1683118	187.2571191	0.2915654029	0.6899781
159	0.139159191	0.129557551	0.273236992	0.378534322	0.476827346	-18.7026905	100.8017408	125.9926739	152.6700608	187.368209	0.2928436624	0.6799497
160	0.138674716	0.130332805	0.267863216	0.399486644	0.477274335	-19.2935898	100.8664826	122.5096047	157.256381	186.7692212	0.2897903971	0.6736007
161	0.139159191	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	125.9926739	158.2232407	187.368209	0.292425305	0.6856873
162	0.139159191	0.129557551	0.273236992	0.39949087	0.476819839	-18.617181	100.8007026	125.9926739	158.2232407	187.368209	0.292425305	0.6856873
163	0.139159191	0.12996597	0.268799288	0.395566612	0.476827417	-18.9261929	100.8667156	126.2154796	152.2809425	187.0120845	0.2941498454	0.7114686
164	0.146977511	0.130542744	0.27059594	0.398706278	0.477291092	-18.617181	100.8007026	126.1984906	158.9671567	187.368209	0.2924517382	0.6898458
165	0.139159191	0.110297412	0.269219328	0.384383907	0.476783175	-18.9261929	100.8007026	125.993161	153.0248586	187.1796672	0.2932557455	0.6961145
166	0.139159191	0.110297412	0.269219328	0.384383907	0.476783175	-18.9261929	100.8007026	125.993161	153.0248586	186.3495873	0.293288917	0.6969909
167	0.138620609	0.129432504	0.267863216	0.394620367	0.477281843	-18.7013695	100.7999135	123.2775712	150.728342	186.742417	0.2915581138	0.6895615
168	0.141273428	0.130457852	0.273367614	0.39949087	0.476819839	-18.6162216	100.8683099	124.1711669	158.7454728	187.3950131	0.2890707493	0.6638979
169	0.139159191	0.110297412	0.269192233	0.384383907	0.476774475	-18.9261088	100.8007026	125.993161	152.9857323	187.2571191	0.2936951069	0.696058
170	0.139159191	0.110297412	0.269461149	0.384235798	0.476926818	-18.9190235	100.8007026	125.1143772	153.5536209	187.2571191	0.2905942934	0.6819308
171	0.151956064	0.129186991	0.267971389	0.399457643	0.479554183	-18.9048855	100.8675208	126.1017499	151.7032011	187.2618933	0.2944589743	0.7223011
172	0.141305662	0.129553944	0.273128819	0.389722772	0.476819839	-18.6318467	100.8007026	125.9926739	158.2232407	187.370073	0.2930770695	0.6755839
173	0.139159191	0.110297412	0.269219328	0.384383907	0.476783175	-18.9261929	100.8007026	125.993161	153.0248586	187.2571191	0.2932557455	0.6961145
174	0.139159191	0.110297412	0.269219328	0.384383907	0.476783175	-18.9261929	100.8007026	125.993161	153.0248586	187.2571191	0.2932557455	0.6961145
175	0.139159191	0.129553291	0.26782474	0.39478202	0.477298669	-18.9266027	100.8667156	125.9940153	153.0248586	187.0120845	0.2942065303	0.7084707
176	0.139159191	0.130595252	0.269173454	0.38370279	0.476819839	-18.9261873	100.8108496	126.2110964	153.0292977	187.9313835	0.29380237	0.6931684
177	0.139048485	0.12919634	0.267863216	0.399457643	0.479554183	-18.9195512	100.8675208	125.8950514	151.7032011	186.7576659	0.2934356742	0.7182069
178	0.143079493	0.132051275	0.273475421	0.400911774	0.477581986	-13.91814	100.8675208	126.0769071	151.7032011	186.3875906	0.2916048583	0.7177753
179	0.139159191	0.110297412	0.265311445	0.384235798	0.475268513	-18.9258682	100.8007026	125.993161	153.0525695	187.2571191	0.2947320604	0.7041441
180	0.139159191	0.110297412	0.269411269	0.384383907	0.476783175	-18.9192641	100.8007026	125.993161	153.5179811	187.2571191	0.2925711367	0.6927722
181	0.138749471	0.110297412	0.265245712	0.384235798	0.475236531	-18.9258682	100.8007026	125.998514	152.27457	187.0091537	0.2957751972	0.7063428
182	0.138549038	0.120325925	0.268865021	0.395566612	0.476859399	-18.9261929	100.8667156	126.2101266	153.058942	187.2600499	0.2953297484	0.7090799
183	0.138308547	0.111772299	0.267936288	0.385256867	0.476783175	-18.9261929	100.800691	126.0034439	152.1799871	187.2568841	0.2951321384	0.7025983
184	0.152806708	0.127712104	0.26925443	0.398584684	0.479554183	-18.9048855	102.5870807	126.0914671	153.0018853	187.2621282	0.2945675442	0.7179377
185	0.139159191	0.110160541	0.265237901	0.384235798	0.475286428	-18.918643	100.8007026	125.3711765	152.6849931	187.2571191	0.2922766822	0.6955597
186	0.139159191	0.130560417	0.273310536	0.378534322	0.476809432	-19.5951907	101.6766267	125.9931506	153.0376372	187.368209	0.2932520903	0.6790332
187	0.146977511	0.129557551	0.267509296	0.399457374	0.476892801	-18.617181	100.8007026	125.834073	158.2232407	187.368209	0.2931568996	0.701885
188	0.139048485	0.12919634	0.273590913	0.399491139	0.479481221	-18.9195512	100.4477687	127.2535741	151.7032011	186.7576659	0.2924386298	0.7153838
189	0.139159191	0.112183967	0.269219328	0.383684787	0.475052404	-18.2660011	100.8007026	125.993161	153.0248691	186.2723222	0.292893577	0.6978708
190	0.139159191	0.127670996	0.267843668	0.384401909	0.475422618	-18.9265971	100.8108496	125.9926264	153.0292872	187.4454741	0.2946769138	0.6972803
191	0.139159191	0.110022372	0.267843668	0.383720061	0.476783785	-18.9265859	100.8108496	125.9926264	153.0084258	187.254887	0.2938475543	0.6991489
192	0.139159191	0.129832591	0.269219328	0.384366636	0.476819229	-18.9262041	100.8007026	125.993161	153.0293032	187.370441	0.29389031	0.6942813
193	0.139159191	0.107558519	0.265311445	0.384235798	0.475268513	-18.926695	100.8007026	125.9931732	153.0250014	187.0141012	0.2946068412	0.7042403
194	0.139159191	0.132292184	0.26782474	0.39478202	0.477298669	-18.9257759	100.8667156	125.9940031	153.0524266	187.2551023	0.2934378226	0.7094188
195	0.139159191	0.129557551	0.267843668	0.38370279	0.476819839	-18.9265971	100.8108496	125.9926264	153.0292977	187.368209	0.2944454715	0.6946756
196	0.139159191	0.129557551	0.267843668	0.38370279	0.476819839	-19.7291654	100.8108496	125.9926264	153.0292977	187.368209	0.2941314943	0.6938871
197	0.139137528	0.110640079	0.273128819	0.384711907	0.476781291	-18.6318467	100.8007026	125.9926665	158.2232407	187.370073	0.2911208419	0.666699
198	0.141327325	0.129211277	0.269219328	0.389394772	0.476821723	-18.9261929	100.8007026	125.9931684	153.0248586	186.3495873	0.2941965116	0.7001742
199	0.139148177	0.112974306	0.269219328	0.384383907	0.476783175	-18.9261929	100.800084	125.993161	151.7209691	186.3508189	0.2946448185	0.6998843
200	0.139159861	0.126506491	0.267863216	0.399457643	0.479554183	-18.9195512	100.8681393	126.1017499	153.0840682	187.2625258	0.293975942	0.7133403
201	0.139159191	0.110297412	0.265311445	0.382834556	0.475268513	-18.9258682	100.8007026	125.993161	153.0525695	187.2571191	0.2944106543	0.7030663
202	0.139159191	0.110297412	0.265311445	0.384235798	0.475268513	-19.3449085	100.8007026	125.993161	153.0525695	187.2571191	0.2947320604	0.7041441
203	0.139148089	0.121626291	0.267843668	0.384384407	0.475422618	-18.9265798	100.8108496	125.9926252	151.7365639	186.3600297	0.2951678923	0.7011303

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
204	0.142573037	0.127643467	0.269219328	0.384401409	0.476783175	-18.9262102	100.800084	125.9931622	153.0136923	187.4362633	0.2941000816	0.6951049
205	0.140482265	0.127712104	0.26925443	0.394918076	0.479554183	-18.2520414	100.8595885	126.0914671	152.8906014	187.0037956	0.2933243124	0.7079541
206	0.147946744	0.130590993	0.269154526	0.398448628	0.477298669	-18.2724496	102.5942078	126.2124853	153.0248586	187.2704171	0.2950899186	0.7169632
207	0.139159191	0.107766435	0.265311445	0.388952557	0.475772184	-18.926695	100.8007026	125.9931609	153.0242972	187.0141012	0.2950516154	0.7088665
208	0.139159191	0.110297412	0.265311445	0.384235798	0.475268513	-18.9258682	100.8007026	125.9931734	153.0532737	187.2571191	0.2947320604	0.7041441
209	0.139159191	0.130590993	0.269154526	0.39478202	0.476823857	-18.9261929	100.8667156	126.3453158	153.0248586	187.0120845	0.2940945191	0.7073571
210	0.13663119	0.130590993	0.269154526	0.39478202	0.477298669	-18.9261929	100.8667156	126.2124853	153.0248586	187.0120845	0.2934904634	0.7048356
211	0.138278998	0.110968649	0.269154526	0.39478202	0.477298669	-18.8069081	99.47341662	126.0034112	152.1803748	187.0120845	0.2956835949	0.713952
212	0.13918874	0.131394642	0.267936288	0.385256867	0.475175493	-18.9261929	100.800691	126.212518	153.0244708	187.2568841	0.293809424	0.6965861
213	0.139669348	0.127586566	0.269152489	0.394558533	0.477298669	-18.9263388	100.2060097	126.2124853	153.0023418	187.0120845	0.2938998384	0.7063529
214	0.152296551	0.13071653	0.269256467	0.398808171	0.479554183	-18.9047396	102.5870807	126.0914671	153.024402	187.2621282	0.2942601326	0.7088223
215	0.138749471	0.108659709	0.265098764	0.387654636	0.475236531	-18.9258682	100.8005994	125.998514	152.27457	187.0091537	0.2958618046	0.7111661
216	0.139159191	0.129308698	0.267990616	0.384401909	0.475422618	-18.9265971	100.8109528	125.9926264	153.0292872	188.0455282	0.29406287	0.6982086
217	0.139159191	0.106150414	0.267843668	0.384401909	0.475422618	-18.9266886	100.8108496	125.9926264	153.0292872	186.8977095	0.2935059199	0.7008532
218	0.139159191	0.126943892	0.265311445	0.384235798	0.475268513	-18.9266035	100.8007026	125.9931732	153.0250014	187.0141012	0.2945609742	0.6999238
219	0.139159191	0.106956963	0.265260668	0.384235798	0.475268513	-18.926695	99.84133313	125.9931732	153.0035132	187.1295412	0.2948028479	0.7046163
220	0.152806708	0.12831366	0.269305207	0.398584684	0.479554183	-18.9048855	102.4639621	126.0914671	153.0233735	187.0779912	0.2945111325	0.7176448
221	0.139159191	0.110297412	0.265230642	0.385618242	0.475153432	-18.9258682	100.8007026	125.9931627	153.0532737	187.2571191	0.2950271743	0.7059601
222	0.138278998	0.110968649	0.270620835	0.393399576	0.47199289	-18.8069081	102.0691576	126.0034218	152.1803748	187.0120845	0.2951106427	0.7077428
223	0.139159191	0.107766435	0.265311445	0.388930489	0.475772184	-19.4285811	99.5852388	125.9931609	153.0242972	187.0141012	0.2958162602	0.7085366
224	0.138278998	0.106270564	0.269154526	0.400592233	0.477298669	-18.8284128	100.6888804	126.0034112	152.1803748	187.0120845	0.2947144125	0.7211851
225	0.139159191	0.109650127	0.265507052	0.384243016	0.475268513	-19.3435124	100.8007026	125.9926704	153.0525695	186.3060947	0.2944974976	0.7027143
226	0.139148089	0.122273576	0.268556953	0.384377189	0.475422618	-18.9279758	100.8108496	125.9931158	151.7365639	187.311054	0.2958263731	0.7008081
227	0.138313452	0.11031244	0.260757173	0.38696721	0.476783175	-18.9261929	100.800691	126.0034439	152.1498679	187.2568841	0.2967991752	0.7173976
228	0.139154286	0.11175727	0.26796352	0.384235798	0.47537856	-18.9258682	101.3190641	125.9931734	153.0833929	187.2571191	0.294295616	0.6982328
229	0.139148089	0.121626291	0.267843668	0.384384407	0.475422618	-18.9265798	100.8108496	126.2546794	150.1898299	186.3600297	0.295889162	0.7084284
230	0.148135459	0.121626291	0.267843668	0.384384407	0.475422618	-18.9265798	100.8108496	125.9926252	151.7365639	186.3600297	0.2950580142	0.705505
231	0.138301116	0.107557817	0.265311445	0.384235798	0.475586775	-18.9141313	99.95993296	125.9927971	153.0250014	187.0141012	0.2950588472	0.7036675
232	0.139137072	0.110969351	0.269154526	0.39478202	0.476980408	-18.8194718	100.7845809	126.0037873	152.1803748	187.0120845	0.2952929426	0.7129025
233	0.138278998	0.110968649	0.269154526	0.39478202	0.477333916	-18.9233891	99.47341662	125.9989685	152.1803748	187.0088886	0.2955481909	0.7118615
234	0.138749471	0.108659709	0.265098764	0.387654636	0.477278345	-18.8093872	100.8005994	126.0029568	152.27457	187.0123496	0.2963501631	0.7107454
235	0.138278998	0.110968649	0.264765211	0.390015164	0.475782842	-18.3505118	99.47341662	125.9928017	152.5316409	187.0119671	0.2960526746	0.7103905
236	0.139220686	0.107766435	0.26970076	0.394715267	0.477288011	-18.80669	100.8007026	126.0037704	153.0242972	187.0142185	0.2948086043	0.7089356
237	0.139148574	0.121626291	0.267843668	0.384182902	0.475422618	-18.9265798	100.8108496	125.9926252	151.7365639	186.35731	0.2949806706	0.7010462
238	0.139158705	0.106956963	0.265260668	0.384386006	0.475268513	-18.926695	99.50966822	125.9931732	153.0035132	187.1322609	0.2948354981	0.7051408
239	0.138749471	0.109286808	0.265104487	0.387617687	0.475236531	-18.9267485	100.8005994	125.9932026	152.2401299	187.0091537	0.2963380169	0.7118346
240	0.139159191	0.107766435	0.265305722	0.388989506	0.475772184	-18.3521695	100.8007026	125.9984723	153.0587373	187.0141012	0.2946913047	0.7105298
241	0.13640541	0.124853459	0.268556953	0.384377189	0.475422618	-18.9279758	100.8108496	125.9931158	151.7365639	187.311054	0.2949319729	0.6996886
242	0.139148089	0.122273576	0.268556953	0.384377189	0.475422618	-19.3514247	100.8108496	125.9931158	151.7365639	187.311054	0.2958263731	0.7008081
243	0.138278998	0.110968649	0.264915624	0.390110605	0.475776156	-18.9233891	99.47341662	125.9932847	152.1818384	187.0089473	0.2961725215	0.7132404
244	0.138278998	0.102783159	0.269004113	0.394686579	0.477340602	-18.3505118	99.47341662	125.9984855	152.5301773	187.0119084	0.2946130954	0.7106437
245	0.138407339	0.11106601	0.267548353	0.383980415	0.475422618	-18.9201441	100.8108496	125.9972539	150.1898299	186.402613	0.2966117079	0.7101125
246	0.139019748	0.12152893	0.270202003	0.395186012	0.477298669	-18.8133438	99.47341662	126.2608367	152.1803748	186.9695012	0.2943969687	0.7081922
247	0.138549038	0.120438175	0.267880012	0.383663872	0.476859399	-18.7511526	100.8667156	126.2101266	150.60056	187.2600499	0.2954958085	0.7036621
248	0.139148089	0.121514041	0.268828677	0.396287148	0.475422618	-18.9262298	100.8108496	126.2546794	152.9105487	186.3600297	0.2952876486	0.7107221
249	0.139147685	0.103316782	0.265216936	0.384331185	0.475772184	-19.4285811	99.5852388	125.9931609	153.0242972	186.3813776	0.2941111723	0.7044348
250	0.139159595	0.121626291	0.267938177	0.388983712	0.475422618	-18.9265798	100.8108496	126.9553453	150.2588749	186.9927533	0.2971907545	0.7212977
251	0.138222246	0.108682847	0.269154526	0.39478202	0.47727783	-18.8069081	99.47853288	126.0028927	152.1785696	187.0120845	0.2953239381	0.7119182
252	0.138806223	0.110945512	0.265098764	0.387654636	0.477299184	-18.8093872	100.7954832	126.0034753	152.2763752	187.0123496	0.2960533191	0.7109474
253	0.138764391	0.110585612	0.265281186	0.384238677	0.475236255	-18.9258682	100.8007026	125.9934911	152.27457	187.0091537	0.295413855	0.7064169
254	0.139133168	0.121338091	0.271335464	0.384381528	0.475422894	-18.9265798	100.8108496	125.9976481	151.5382674	186.4355743	0.2943550539	0.6953306
255	0.138274708	0.110297412	0.265498786	0.384120921	0.475236531	-18.9258682	100.8007026	125.998514	152.27457	187.0091737	0.2954305185	0.7068385
256	0.138753762	0.110968649	0.268901452	0.394896897	0.477298669	-18.8069081	99.47341662	126.0034112	152.1803748	187.0120644	0.295442672	0.7133661
257	0.137642175	0.110436646	0.264632001	0.384384407	0.475422618	-18.9265562	100.8002404	125.9926252	151.7365639	186.4029589	0.2956900031	0.7062472
258	0.147944093	0.121487057	0.265245712	0.384235798	0.475236531	-18.9258918	100.4935084	125.998514	152.27457	186.9662244	0.2956962129	0.7068686
259	0.138278998	0.110968649	0.269154526	0.39478202	0.476747317	-18.9230083	99.47341662	125.9989685	152.223283	186.9064032	0.295624468	0.7107616
260	0.138278998	0.110968649	0.269154526	0.39478202	0.477336517	-18.8072889	99.47341662	126.0034112	152.1803748	187.0120845	0.2954677312	0.712486
261	0.139148089	0.110337223	0.265100458	0.384345749	0.47498744	-18.9265798	100.8108496	126.2546794	150.1898299	186.3600297	0.2966786727	0.7152649
262	0.138806223	0.12223458	0.267841974	0.387693294	0.476243121	-18.8093872	100.7954832	126.0034753	152.2763752	187.0123496	0.2955188256	0.7046176
263	0.143660791	0.11031244	0.260757173	0.384411657	0.476783175	-18.9280164	100.800691	125.9941094	152.1498679	187.246142	0.296938785	0.7161666
264	0.139148089	0.122273576	0.268556953	0.386932741	0.475422618	-18.9261524	100.8108496	126.0024503	151.7365639	187.3217961	0.2954130811	0.7013139
265	0.139159595	0.121626291	0.262912363	0.387488062	0.475239568	-18.9267469	100.8009869	126.1792972	150.2523221	186.9914407	0.2966785948	0.7183314
266	0.138749471	0.109286808	0.268061871	0.389113337	0.475141774	-18.9265813	100.8104621	125.9932026	152.2466827	187.0104663	0.2955752985	0.707147
267	0.139148089	0.109094225	0.260832572	0.384322684	0.475422618	-18.9265883	100.8006288	126.0039313	150.1898299	186.3418355	0.2977501627	0.7202039
268	0.138313452	0.123350634	0.267768269	0.387028933	0.476783175	-18.9261844	100.8109117	126.254192	152.1498679	187.2750783	0.2953737768	0.7041963
269	0.138505263	0.121626291	0.267843668	0.384384407	0.475422618	-18.9265798	100.8108496	126.0011453	150.1898299	186.3603157	0.2955814087	0.7084385
270	0.139050164	0.11106601	0.267548353	0.383980415	0.476112143	-18.9201441	100.8108496	126.2507879	150.0125094	186.7006829	0.2957787211	0.7095259
271	0.138756605	0.108181119	0.268556953	0.384390783	0.475607765	-19.3514247	101.3669466	125.9931158	151.7365639	186.9683623	0.294525321	0.701513
272	0.139140955	0.116136624	0.265098764	0.387641041	0.477093198	-18.8093872	100.8108761	125.6912486	152.27457	187.3550412	0.2961797299	0.7097744
273	0.138806223	0.110625514	0.264904587	0.387654636	0.475405373	-18.8093872	100.7907745	126.0034753	152.2763752	185.8856717	0.2962153792	0.710993
274	0.139148089	0.121946288	0.268037845	0.384384407	0.477316429	-18.9265798	100.4244562	126.2546794	150.1898299	187.0043189	0.2952157704	0.7074085
275	0.137642175	0.110436646	0.264689851	0.384243388	0.475243007	-18.9265562	100.8002404	126.0252104	151.6518767	186.3518324	0.2954474185	0.7060261
276	0.147944093	0.121487057	0.265187862	0.384376816	0.475416143	-18.9258918	100.4935084	125.998514	152.3592572	187.0173509	0.2955230288	0.7088425
277	0.138752962	0.107789998	0.26509668	0.387617687	0.475236531	-18.9267485	99.60071489	125.9932026	151.7500413	187.0091537	0.2962919254	0.7103093
278	0.139155701	0.109263245	0.265319252	0.384831648	0.475772184	-19.4285811	100.7851234	125.9931609	152.8121164	187.0141012	0.2948624693	0.7061574
279	0.138275584	0.110971873	0.264576112	0.383980415	0.480065829	-18.9201441	100.8108496	125.9972539	150.1898299	186.402613	0.2953110945	0.7139098
280	0.144306265	0.111062787	0.267737453	0.390015164	0.4764152	-18.3505118	99.47341662	125.9928017	152.5776078	187.0119671	0.2948410253	0.7070892

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
281	0.13882423	0.11028342	0.264904587	0.387479057	0.475405373	-18.8093872	100.7909174	126.0034753	150.3061993	185.8613823	0.2968338921	0.7183249
282	0.139141588	0.121968386	0.262912363	0.38766364	0.475239568	-18.9267469	100.8008441	126.1792972	152.222498	186.9914407	0.2961152832	0.7125951
283	0.138306884	0.110372223	0.265450429	0.385912508	0.475807665	-18.8060579	99.56500733	125.9923396	152.5316409	187.0119671	0.2954308059	0.7046282
284	0.138778337	0.111200704	0.265100213	0.389763884	0.477274361	-18.3538411	100.7038925	126.0039374	152.2763752	187.0123496	0.2962190932	0.7136947
285	0.141948809	0.11031244	0.260757173	0.384411657	0.476783175	-19.5419522	100.800691	125.9941094	152.2348881	187.2472935	0.2973305343	0.7155364
286	0.144240333	0.11031244	0.260757173	0.38696721	0.476783175	-18.9260292	100.800691	126.0034439	152.0896505	187.2557327	0.2970532635	0.7194834
287	0.138016614	0.109094225	0.260605027	0.384322684	0.475422618	-18.4428271	100.8006288	126.0039313	150.0082859	186.3418355	0.2973485325	0.72264
288	0.144792266	0.11031244	0.260835004	0.384411657	0.476783175	-18.9265552	100.800691	125.9941094	152.1498679	187.246142	0.2966414663	0.7160303
289	0.148042787	0.110976791	0.264915624	0.383625269	0.475776156	-18.9236037	99.47341662	125.9932847	150.2351365	187.0089473	0.2969227676	0.7145447
290	0.138407339	0.111057869	0.267548353	0.390465751	0.475422618	-18.9199294	100.8108496	125.9972539	152.1407779	186.402613	0.2958093063	0.7103143
291	0.139293191	0.11031244	0.260760558	0.384411657	0.474876144	-18.9280311	100.800691	125.8546329	150.0881051	187.246142	0.2977643055	0.7207171
292	0.143515689	0.110337223	0.265097073	0.395642825	0.476894471	-18.4868849	100.8108496	126.2427623	152.2515927	186.3600297	0.2953140457	0.7253441
293	0.139148089	0.110313588	0.261238622	0.38295763	0.474921327	-19.0410945	100.8004193	126.2546794	150.1977044	186.3600297	0.2972870019	0.7194712
294	0.143660791	0.110336075	0.264619009	0.384409334	0.476849288	-18.9280164	100.8111212	125.855702	152.1419934	187.246142	0.2952909806	0.7100047
295	0.138806223	0.110625514	0.264904587	0.387654636	0.475453319	-18.8093872	100.7909148	126.0034753	152.2763752	185.8090331	0.2966409307	0.7106915
296	0.138806223	0.110945512	0.265098764	0.387654636	0.477251238	-18.8093872	100.7953429	126.0034753	152.2763752	186.9668223	0.2961683945	0.710272
297	0.13874951	0.108659709	0.265098764	0.387640238	0.475236531	-18.9231183	100.8015951	125.6935289	152.27457	187.0091537	0.2958745154	0.7109735
298	0.139140916	0.116136624	0.265098764	0.387655439	0.477093198	-18.8121371	100.8098805	126.6669701	152.27457	187.3550412	0.2977864558	0.7171026
299	0.139140955	0.116136624	0.265098764	0.387640668	0.477093198	-18.9200132	99.87980561	125.6912486	152.27457	187.3550412	0.2957507625	0.7107918
300	0.138749471	0.108853497	0.265098764	0.386346735	0.475236531	-18.8152422	100.8131134	125.998514	152.27457	187.0091537	0.2957642187	0.7097679
301	0.139132166	0.110337223	0.265100458	0.384345749	0.47498744	-18.7837863	100.8024293	126.0003981	150.1898299	186.4039493	0.2965251335	0.7132495
302	0.141964731	0.11031244	0.260757173	0.384411657	0.476783175	-19.5419522	100.8091112	126.2483907	152.2348881	187.2033738	0.2974632615	0.7143881
303	0.138302405	0.11031244	0.260757273	0.38696721	0.476783175	-19.1859253	100.800691	125.8567321	150.2838882	187.2462676	0.2977264982	0.724083
304	0.139304238	0.11031244	0.260760458	0.384411657	0.474876144	-18.9262543	100.800691	126.0013447	151.9322307	187.2567586	0.2972898814	0.7151581
305	0.138837806	0.110707515	0.264926272	0.384428821	0.475009921	-18.8093872	100.7929336	126.0034753	150.3061993	185.8636839	0.2966979395	0.714265
306	0.154499737	0.110341152	0.264055304	0.387395985	0.475382892	-18.9265798	100.8088334	126.2546794	150.1898299	186.3577281	0.2962547705	0.7251029
307	0.135949553	0.110118379	0.260887559	0.384354725	0.474858655	-18.8093872	100.7909174	126.0034753	150.3061993	184.439599	0.2968911478	0.7188102
308	0.139302718	0.11031244	0.265044466	0.38753599	0.475422863	-18.9280311	100.800691	125.8546329	150.0881051	187.246142	0.29700315	0.7179272
309	0.138856674	0.11028367	0.261567898	0.38295598	0.474921327	-19.0410945	100.8004193	126.02722	150.1977044	185.8553931	0.2974081627	0.7176314
310	0.139115644	0.110313338	0.26457531	0.387480707	0.475405373	-18.8093872	100.7909174	126.2309347	150.3061993	186.3660189	0.2968727483	0.7178608
311	0.139147886	0.121626291	0.261861311	0.39051566	0.473541743	-18.9265883	100.8008604	126.0490871	150.1863218	186.9927533	0.2973426259	0.7242159
312	0.139231577	0.109094225	0.266909438	0.384322684	0.475422618	-18.9265797	100.810618	126.9101895	150.2623829	186.3418355	0.2977576151	0.7193818
313	0.138604842	0.10901752	0.260613509	0.38432111	0.475422618	-18.4428271	100.8006288	126.0039313	150.0045014	186.2277194	0.2976930648	0.7227164
314	0.143072564	0.110389145	0.260748691	0.384413231	0.476783175	-18.9280164	100.800691	125.9941094	152.1498679	187.3602582	0.2967642088	0.7158081
315	0.13867532	0.110312413	0.260757173	0.382284797	0.474913072	-19.0425342	100.800691	126.0101158	152.1498679	186.3999208	0.2964971971	0.7119808
316	0.139148089	0.110313615	0.261238622	0.387640043	0.47679143	-18.9247531	100.8004193	127.2156293	150.1977044	187.216993	0.2988355229	0.7302884
317	0.139148089	0.110313588	0.261238622	0.38295763	0.474921327	-19.0410945	100.8004193	126.2546794	150.1977044	186.3600297	0.2972870019	0.7194712
318	0.139148089	0.110313588	0.261238622	0.38295763	0.474921327	-19.0410945	100.8004193	126.2546794	150.1977044	186.3600297	0.2972870019	0.7194712
319	0.14079086	0.109076973	0.260764589	0.384322684	0.474937647	-18.9265883	100.8006288	126.0039313	150.1898299	186.3400739	0.2979493784	0.722059
320	0.139148089	0.110354474	0.265168441	0.384345749	0.475472411	-18.9265798	100.8108496	126.109145	150.1898299	186.3617913	0.2967204324	0.7141478
321	0.139148089	0.110313615	0.260759971	0.38469529	0.474808484	-18.9247531	100.8004193	128.2908503	150.0875527	187.2183826	0.300872434	0.7342045
322	0.139293191	0.11031244	0.261239209	0.388351097	0.47685909	-18.9280311	100.800691	127.2316792	150.1982568	187.2447524	0.299087627	0.731959
323	0.139151085	0.110312637	0.260764125	0.38295763	0.474921327	-19.0410945	100.8004193	125.8408016	150.0866616	186.3600297	0.2977838971	0.7193276
324	0.139290195	0.110313392	0.261235054	0.388750677	0.474876144	-18.9280311	100.800691	126.2685106	150.1991479	187.9422827	0.2986520763	0.7265759
325	0.138016614	0.109094225	0.260605027	0.384322684	0.475422618	-18.4428271	100.8006288	126.0025362	150.0119477	186.3418355	0.2973485325	0.72264
326	0.139147886	0.121626291	0.261861311	0.39051566	0.473541743	-18.9265883	100.8008604	126.0504821	150.1863218	186.9927533	0.2973426259	0.7242159
327	0.138856674	0.110245659	0.261567898	0.382846421	0.474649254	-19.0226804	100.8011437	126.02722	150.343361	185.8553931	0.297416454	0.7171803
328	0.139140916	0.116174636	0.265098764	0.387764998	0.477238555	-18.8305512	99.96122546	126.6669701	152.1289133	187.3550412	0.2972696868	0.7175489
329	0.138513489	0.11031244	0.260757241	0.384549216	0.474872445	-19.1978982	100.800691	125.8553882	150.3747056	187.2462676	0.2977649112	0.7215237
330	0.139369026	0.11031244	0.26076049	0.386829652	0.476786875	-18.9142813	100.800691	126.0026886	151.8414133	187.2567586	0.2970687696	0.717268
331	0.139140916	0.116136624	0.265098764	0.386984563	0.476774341	-18.8121371	100.8098805	126.6669701	152.27457	187.3550412	0.2976452552	0.7166842
332	0.138302405	0.11031244	0.260757273	0.387638086	0.477102033	-19.1859253	100.800691	125.8567321	150.2838882	187.2462676	0.2981306984	0.7234556
333	0.139148089	0.110313588	0.261238622	0.381698219	0.474921327	-19.0410945	100.8004193	126.2546794	150.1977044	186.3600297	0.2973964674	0.7173171
334	0.142089935	0.110313588	0.261238622	0.384838785	0.474921327	-19.0410945	100.8004193	126.2546794	150.1832791	186.3600297	0.2977052074	0.7228587
335	0.138851013	0.11112874	0.261567898	0.382956113	0.474921327	-19.0410945	100.8004193	126.02722	150.1977044	185.8894301	0.2974987888	0.7176584
336	0.13915375	0.110313588	0.261238622	0.382957497	0.474921327	-19.0410945	100.8004193	126.2546794	150.1977044	186.3600297	0.2971122077	0.7198407
337	0.138621881	0.116136624	0.265098764	0.384380904	0.477093198	-18.8269353	100.8001538	126.6669701	152.27457	186.2620815	0	0
338	0.139123877	0.10901752	0.260613509	0.384416495	0.475422618	-18.498303	100.8103555	126.0039313	150.0045014	187.3206791	0.2977997151	0.722556
339	0.139141006	0.109281908	0.265098764	0.384401347	0.478143324	-18.8121371	100.8098805	126.6669701	152.27457	186.3665462	0.2965631064	0.714123
340	0.139147999	0.115948941	0.260832572	0.387576776	0.477111522	-18.9265883	100.8006288	126.0039313	150.1898299	187.3303305	0.2977939498	0.7241959
341	0.14079086	0.109112495	0.260764589	0.384322684	0.474937647	-18.9265883	100.8004116	125.9965078	150.1898299	186.1590237	0.2976699041	0.7232086
342	0.142089935	0.110278067	0.261238622	0.384838785	0.474921327	-19.0410945	100.8006366	126.2621028	150.2009779	186.3600297	0.2979590748	0.7222949
343	0.138851013	0.11112874	0.261614945	0.383023648	0.474921327	-19.0410945	100.8004193	126.02722	150.2030939	185.9764722	0.2971683893	0.7182137
344	0.139140916	0.116136624	0.265051717	0.386917028	0.476774341	-18.1819405	100.7764029	126.6669701	152.2691804	187.3494369	0.2977355761	0.7185383
345	0.139148089	0.110313615	0.261238622	0.387640043	0.47679143	-18.0100618	100.8004193	127.2156293	150.1977044	187.216993	0.2989210638	0.7313259
346	0.139148089	0.110313615	0.261238622	0.385175379	0.47679143	-18.9247531	100.8004193	127.2156293	150.1977044	187.216993	0.2989459178	0.7279921
347	0.14079086	0.108937509	0.260757636	0.384322684	0.474937647	-19.1995737	100.8006309	125.8615896	150.1898299	186.3400739	0.2979163414	0.7215952
348	0.138513489	0.105493052	0.260764194	0.384549216	0.474872445	-18.9249128	100.8006889	125.9977298	150.3747056	187.2462676	0.2978174969	0.7214205
349	0.139290628	0.11031244	0.261239209	0.388351097	0.474914805	-18.9280311	100.800691	126.273114	150.1982584	187.2447524	0.2980204066	0.7232796
350	0.139292758	0.110313392	0.261235054	0.388750677	0.476820429	-18.9280311	100.816626	127.2270758	150.1991463	187.9422827	0.2995137036	0.7330176
351	0.13844773	0.11031244	0.260757923	0.386424205	0.474861112	-19.3144302	100.800691	125.8553882	150.1661518	187.2462676	0.29778492	0.7226793
352	0.140856619	0.109076973	0.260763907	0.384322684	0.474948979	-18.5121855	100.8006288	126.0039313	150.3983837	186.3400739	0.2979166872	0.7223394
353	0.13914078	0.11055208	0.25594355	0.387640043	0.47679143	-18.9260431	100.8004012	126.6676472	150.1977044	187.2138025	0.2999006979	0.7373443
354	0.139148225	0.123311556	0.265192477	0.387655439	0.477093198	-19.7943556	100.8098986	127.2149521	152.27457	187.3582317	0.2964700819	0.7156301
355	0.138513489	0.11031244	0.260758034	0.382929946	0.475820036	-19.1978982	100.230708	125.8398917	150.0839414	187.2462676	0.2977357157	0.7179498
356	0.138884198	0.110312637	0.260763333	0.3845769	0.47508525	-19.0723053	100.0864137	126.3581157	150.3774258	186.3600297	0.29755961	0.7212325
357	0.139148089	0.109017349	0.260832572	0.384322684	0.475422618	-18.9415201	100.8006288	126.0039313	150.1898299	186.3418355	0.2977240424	0.721889

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	CP	CPdif
358	0.139123877	0.109094396	0.260613509	0.384416495	0.475422618	-18.4833712	102.1003386	126.0039313	150.0045014	187.3206791	0.2973378995	0.7229307
359	0.139269254	0.109076973	0.260825661	0.384322684	0.474937526	-18.9265883	100.8009346	126.0210483	150.1901177	186.3400739	0.2976175664	0.7221189
360	0.140753183	0.109094225	0.266848366	0.384322684	0.475422739	-18.9265797	100.8103123	126.8930725	150.2620951	186.3418355	0.2981837497	0.7217281
361	0.139140215	0.113031702	0.255922713	0.387661544	0.47679143	-18.9260431	100.8004214	126.6515336	150.1977044	187.2136498	0.299890275	0.7365332
362	0.139293757	0.11031244	0.261260045	0.388329596	0.47685909	-18.9280311	100.8006708	127.2477928	150.1982568	187.2449051	0.2992407256	0.7317649
363	0.139124758	0.10901752	0.260613509	0.384421862	0.475453599	-18.498303	100.8103555	126.0039313	150.0018271	187.5194289	0.2979784802	0.7221482
364	0.139147208	0.110313615	0.261238622	0.387634676	0.47676045	-18.9247531	100.8004193	127.2156293	150.2003786	187.216993	0.2989123443	0.7306831
365	0.138302405	0.11031244	0.260748135	0.384915467	0.476811313	-19.2124003	100.800691	125.8642064	150.1954245	187.7490917	0.2981048733	0.7208141
366	0.139148089	0.110313615	0.261247759	0.387640117	0.47708215	-18.8982781	101.3102992	127.2081549	150.2861681	187.2491936	0.2992373325	0.7298679
367	0.139147999	0.115948941	0.253258497	0.387576776	0.477111522	-18.9265962	100.8006288	126.0039313	150.1913068	187.3303305	0.2986380441	0.7313751
368	0.13914078	0.11055208	0.260735686	0.387640043	0.47679143	-18.9260352	100.8004012	126.6676472	150.1962275	187.2138025	0.2990621173	0.7307669
369	0.138513489	0.105493052	0.260761015	0.384549216	0.474872445	-18.9249128	100.8004228	126.0907845	150.1689675	187.2462676	0.2978570142	0.722741
370	0.139148089	0.110313615	0.261241801	0.385175379	0.47679143	-18.9247531	100.8006855	127.1225746	150.4034425	187.216993	0.2989922751	0.7270618
371	0.139290632	0.11031244	0.261234797	0.388366005	0.47685909	-18.9280311	100.800691	127.2316792	150.1982856	187.2447524	0.2991335059	0.732311
372	0.139292754	0.110313392	0.261239465	0.38873577	0.473630304	-18.8445829	100.800691	126.2685106	150.1991191	187.9422827	0.2984138377	0.7245858
373	0.139193182	0.109076973	0.260764589	0.384322684	0.474937647	-18.1679164	100.8006288	125.8484003	150.1901203	186.2679341	0.2972484921	0.7223113
374	0.140890869	0.11031244	0.261239209	0.388351097	0.47685909	-18.9266811	100.800691	127.3872102	150.1979664	187.3168921	0.2992356599	0.7310999
375	0.137260464	0.110308986	0.255795893	0.387640043	0.47679143	-18.0100618	100.800401	127.2156293	150.1977044	187.216993	0.3000604762	0.7367334
376	0.139148231	0.110556709	0.261386279	0.387640043	0.47679143	-18.9260431	100.8004195	126.6676472	150.1977044	187.2138025	0.2990200389	0.7308653
377	0.139148089	0.110313615	0.261234873	0.38757914	0.476789739	-18.9296009	100.7997911	127.2153627	150.1975553	187.2308722	0.299093543	0.7317719
378	0.139292758	0.110313392	0.261238803	0.388811581	0.47682212	-18.008492	100.8172542	127.2273424	150.1992953	187.9284035	0.2993366439	0.7326794
379	0.142089935	0.109076416	0.260775297	0.384342165	0.474922876	-19.0411001	100.8006366	126.2621028	150.3878007	186.3418688	0.2979086625	0.7238461
380	0.140856619	0.110278625	0.261227232	0.384819304	0.47494743	-18.5121798	100.8006288	126.0039313	150.3983837	186.3582347	0.2978404154	0.7212879
381	0.139293757	0.11031244	0.261239274	0.38833066	0.47685909	-18.9280311	100.8006668	127.2477928	150.1982568	187.2447438	0.2993609531	0.7315475
382	0.139293191	0.11031244	0.26125998	0.388350033	0.47685909	-18.9280311	100.8006949	127.2316792	150.1913031	187.2449136	0.2990805855	0.7335052
383	0.139140215	0.117463925	0.25561274	0.387822037	0.47679143	-18.9278478	100.8001365	126.6515336	150.1197569	187.2093799	0.298526394	0.7348619
384	0.139292758	0.112841686	0.261545027	0.388590184	0.476820429	-18.9262264	100.8169109	127.2270758	150.1991463	187.9465527	0.2988612723	0.7309243
385	0.137433665	0.110334171	0.255986809	0.38764226	0.47679143	-19.9599081	100.800401	126.6135321	150.1977044	187.216993	0.3002010964	0.7349669
386	0.138967013	0.113006518	0.255922741	0.387659327	0.47679143	-18.9260431	100.8004214	127.2536308	150.1977044	187.2136498	0.2993610204	0.7365985
387	0.139430936	0.109116351	0.261238988	0.388351097	0.47685909	-18.9280513	100.8006706	128.3920311	150.1979665	187.2338799	0	0
388	0.140753691	0.11031244	0.261260266	0.388329596	0.47685909	-18.9266609	100.8006911	127.2477928	150.1982567	187.3279173	0.2995333069	0.7334629
389	0.140890869	0.110312314	0.261239209	0.388351097	0.47685909	-18.9266811	101.0434728	127.2219979	150.1979664	187.9692332	0.2996739884	0.7317722
390	0.139148089	0.110313742	0.261238622	0.384428057	0.47679143	-18.9247531	99.6972893	127.3808416	150.1977044	187.216993	0.2988823864	0.7266546
391	0.139148089	0.110312525	0.260759971	0.38469529	0.474808484	-18.9247531	100.8004193	128.2908503	150.0875527	187.2183826	0.3008337525	0.735141
392	0.140890869	0.10804809	0.263617972	0.388351097	0.47685909	-18.9266811	101.038583	127.3872102	150.1979664	187.3168921	0.2985481811	0.7292376
393	0.137250783	0.110305379	0.25581216	0.387640043	0.47679143	-18.9680308	100.8004012	126.6676472	150.1977044	187.2138025	0.299825765	0.7360166
394	0.139150461	0.110555687	0.255927283	0.387640043	0.47679143	-17.968074	100.800401	127.2156293	150.1977044	187.216993	0.29989285	0.7367612
395	0.139141092	0.113665315	0.255774634	0.387572102	0.47679143	-18.9297459	100.8004012	126.6512176	150.197554	187.2138025	0.2994708896	0.7356444
396	0.139147777	0.110533882	0.270405715	0.38764708	0.476789739	-18.925898	100.7997911	127.2317923	150.1977057	187.2308722	0.2968915208	0.7181508
397	0.13907617	0.11031244	0.255788069	0.388351097	0.47685909	-18.9231577	97.84239906	127.3872102	150.1977303	187.3168921	0.2980076417	0.7354338
398	0.140954913	0.113031702	0.261373852	0.387661544	0.47679143	-18.9260863	100.800709	125.7220624	150.1979405	187.2136498	0.2976786656	0.7252886
399	0.139140215	0.113031702	0.255922713	0.387661544	0.476787259	-18.9260431	100.8003961	126.6500578	150.1977042	187.2127846	0.2996103806	0.7356041
400	0.140890869	0.11031244	0.261239209	0.388351097	0.47686326	-18.9266811	100.8007163	127.388686	150.1979665	187.3177574	0.2995733055	0.7323552
401	0.137443667	0.113031702	0.255923061	0.387641042	0.476787468	-18.9260431	100.8003961	126.6144019	150.1977042	187.2127838	0.2992855042	0.7360101
402	0.139130213	0.110334171	0.255986461	0.387662761	0.476791221	-19.9599081	100.800401	126.6491881	150.1977044	187.2169937	0.2998915904	0.7353657
403	0.139164689	0.110313392	0.261235054	0.388750677	0.476820429	-18.899758	100.816626	127.2166336	150.1991463	187.2443501	0.2994212136	0.7315174
404	0.13927853	0.110555687	0.256275232	0.387640043	0.47679143	-17.9963471	100.2273584	127.2260715	150.1977044	187.9149256	0.2998233443	0.7363569
405	0.139127698	0.110555687	0.255920513	0.387640043	0.47679143	-18.9346661	100.8004009	127.2000642	150.1977149	187.216993	0.2999367168	0.7371487
406	0.140913632	0.11031244	0.261245978	0.388351097	0.47685909	-17.960089	100.8006911	127.4027753	150.1979559	186.7353938	0.2992858836	0.7325907
407	0.140338119	0.11030057	0.25594355	0.387640043	0.473433914	-18.9260431	100.8004012	126.6676472	150.1977044	187.2138025	0.3008251445	0.7383012
408	0.139071455	0.110560496	0.255795893	0.384328335	0.47679143	-18.0100618	100.800401	127.2156293	150.2297302	187.216993	0.300167889	0.7361798
409	0.139292758	0.110313392	0.256397365	0.387528864	0.476794272	-18.008492	100.8011511	127.2151827	150.1992953	187.6683423	0.299970155	0.7373698
410	0.139150461	0.111494176	0.26076872	0.384467632	0.476819278	-17.968074	100.8165042	127.227789	150.1977044	187.216993	0.2989519245	0.7283006
411	0.137429124	0.110334171	0.255986809	0.38764226	0.476787149	-19.972065	100.8003962	126.6135321	150.1977044	187.216993	0.2998962361	0.7333716
412	0.139144756	0.10903455	0.255922713	0.387661544	0.47679154	-18.9138862	100.800401	126.6500578	150.1977042	187.2127846	0.3003491251	0.7375572
413	0.139140215	0.113031702	0.255648543	0.387661544	0.47679143	-18.9260431	100.8004214	126.6515336	150.1977044	187.2128186	0.2996891625	0.736609
414	0.139150461	0.110555687	0.255927283	0.387640043	0.47679143	-18.9297459	100.8004012	126.6512176	150.1977044	187.216993	0.29979285	0.7367612
415	0.139224758	0.10901752	0.260613509	0.387634476	0.47676045	-18.9247531	100.800691	125.8642064	150.1954245	187.7490917	0.2981148733	0.7208141
416	0.13914078	0.115948941	0.253258497	0.387576776	0.47608215	-18.8782781	101.3102992	125.8642064	150.1954245	187.7490917	0.2999922751	0.7270618
417	0.131230936	0.109116366	0.261238988	0.388351097	0.47685909	-18.9280513	100.8089706	128.3920311	151.1979665	187.2338799	0.2994482136	0.7361487
418	0.139224758	0.105493052	0.260761015	0.385175379	0.47679143	-18.9247531	100.8006288	126.0039313	150.1954245	187.216993	0.2990621173	0.7308669
419	0.139193182	0.109076973	0.260764589	0.388366005	0.47685909	-18.8445829	100.800691	126.2685106	150.1962275	187.2138025	0.2992373325	0.7307669
420	0.137260464	0.110308986	0.261247759	0.387640117	0.47708215	-19.2124003	100.800691	127.2316792	150.1982856	187.2447524	0.29989285	0.7310999

Second optimization process

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
1	0.1391	0.1094	0.2602	0.3844	0.4742	-18.75	101.25	128.13	150.31	187.19	1.0031	0.99219	0.30008	0.73819	0.46212	InitializingPopulation
2	0.1672	0.1031	0.2695	0.2656	0.4844	-32.969	78.125	134.22	150.31	190.94	1.1672	1.10938	0.15222	0.94465	-0.33578	InitializingPopulation
3	0.0711	0.2063	0.1594	0.2781	0.4773	-3.5156	97.5	121.09	156.88	177.81	1.05	0.57031	0.03847	1.07253	-0.91865	InitializingPopulation

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
4	0.0734	0.0969	0.1734	0.3688	0.4867	-21.797	105.63	124.84	157.81	194.06	1.1906	1.08594	0.29363	1.04491	0.12963	InitializingPopulation
5	0.125	0.1844	0.2016	0.4125	0.4953	10.703	91.25	122.03	159.69	178.44	0.8391	1.83594	0.1962	0.67701	0.10781	InitializingPopulation
6	0.0523	0.1156	0.1734	0.3	0.475	-35	108.13	127.19	147.5	194.69	0.9641	0.5	0.17625	0.82847	-0.12349	InitializingPopulation
7	0.0992	0.1313	0.2813	0.4156	0.4578	-3.5156	78.75	117.34	148.91	185	1.0734	0.78125	0.22242	0.74761	0.14207	InitializingPopulation
8	0.1625	0.0531	0.2203	0.2656	0.4906	17.813	105.63	124.38	161.09	187.5	0.8781	1.78906	0.14277	0.6689	-0.09781	InitializingPopulation
9	0.193	0.1656	0.2648	0.4063	0.4984	-35	71.25	119.69	155.94	182.81	0.9875	1.78906	0.20807	0.73167	0.10062	InitializingPopulation
10	0.1039	0.1875	0.2555	0.3406	0.4523	14.766	101.88	135.63	168.59	177.81	0.8391	1.53125	0.214119	0.58709	0.26939	InitializingPopulation
11	0.1508	0.1813	0.2297	0.3844	0.4758	-19.766	96.875	119.22	147.97	188.75	0.9172	1.22656	0.24209	0.61468	0.35369	InitializingPopulation
12	0.0711	0.0688	0.2602	0.2781	0.4633	-16.719	98.125	140.78	168.59	177.81	0.9094	1.46094	0	0	-3E+41	InitializingPopulation
13	0.1555	0.1688	0.1852	0.3438	0.4758	-13.672	73.75	134.69	140.47	184.38	0.8234	1.76563	0.15191	0.56694	0.0407	InitializingPopulation
14	0.1531	0.0938	0.2109	0.2781	0.4984	-18.75	98.75	124.84	163.91	179.69	1.0656	0.52344	0.16045	1.03139	-0.38958	InitializingPopulation
15	0.0828	0.1469	0.1523	0.2625	0.4695	12.734	71.875	135.63	140	194.69	0.8469	1.57813	0.13964	0.78619	-0.22761	InitializingPopulation
16	0.0758	0.1188	0.2625	0.3063	0.4953	4.6094	80.625	119.69	145.16	190.94	1.0734	1.71875	0.23559	0.72036	0.22202	InitializingPopulation
17	0.0711	0.0688	0.2438	0.2688	0.4633	-15.703	98.125	140.78	168.59	191.88	0.9094	1.46094	0.18105	0.77275	-0.04857	Generation=2/Individual=0/
18	0.0711	0.0688	0.2602	0.2781	0.4633	-21.797	98.125	140.78	168.59	177.81	0.9094	1.39063	0.20359	0.6688	0.14554	Generation=2/Individual=1/
19	0.1555	0.1688	0.1852	0.3438	0.4758	-13.672	73.75	134.69	140.94	184.38	1.0188	1.76563	0.10377	0.94474	-0.52967	Generation=2/Individual=2/
20	0.0922	0.1688	0.1852	0.3438	0.4758	-13.672	73.75	134.69	140.47	184.38	0.8234	1.57813	0.13544	0.566	-0.02423	Generation=2/Individual=3/
21	0.125	0.2094	0.2016	0.4125	0.4953	10.703	91.25	122.03	159.69	178.44	1.2531	1.83594	0.09098	1.25921	-0.89527	Generation=2/Individual=4/
22	0.1273	0.1844	0.2016	0.4219	0.4953	10.703	91.25	122.03	159.69	178.44	0.8391	1.83594	0.19674	0.67524	0.111719	Generation=2/Individual=5/
23	0.0969	0.1875	0.2555	0.3406	0.4719	14.766	97.5	135.63	167.19	177.81	0.8391	1.53125	0.19147	0.63073	0.13514	Generation=2/Individual=6/
24	0.1039	0.1875	0.2555	0.3406	0.4719	14.766	101.25	135.63	168.59	177.81	0.8781	1.53125	0.19446	0.67218	0.10564	Generation=2/Individual=7/
25	0.0758	0.1188	0.2977	0.3063	0.4953	4.6094	81.25	119.69	145.16	190.94	1.0734	1.71875	0.23146	0.62206	0.30378	Generation=2/Individual=8/
26	0.0758	0.1188	0.2625	0.3063	0.4953	-2.5	83.75	119.69	145.16	190.94	1.0813	1.71875	0.23791	0.71727	0.23436	Generation=2/Individual=9/
27	0.1508	0.1156	0.2297	0.3844	0.4758	-19.766	102.5	117.81	147.97	189.06	0.9172	1.22656	0.28703	0.60205	0.54607	Generation=2/Individual=10
28	0.1508	0.1813	0.2297	0.3844	0.4758	-19.766	96.875	119.22	147.97	188.75	0.9172	0.5	0.19574	0.62229	0.16066	Generation=2/Individual=11
29	0.0734	0.0969	0.2742	0.3688	0.4813	-32.969	73.75	124.84	157.81	194.06	1.1906	1.20313	0.14824	0.91217	-0.31921	Generation=2/Individual=12
30	0.0711	0.0969	0.1734	0.3688	0.4867	-21.797	105.63	124.84	157.81	194.06	1.1906	0.64063	0.22812	1.07743	-0.16494	Generation=2/Individual=13
31	0.1391	0.1094	0.1875	0.3844	0.4734	-15.703	101.25	128.59	150.31	182.5	1.0031	0.99219	0.2782	0.81083	0.30196	Generation=2/Individual=14
32	0.1391	0.1094	0.2602	0.3844	0.4742	-11.641	101.25	128.13	150.31	187.19	1.0031	0.73438	0.26656	0.7545	0.31172	Generation=2/Individual=15
33	0.0734	0.0969	0.1734	0.3688	0.4813	-22.813	105.63	124.84	166.72	194.06	1.2766	1.08594	0.21739	1.27775	-0.40821	Generation=3/Individual=0/
34	0.0992	0.0969	0.1734	0.3688	0.4867	-21.797	105.63	124.38	157.81	194.06	1.1906	1.08594	0.30195	1.04423	0.16356	Generation=3/Individual=1/
35	0.1367	0.1094	0.2602	0.3125	0.4734	-14.688	100.63	128.59	150.31	182.5	1.0031	0.99219	0.2785	0.69279	0.4212	Generation=3/Individual=2/
36	0.1391	0.1094	0.1875	0.3844	0.4508	-18.75	101.25	128.13	150.31	187.19	1.0031	0.73438	0.26024	0.82777	0.21318	Generation=3/Individual=3/
37	0.1391	0.1125	0.2555	0.3844	0.4742	-18.75	101.88	116.41	150.31	187.19	1.0031	0.92188	0.27039	0.61414	0.46743	Generation=3/Individual=4/
38	0.1461	0.1094	0.2602	0.375	0.4742	-18.75	101.25	127.66	150.31	187.19	1.0031	1.01563	0.29899	0.73052	0.46544	Generation=3/Individual=5/
39	0.1438	0.1813	0.2297	0.3844	0.4758	-35	96.875	119.22	147.97	188.75	0.8	1.22656	0.23324	0.4677	0.46526	Generation=3/Individual=6/
40	0.1508	0.1813	0.2297	0.3844	0.4758	-19.766	82.5	119.22	147.97	185.94	0.9172	1.22656	0.21552	0.63525	0.22684	Generation=3/Individual=7/
41	0.1438	0.1875	0.2555	0.3406	0.4523	13.75	102.5	127.19	147.97	189.38	0.8	1.22656	0.23183	0.5146	0.4127	Generation=3/Individual=8/
42	0.1508	0.1375	0.2297	0.3844	0.4758	14.766	101.88	135.63	168.59	177.81	0.8391	1.53125	0.23479	0.64189	0.29725	Generation=3/Individual=9/
43	0.1555	0.1688	0.1898	0.3406	0.4523	14.766	101.88	135.63	168.59	177.81	0.8391	0.94531	0	0	-3E+41	Generation=3/Individual=10
44	0.1039	0.1875	0.2625	0.3438	0.4758	-13.672	73.75	133.75	140.47	184.38	1.2688	1.76563	-0.06268	1.64514	-1.89586	Generation=3/Individual=11
45	0.0922	0.1688	0.1852	0.3438	0.4758	-14.688	73.75	134.69	140.47	184.38	0.8234	1.76563	0.13633	0.56979	-0.02445	Generation=3/Individual=12
46	0.1555	0.1688	0.1852	0.3438	0.475	-13.672	73.75	139.84	169.06	184.38	0.8859	1.57813	0.18582	0.83684	-0.09358	Generation=3/Individual=13
47	0.0711	0.0781	0.2602	0.2781	0.4625	-16.719	98.125	140.78	168.59	177.81	0.8703	1.53125	0.20954	0.59751	0.24066	Generation=3/Individual=14
48	0.0711	0.0688	0.2602	0.2688	0.4633	-16.719	98.125	140.78	168.59	177.81	0.9094	1.39063	0.199411	0.66458	0.13306	Generation=3/Individual=15
49	0.0711	0.0688	0.2602	0.2938	0.4633	-16.719	98.125	140.78	168.59	177.81	0.9094	1.76563	0.19039	0.71067	0.0509	Generation=4/Individual=0/
50	0.0711	0.0688	0.2602	0.3188	0.4633	-17.734	98.75	140.78	168.59	177.81	1.1828	1.46094	0.16645	1.17618	-0.51039	Generation=4/Individual=1/
51	0.1555	0.1688	0.1828	0.3438	0.4758	-13.672	73.75	134.69	140.47	184.38	0.8234	1.625	0.14777	0.57326	0.01783	Generation=4/Individual=2/
52	0.0922	0.1688	0.1852	0.3438	0.4758	7.6563	73.75	134.69	142.81	184.38	0.8234	1.46094	0.1544	0.52822	0.08938	Generation=4/Individual=3/
53	0.1438	0.1875	0.2555	0.3313	0.4523	-19.766	101.88	127.19	147.97	177.81	0.8391	1.53125	0.25287	0.50903	0.50244	Generation=4/Individual=4/
54	0.1039	0.1594	0.2555	0.3375	0.4523	14.766	101.88	136.09	168.59	189.38	0.8	1.22656	0.21828	0.54269	0.33042	Generation=4/Individual=5/
55	0.1508	0.1813	0.2297	0.3125	0.4758	-19.766	96.875	119.22	147.97	188.75	0.8	1.22656	0.23831	0.46255	0.49069	Generation=4/Individual=6/
56	0.1438	0.1813	0.2297	0.3844	0.4758	-19.766	96.875	119.22	147.97	190.94	0.9172	1.22656	0.23982	0.60984	0.34943	Generation=4/Individual=7/
57	0.1367	0.1156	0.2555	0.3906	0.4742	-3.5156	79.375	116.41	144.22	187.19	1.0031	0.92188	0.26765	0.68062	0.38997	Generation=4/Individual=8/
58	0.1391	0.1125	0.2602	0.3219	0.4734	-14.688	100.63	128.59	150.31	182.19	1.0109	0.99219	0.28268	0.71534	0.41536	Generation=4/Individual=9/
59	0.1461	0.1094	0.2602	0.375	0.4742	-18.75	101.88	127.66	149.84	187.19	0.9172	1.22656	0.29735	0.61706	0.57235	Generation=4/Individual=10
60	0.1508	0.1156	0.2297	0.3844	0.4758	-19.766	102.5	117.81	147.97	189.06	1.0031	1.01563	0.28735	0.7042	0.4452	Generation=4/Individual=11
61	0.1367	0.1094	0.2602	0.3625	0.4742	-18.75	103.13	128.13	150.31	187.19	1.0031	0.99219	0.29794	0.71847	0.4733	Generation=4/Individual=12
62	0.1414	0.1094	0.2602	0.3625	0.4742	-18.75	96.25	128.13	144.22	187.19	0.8391	0.99219	0.27469	0.49914	0.5996	Generation=4/Individual=13
63	0.1555	0.2	0.1734	0.3656	0.4867	-21.797	105.63	124.38	158.28	194.06	1.1828	1.08594	-0.01713	1.32495	-1.39349	Generation=4/Individual=14
64	0.1109	0.1281	0.1898	0.4375	0.4523	14.766	101.88	135.16	140.94	177.81	0.8391	0.94531	0.18485	0.6067	0.13271	Generation=4/Individual=15
65	0.0992	0.0969	0.1711	0.2563	0.4516	14.766	97.5	135.63	168.59	181.88	0.8156	0.92188	0.21899	0.62422	0.25172	Generation=5/Individual=0/
66	0.0945	0.1719	0.1922	0.3688	0.4867	-21.797	104.38	124.38	157.81	194.06	1.1906	1.08594	0.10718	1.151	-0.72228	Generation=5/Individual=1/
67	0.1391	0.1094	0.2602	0.4219	0.475	-18.75	101.25	128.13	150.31	187.19	1.0031	0.99219	0.29412	0.78628	0.39022	Generation=5/Individual=2/
68	0.1391	0.1063	0.2625	0.3844	0.4742	-18.75	101.25	128.13	150.31	186.25	1.0031	0.99219	0.29922	0.73727	0.45963	Generation=5/Individual=3/
69	0.1086	0.1094	0.225	0.375	0.468	-18.75	101.25	127.66	150.31	185	1.0031	1.01563	0.29213	0.76077	0.40775	Generation=5/Individual=4/
70	0.1484	0.1094	0.2531	0.3625	0.4742	-11.641	103.13	123.91	150.31	187.19	1.0031	0.92188	0.28022	0.70673	0.41416	Generation=5/Individual=5/
71	0.1367	0.1094	0.2578	0.3125	0.4734	-14.688	78.75	117.81	147.97	189.06	1.0031	0.71094	0.20598	0.644	0.17993	Generation=5/Individual=6/
72	0.1508	0.1156	0.2297	0.3844	0.4758	-18.75	102.5	129.06	159.22	177.19	1.0031	0.99219	0.28519	0.77566	0.36508	Generation=5/Individual=7/
73	0.1719	0.1156	0.2297	0.3844	0.4742	-18.75	101.88	127.66	149.84	187.19	0.9172	1.22656	0.29365	0.64206	0.53254	Generation=5/Individual=8/
74	0.1461	0.1094	0.2602	0.3719	0.4797	-19.766	102.5	117.81	147.97	189.06	0.9172	1.22656	0.27265	0.53065	0.55995	Generation=5/Individual=9/
75	0.1414	0.1094	0.1875	0.3625	0.4742	-18.75	93.125	116.41	144.22	177.81	1.0031	1.55469	0.28681	0.75114	0.39609	Generation=5/Individual=10
76	0.1414	0.1875	0.2555	0.3313	0.4523	-19.766	101.88	127.19	150.31	187.19	0.8391	0.99219	0.24221	0.4932	0.47562	Generation=5/Individual=11
77	0.1508	0.2188	0.2297	0.3219	0.4984	-35	82.5	119.22	147.97	188.75	0.8	1.17969	0.17106	0.59106	0.09318	Generation=5/Individual=12
78	0.1789	0.1813	0.293	0.375	0.4758	13.75	96.875	119.22	147.97	188.75	0.8	1.22656	0.23004	0.43359	0.48658	Generation=5/Individual=13
79	0.0688	0.0688	0.2602	0.2781	0.4633	-13.672	98.125	140.78	168.59	177.81	0.9094	1.46094	0.20794	0.66549	0.16628	Generation=5/Individual=14
80	0.0711	0.2281	0.2602	0.2781	0.4633	-16.719	98.125	140.78	168.13	177.81	0.9094	1.46094	0.13912	0.76425	-0.20776	Generation=5/Individual=15

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
81	0.0688	0.0688	0.2602	0.2781	0.4609	-17.734	98.125	118.75	155.94	177.81	0.9094	1.46094	0.18427	0.57425	0.16285	Generation=6/Individual=0/
82	0.0711	0.0688	0.2602	0.2781	0.4633	-5.5469	98.125	139.38	168.59	177.81	0.8703	1.46094	0.20772	0.58569	0.24521	Generation=6/Individual=1/
83	0.1438	0.1813	0.293	0.3781	0.4797	-19.766	96.875	125.31	147.97	188.75	0.8	1.22656	0.24927	0.41475	0.58232	Generation=6/Individual=2/
84	0.1789	0.1156	0.2297	0.3844	0.4758	-35	96.25	119.22	147.97	188.75	0.8	1.22656	0	0	-3E+41	Generation=6/Individual=3/
85	0.1414	0.1875	0.2484	0.3344	0.4734	-19.766	96.875	119.22	147.97	188.75	0.8	1.22656	0.24414	0.42644	0.55012	Generation=6/Individual=4/
86	0.1531	0.1813	0.2297	0.3313	0.4523	-26.875	101.88	127.19	150.31	187.5	0.8391	0.99219	0.21634	0.57691	0.28845	Generation=6/Individual=5/
87	0.1508	0.1156	0.2297	0.3844	0.4984	-26.875	102.5	117.81	147.97	187.5	0.8313	0.99219	0.25964	0.50936	0.52919	Generation=6/Individual=6/
88	0.1414	0.1094	0.2602	0.3625	0.4742	-18.75	96.25	128.13	144.22	185.63	0.9172	1.22656	0.29075	0.61398	0.54904	Generation=6/Individual=7/
89	0.1367	0.1094	0.2602	0.3625	0.4742	-18.75	106.25	127.66	150.78	187.19	0.9172	1.22656	0	0	-3E+41	Generation=6/Individual=8/
90	0.1461	0.1094	0.2602	0.4219	0.4742	-18.75	101.88	128.13	150.31	187.19	1.0031	0.99219	0.2953	0.79022	0.391	Generation=6/Individual=9/
91	0.1648	0.1063	0.2602	0.375	0.4742	-18.75	101.25	128.59	150.31	187.19	1.0031	1.01563	0.29948	0.74612	0.4518	Generation=6/Individual=10
92	0.1461	0.1094	0.2625	0.3844	0.4742	-18.75	101.25	128.13	150.31	186.25	1.0813	0.99219	0.30025	0.83798	0.36303	Generation=6/Individual=11
93	0.1391	0.1094	0.2602	0.3844	0.4742	-18.75	101.25	128.13	159.22	185	1.0031	0.99219	0.29367	0.70893	0.46574	Generation=6/Individual=12
94	0.1367	0.1063	0.2602	0.3844	0.4742	-18.75	101.25	131.41	161.56	186.25	1.0031	0.99219	0.29562	0.72038	0.46211	Generation=6/Individual=13
95	0.0922	0.1688	0.1898	0.3688	0.4867	-21.797	105.63	135.16	157.81	194.06	1.1906	1.08594	0.08381	1.17521	-0.83998	Generation=6/Individual=14
96	0.0992	0.0969	0.1734	0.3406	0.4523	14.766	101.88	135.63	168.59	177.81	0.8391	0.94531	0.24599	0.61428	0.36969	Generation=6/Individual=15
97	0.0992	0.0969	0.1734	0.4313	0.4773	14.766	101.88	123.91	168.59	177.81	0.8391	0.78125	0.23575	0.58841	0.3546	Generation=7/Individual=0/
98	0.1555	0.1688	0.1898	0.3406	0.4617	-21.797	105.63	127.66	157.81	194.06	1.1906	1.08594	0.01543	1.4701	-1.4084	Generation=7/Individual=1/
99	0.1086	0.1094	0.2602	0.3844	0.468	-18.75	101.25	128.13	150.31	183.44	1.0734	0.99219	0.29648	0.81851	0.36743	Generation=7/Individual=2/
100	0.1461	0.1094	0.2625	0.4125	0.4742	-18.75	101.25	129.53	150.31	187.19	1.0031	0.99219	0.2977	0.78326	0.40753	Generation=7/Individual=3/
101	0.1461	0.1063	0.2648	0.3844	0.4742	-18.75	78.125	128.13	150.31	187.19	1.0031	0.99219	0.28014	0.72242	0.39815	Generation=7/Individual=4/
102	0.1391	0.0875	0.2602	0.3844	0.4742	-2.5	101.25	128.13	150.31	186.25	1.0031	1.48438	0.28602	0.76916	0.37492	Generation=7/Individual=5/
103	0.1391	0.1094	0.2227	0.375	0.4742	-18.75	101.25	127.66	150.31	187.19	1.0031	0.71094	0.26864	0.76076	0.31378	Generation=7/Individual=6/
104	0.1484	0.1063	0.2602	0.3625	0.4742	-18.75	103.13	128.13	150.31	187.19	1.0031	0.99219	0.29702	0.72736	0.46074	Generation=7/Individual=7/
105	0.1461	0.1094	0.2602	0.375	0.4688	-18.75	107.5	127.66	149.84	187.5	0.9172	1.08594	0.29486	0.61595	0.56351	Generation=7/Individual=8/
106	0.1391	0.1094	0.2602	0.375	0.4742	-18.75	101.25	128.13	159.22	185	1.0031	0.99219	0.29147	0.69982	0.46607	Generation=7/Individual=9/
107	0.1484	0.1125	0.2297	0.3844	0.4758	-17.734	96.25	128.13	144.22	189.06	0.9172	1.22656	0.27834	0.65082	0.46253	Generation=7/Individual=10
108	0.1813	0.1094	0.2602	0.3625	0.4742	-19.766	102.5	126.72	147.97	189.06	0.9172	1.22656	0.29696	0.60414	0.58371	Generation=7/Individual=11
109	0.1438	0.1813	0.293	0.3281	0.4797	-18.75	96.25	131.41	142.81	187.19	0.8391	0.99219	0.25107	0.46775	0.53653	Generation=7/Individual=12
110	0.1438	0.1094	0.2602	0.3625	0.4742	-19.766	96.875	125.31	147.97	188.75	0.8	1.20313	0.27302	0.44308	0.64899	Generation=7/Individual=13
111	0.1367	0.1094	0.2555	0.3844	0.4758	-35	96.25	140.78	147.97	188.75	0.8	1.22656	0.24552	0.53946	0.44262	Generation=7/Individual=14
112	0.1789	0.1156	0.225	0.3625	0.4742	-18.75	106.25	127.66	151.25	187.19	0.8625	1.22656	0.29038	0.56716	0.59437	Generation=7/Individual=15
113	0.1789	0.1125	0.2508	0.3625	0.4742	-18.75	106.25	127.66	150.78	187.19	0.9094	1.22656	0.29779	0.61159	0.57958	Generation=8/Individual=0/
114	0.1367	0.0906	0.2297	0.3813	0.4758	-35	96.25	140.31	147.97	188.75	0.8547	1.22656	0.2419	0.64225	0.32534	Generation=8/Individual=1/
115	0.1438	0.1844	0.293	0.3281	0.4797	-19.766	96.25	131.41	142.81	187.19	0.8313	1.22656	0.25023	0.45816	0.54274	Generation=8/Individual=2/
116	0.1766	0.1906	0.293	0.3781	0.4797	-19.766	96.875	125.31	150.31	188.75	0.8078	0.99219	0.24837	0.4305	0.56297	Generation=8/Individual=3/
117	0.1414	0.1094	0.225	0.3625	0.4734	-18.75	103.13	126.72	150.31	188.75	0.8	1.20313	0	0	-3E+41	Generation=8/Individual=4/
118	0.1438	0.1094	0.2438	0.3594	0.4742	-19.766	96.875	123.91	144.22	187.19	0.8391	0.99219	0.27801	0.49494	0.61709	Generation=8/Individual=5/
119	0.1813	0.1063	0.2602	0.3625	0.4742	-19.766	106.25	127.19	152.66	187.19	0.9172	1.22656	0.29267	0.60745	0.56323	Generation=8/Individual=6/
120	0.1789	0.1156	0.225	0.3625	0.4742	-18.75	106.88	126.72	150.31	189.06	0.8938	1.22656	0.29907	0.59941	0.59687	Generation=8/Individual=7/
121	0.1367	0.1094	0.2602	0.3344	0.4555	-18.75	103.13	128.13	147.97	187.19	0.9875	1.20313	0.287119	0.69419	0.45428	Generation=8/Individual=8/
122	0.1461	0.1094	0.2602	0.375	0.4719	-18.75	107.5	116.88	149.84	192.5	0.9016	0.99219	0.24892	0.45364	0.54204	Generation=8/Individual=9/
123	0.1414	0.1156	0.2625	0.375	0.4742	-18.75	103.13	127.66	150.31	186.25	1.0031	1.01563	0.29819	0.72513	0.46764	Generation=8/Individual=10
124	0.1461	0.1094	0.2602	0.3844	0.4742	-15.703	101.25	128.13	150.31	185.94	1.0031	0.99219	0.29867	0.74593	0.44876	Generation=8/Individual=11
125	0.1461	0.1094	0.2625	0.3844	0.4742	-15.703	100.63	128.13	159.22	186.25	1.0891	0.99219	0.29147	0.82469	0.34119	Generation=8/Individual=12
126	0.1578	0.1375	0.2602	0.3844	0.4773	-18.75	101.25	128.13	150.31	187.19	1.0109	1.17969	0.28598	0.75371	0.39023	Generation=8/Individual=13
127	0.1555	0.1688	0.1898	0.3406	0.4523	14.766	101.88	135.63	169.06	194.06	1.1906	1.08594	0.05819	1.64802	-1.41524	Generation=8/Individual=14
128	0.0992	0.0969	0.1711	0.3688	0.4836	-21.797	105.63	124.38	157.34	177.81	0.8391	1.53125	0.26824	0.59199	0.48097	Generation=8/Individual=15
129	0.0992	0.1281	0.1898	0.3406	0.4523	14.766	101.88	135.63	168.59	178.13	0.8391	0.94531	0.2263	0.61428	0.29092	Generation=9/Individual=0/
130	0.0922	0.2	0.1734	0.3688	0.4867	-21.797	105.63	124.38	157.81	194.06	1.1906	1.08594	-0.00715	1.24841	-1.27699	Generation=9/Individual=1/
131	0.1391	0.1	0.2625	0.3844	0.4742	-18.75	101.25	123.91	150.31	186.25	1.0813	0.99219	0.28966	0.79438	0.36424	Generation=9/Individual=2/
132	0.1016	0.1094	0.2602	0.4125	0.475	-18.75	101.25	128.13	150.78	187.19	1.0031	0.99219	0.28381	0.76464	0.37061	Generation=9/Individual=3/
133	0.1789	0.1156	0.225	0.3625	0.45	-18.75	106.88	126.72	150.31	188.44	1.0031	0.99219	0.29756	0.8044	0.38586	Generation=9/Individual=4/
134	0.1391	0.1063	0.2648	0.3844	0.4742	-18.75	98.125	128.13	150.31	186.56	0.8938	1.22656	0.29134	0.58253	0.58285	Generation=9/Individual=5/
135	0.1414	0.1125	0.225	0.3625	0.4742	-18.75	105.63	127.66	151.25	187.19	0.8625	0.875	0.2811	0.55884	0.56556	Generation=9/Individual=6/
136	0.1438	0.1094	0.2602	0.3625	0.4742	-15.703	96.25	128.13	142.81	187.19	0.8313	0.99219	0.27298	0.49382	0.59811	Generation=9/Individual=7/
137	0.1789	0.1844	0.293	0.3313	0.475	-35	96.875	123.91	144.22	187.19	0.8391	0.96875	0.24725	0.45514	0.53385	Generation=9/Individual=8/
138	0.1414	0.1094	0.2438	0.3875	0.4695	-19.766	96.25	131.41	142.81	187.19	0.8313	1.22656	0.259	0.53268	0.50332	Generation=9/Individual=9/
139	0.1766	0.2063	0.293	0.3781	0.4789	-19.766	102.5	125.31	147.97	188.75	0.8	1.20313	0.2516	0.42289	0.58349	Generation=9/Individual=10
140	0.1438	0.1094	0.2602	0.3625	0.4742	-19.766	96.875	125.31	147.97	188.75	0.8078	1.01563	0.27057	0.44831	0.63398	Generation=9/Individual=11
141	0.1391	0.1094	0.2602	0.3688	0.4797	-19.766	96.875	125.31	147.97	188.75	0.8	1.22656	0.26907	0.44701	0.62926	Generation=9/Individual=12
142	0.1438	0.1813	0.293	0.3844	0.4734	-18.75	106.25	127.66	151.25	187.19	0.9172	1.22656	0.27678	0.57263	0.5345	Generation=9/Individual=13
143	0.1883	0.1156	0.2273	0.3719	0.4734	-18.75	103.13	126.72	150.31	188.75	0.8234	1.20313	0.2825	0.511111	0.6189	Generation=9/Individual=14
144	0.1391	0.1094	0.232	0.3844	0.4758	28.984	96.25	119.22	147.97	188.75	0.8234	1.22656	0.22446	0.50412	0.39373	Generation=9/Individual=15
145	0.1414	0.1094	0.2273	0.3625	0.4758	-18.75	78.125	125.31	154.06	188.75	0.8	1.22656	0.26453	0.47062	0.5875	Generation=10/Individual=0
146	0.1789	0.1156	0.293	0.3844	0.4508	-35	93.125	117.81	160.16	188.75	0.8	1.20313	0.23782	0.38191	0.56938	Generation=10/Individual=1
147	0.1766	0.2156	0.293	0.3781	0.4805	-19.766	96.875	125.31	147.97	189.06	0.8	1.22656	0.23888	0.41786	0.53765	Generation=10/Individual=2
148	0.1789	0.1875	0.293	0.3781	0.4789	-19.766	102.5	125.31	147.97	188.75	0.8	1.20313	0.25567	0.4339	0.5888	Generation=10/Individual=3
149	0.1438	0.1094	0.2438	0.3625	0.4742	-19.766	96.875	125.31	147.97	188.75	0.8	1.20313	0.27238	0.46009	0.62943	Generation=10/Individual=4
150	0.1438	0.1094	0.2602	0.4375	0.4742	-19.766	97.5	123.91	144.22	187.19	0.8391	0.99219	0.2594	0.56613	0.47148	Generation=10/Individual=5
151	0.1883	0.1156	0.2273	0.3719	0.4633	-18.75	103.75	126.25	152.66	187.19	0.8625	0.875	0.28497	0.55941	0.58046	Generation=10/Individual=6
152	0.1063	0.1125	0.232	0.3625	0.4742	-18.75	105.63	127.19	150.31	188.75	0.8234	1.17969	0.27629	0.49743	0.60773	Generation=10/Individual=7
153	0.1391	0.1063	0.2648	0.3844	0.475	-18.75	98.125	128.13	150.31	187.19	0.8703	1.27344	0.288011	0.55163	0.60042	Generation=10/Individual=8
154	0.1789	0.1156	0.225	0.3719	0.4742	-18.75	106.25	128.13	151.72	186.56	0.9016	1.41406	0.29986	0.6238	0.57566	Generation=10/Individual=9
155	0.1391	0.1063	0.2625	0.3844	0.475	-35	100.63	128.13	150.31	193.44	0.9484	1.22656	0.29063	0.65906	0.50347	Generation=10/Individual=1
156	0.1625	0.1156	0.225	0.3625	0.4742	-18.75	106.88	126.72	147.97	189.06	0.8156	0.99219	0.28091	0.49857	0.62508	Generation=10/Individual=1
157	0.1461	0.1063	0.2602	0.3813	0.4742	-18.75	108.13	128.13	150.31	186.25	1.0031	0.99219	0.29639	0.74698	0.43857	Generation=10/Individual=1

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
158	0.1391	0.1094	0.2531	0.3125	0.4688	-18.75	101.25	128.13	150.31	187.19	1.0813	0.99219	0.27127	0.79811	0.28696	Generation=10/Individual=1
159	0.1555	0.1688	0.1875	0.3063	0.4523	27.969	101.88	135.16	157.81	194.06	1.1984	1.20313	0.02726	1.68531	-1.57628	Generation=10/Individual=1
160	0.0992	0.0969	0.1734	0.3688	0.4867	-24.844	85.625	122.5	168.59	177.81	0.8781	0.94531	0.20987	0.70444	0.13505	Generation=10/Individual=1
161	0.0992	0.0969	0.1734	0.3688	0.4625	-21.797	105.63	135.16	157.81	194.06	0.8391	0.94531	0.24868	0.71663	0.27808	Generation=11/Individual=0
162	0.1555	0.1688	0.2203	0.3406	0.4523	14.766	101.88	131.41	167.19	177.81	1.1906	1.08594	0.18559	1.11437	-0.372	Generation=11/Individual=1
163	0.1273	0.1094	0.2602	0.3844	0.4742	-18.75	101.25	128.13	150.31	187.19	1.0109	0.99219	0.29877	0.74353	0.45155	Generation=11/Individual=2
164	0.1461	0.1094	0.2625	0.3844	0.4742	-15.703	101.88	128.59	147.5	186.25	1.0656	1.10938	0.30096	0.83236	0.37149	Generation=11/Individual=3
165	0.1719	0.0906	0.225	0.3625	0.4625	-18.75	106.25	128.13	151.25	186.56	0.9016	1.41406	0.30243	0.6434	0.56632	Generation=11/Individual=4
166	0.0688	0.1156	0.225	0.3719	0.4742	9.6875	106.88	126.72	150.31	189.06	0.8938	1.22656	0.2758	0.58289	0.5203	Generation=11/Individual=5
167	0.1789	0.1188	0.225	0.3625	0.4742	-11.641	108.13	131.41	143.75	186.56	0.9172	1.22656	0.291134	0.655	0.50953	Generation=11/Individual=6
168	0.1391	0.1094	0.2648	0.3844	0.4734	-18.75	96.25	127.66	151.25	187.19	0.8625	1.22656	0.28424	0.53287	0.60411	Generation=11/Individual=7
169	0.1719	0.1156	0.2273	0.3719	0.4734	-15.703	103.75	126.25	150.31	187.5	0.8703	1.27344	0.29109	0.57059	0.59377	Generation=11/Individual=8
170	0.1391	0.1063	0.2648	0.3844	0.475	-18.75	98.125	128.13	150.31	185.94	0.8313	1.20313	0.27736	0.50356	0.60589	Generation=11/Individual=9
171	0.1461	0.1094	0.2602	0.3594	0.4742	-19.766	96.875	123.91	143.28	187.5	0.8391	0.99219	0.27807	0.48743	0.62486	Generation=11/Individual=1
172	0.1438	0.1094	0.2438	0.3656	0.4742	-19.766	96.875	122.97	146.56	184.69	0.8	1.20313	0.26896	0.46044	0.6154	Generation=11/Individual=1
173	0.1438	0.1844	0.293	0.3188	0.4789	-19.766	102.5	125.31	147.97	188.75	0.8	1.20313	0.24429	0.41153	0.56565	Generation=11/Individual=1
174	0.1789	0.1906	0.2156	0.3781	0.4945	-19.766	95	119.22	147.97	188.75	1.2922	1.22656	0.08062	1.31016	-0.98766	Generation=11/Individual=1
175	0.1414	0.1094	0.225	0.4344	0.4508	-35	96.25	117.81	160.16	188.75	0.9172	1.20313	0.26923	0.6601	0.41682	Generation=11/Individual=1
176	0.1789	0.0813	0.293	0.3844	0.4734	-18.75	76.25	126.72	150.31	189.06	0.8	1.08594	0.26852	0.42537	0.64873	Generation=11/Individual=1
177	0.1789	0.1156	0.2906	0.3625	0.4734	-18.75	103.13	126.72	150.31	188.75	0.8	1.20313	0.2648	0.43252	0.62668	Generation=12/Individual=0
178	0.1391	0.1063	0.2273	0.3844	0.4984	-35	93.125	117.81	160.16	188.75	0.8	1.20313	0.2519	0.44184	0.56574	Generation=12/Individual=1
179	0.1789	0.0813	0.293	0.375	0.4664	-19.766	102.5	125.31	161.56	189.06	0.8	1.20313	0.25194	0.39479	0.61298	Generation=12/Individual=2
180	0.1438	0.1844	0.293	0.3188	0.4758	-18.75	76.25	126.72	149.84	189.06	0.8547	1.08594	0.22197	0.51536	0.37251	Generation=12/Individual=3
181	0.1484	0.1094	0.2625	0.3594	0.4742	-19.766	92.5	123.91	145.16	187.5	1.0031	1.27344	0.28856	0.69302	0.46124	Generation=12/Individual=4
182	0.1438	0.1094	0.2602	0.3625	0.4719	-19.766	92.5	125.31	147.97	188.75	0.8	0.99219	0.26759	0.43363	0.63673	Generation=12/Individual=5
183	0.1063	0.1156	0.225	0.3719	0.4727	-11.641	103.13	127.19	150.31	188.75	0.8234	1.20313	0.27261	0.50789	0.58254	Generation=12/Individual=6
184	0.1859	0.1094	0.2648	0.3844	0.4727	-18.75	95.625	131.88	150.78	187.19	0.8625	1.22656	0.28405	0.56002	0.5762	Generation=12/Individual=7
185	0.1789	0.1156	0.225	0.3656	0.475	-35	97.5	131.41	150.31	187.19	0.8703	1.39063	0.26106	0.59955	0.44471	Generation=12/Individual=8
186	0.1391	0.1094	0.2648	0.3844	0.4625	-17.734	106.25	127.66	158.28	187.19	0.8625	1.22656	0.28642	0.52252	0.62316	Generation=12/Individual=9
187	0.1391	0.1063	0.2953	0.3719	0.4734	-16.719	104.38	126.25	150.31	187.5	0.8703	1.64844	0	0	-3E+41	Generation=12/Individual=1
188	0.1719	0.1156	0.1898	0.3844	0.4742	-18.75	98.125	128.13	150.31	186.56	0.8938	1.22656	0.27297	0.63428	0.45758	Generation=12/Individual=1
189	0.1789	0.1156	0.225	0.425	0.4742	12.734	106.25	128.13	157.81	186.56	0.8859	1.22656	0.25749	0.70246	0.32751	Generation=12/Individual=1
190	0.1789	0.1156	0.225	0.3719	0.4742	-18.75	106.88	126.72	151.72	190.63	0.8078	1.34375	0.28379	0.50788	0.6273	Generation=12/Individual=1
191	0.1297	0.1688	0.1898	0.3406	0.4523	14.766	101.88	135.63	168.59	178.13	0.8156	1.0625	0.17307	0.65259	0.03969	Generation=12/Individual=1
192	0.1719	0.0906	0.225	0.3844	0.4625	-18.75	106.25	128.13	151.25	186.88	0.8391	1.15625	0.2937	0.558	0.6168	Generation=12/Individual=1
193	0.1719	0.0906	0.2578	0.3313	0.4523	14.766	100	135.63	168.13	177.81	0.8391	0.94531	0.19195	0.55688	0.21094	Generation=13/Individual=0
194	0.1672	0.1688	0.15	0.3625	0.4625	-18.75	103.13	128.13	152.66	186.56	0.9406	1.41406	0.12753	0.86738	-0.35725	Generation=13/Individual=1
195	0.1813	0.1156	0.225	0.3625	0.4742	-15.703	106.88	126.72	147.97	186.56	0.9016	1.41406	0.30155	0.62445	0.58177	Generation=13/Individual=2
196	0.1789	0.1156	0.225	0.3719	0.4688	-18.75	106.25	128.13	151.72	189.06	0.8938	1.22656	0.29912	0.60711	0.58937	Generation=13/Individual=3
197	0.1391	0.1063	0.2977	0.3844	0.4617	-18.75	106.25	128.13	151.25	185.63	0.8391	1.15625	0.27479	0.47688	0.62227	Generation=13/Individual=4
198	0.1719	0.0906	0.2578	0.3844	0.4773	-18.75	90.625	128.59	150.31	187.19	1.2219	1.27344	0.28698	1.09944	0.04848	Generation=13/Individual=5
199	0.1836	0.1094	0.2648	0.3875	0.4633	-18.75	106.25	127.66	158.28	187.19	0.8625	1.22656	0.28586	0.53502	0.60844	Generation=13/Individual=6
200	0.1438	0.1156	0.225	0.3719	0.4742	-18.75	92.5	126.72	151.72	190.63	0.8078	1.34375	0.27198	0.49218	0.59575	Generation=13/Individual=7
201	0.1039	0.1375	0.2602	0.3625	0.4742	-19.766	96.875	125.31	147.97	188.75	0.8078	0.73438	0.24066	0.43625	0.52638	Generation=13/Individual=8
202	0.1461	0.1094	0.2602	0.3594	0.4742	13.75	96.875	124.38	141.88	187.5	0.8547	1.20313	0.25599	0.55217	0.4718	Generation=13/Individual=9
203	0.1438	0.1844	0.2953	0.3844	0.4508	-18.75	76.25	132.81	147.97	185.63	0.8	1.08594	0.20695	0.48247	0.34534	Generation=13/Individual=1
204	0.1438	0.0813	0.293	0.3188	0.4703	-19.766	102.5	119.22	161.56	189.06	0.8	1.20313	0.19128	0.38832	0.3768	Generation=13/Individual=1
205	0.0688	0.1156	0.293	0.3844	0.4734	-19.766	86.25	117.81	161.56	185.31	0.9172	1.20313	0.246311	0.4689	0.51635	Generation=13/Individual=1
206	0.1789	0.0813	0.293	0.375	0.4664	-19.766	102.5	125.31	156.88	180	0.8	1.08594	0.2455	0.39089	0.59109	Generation=13/Individual=1
207	0.1414	0.1063	0.225	0.3625	0.4734	-17.734	104.38	118.28	150.31	187.5	0.8703	1.64844	0.2836	0.52236	0.61205	Generation=13/Individual=1
208	0.1391	0.1063	0.2953	0.325	0.4734	-15.703	103.75	126.72	150.78	188.75	0.8	1.20313	0.24085	0.38046	0.58295	Generation=13/Individual=1
209	0.1391	0.1063	0.2953	0.325	0.4734	-15.703	103.75	126.72	150.78	188.75	0.8703	1.64844	0.25662	0.46078	0.5657	Generation=14/Individual=0
210	0.1391	0.1063	0.2953	0.3719	0.4734	-16.719	104.38	126.25	159.22	187.5	0.8	1.20313	0.24894	0.36887	0.62691	Generation=14/Individual=1
211	0.1789	0.2156	0.293	0.3844	0.4734	12.734	76.25	127.19	162.03	189.06	0.8	1.17969	0.20516	0.47826	0.34237	Generation=14/Individual=2
212	0.1789	0.0844	0.293	0.375	0.4672	-19.766	102.5	125.31	150.31	189.06	0.8	1.08594	0.25758	0.39189	0.63843	Generation=14/Individual=3
213	0.1391	0.1375	0.2602	0.3625	0.4742	-19.766	96.875	125.31	147.97	185.94	0.8	0.89844	0.25676	0.44101	0.58603	Generation=14/Individual=4
214	0.1789	0.1063	0.2977	0.3844	0.4617	-18.75	103.13	128.13	151.25	185.63	0.8391	1.15625	0.27762	0.49579	0.61467	Generation=14/Individual=5
215	0.1789	0.1156	0.225	0.3719	0.4742	12.734	107.5	126.72	143.28	187.5	0.8391	0.99219	0.251137	0.59844	0.40611	Generation=14/Individual=6
216	0.1461	0.1594	0.2602	0.3375	0.4742	-19.766	96.875	123.91	152.19	190.63	0.8078	1.32031	0	0	-3E+41	Generation=14/Individual=7
217	0.1391	0.1094	0.2648	0.4125	0.4758	-18.75	98.125	128.13	150.31	187.19	0.8703	1.22656	0.27897	0.57307	0.54281	Generation=14/Individual=8
218	0.1391	0.1094	0.2648	0.3844	0.4617	-17.734	105.63	131.88	158.28	192.5	0.8625	1.95313	0.2868	0.6136	0.5336	Generation=14/Individual=9
219	0.1789	0.1156	0.225	0.3625	0.4688	-18.75	106.25	128.13	151.25	186.88	0.8469	1.32031	0.290117	0.5499	0.61056	Generation=14/Individual=1
220	0.1719	0.0906	0.2977	0.3125	0.4867	12.734	106.25	126.72	150.31	189.06	0.8938	1.22656	0.17136	0.52869	0.15674	Generation=14/Individual=1
221	0.1813	0.1156	0.225	0.3625	0.4742	-15.703	106.88	118.28	151.72	189.06	0.8938	1.22656	0.27799	0.54293	0.56902	Generation=14/Individual=1
222	0.1789	0.1156	0.225	0.325	0.4688	-18.75	106.25	128.59	147.97	186.25	1.1906	1.25	0.29162	1.0515	0.115	Generation=14/Individual=1
223	0.1555	0.1688	0.1898	0.3406	0.45	-18.75	106.25	128.13	151.25	186.56	0.8781	1.41406	0.21923	0.69532	0.18159	Generation=14/Individual=1
224	0.1719	0.2063	0.2813	0.3625	0.4648	27.969	101.88	135.63	168.59	177.81	0.8391	0.96875	0.19829	0.61858	0.17457	Generation=14/Individual=1
225	0.1719	0.0906	0.225	0.3625	0.4633	-18.75	106.25	130	151.25	186.56	0.8781	0.94531	0.29796	0.59789	0.59394	Generation=15/Individual=0
226	0.1555	0.1688	0.1898	0.3313	0.4523	14.766	100	136.09	140.94	177.81	0.8156	1.41406	0.16387	0.55573	0.09975	Generation=15/Individual=1
227	0.1789	0.1156	0.2227	0.3719	0.4805	-18.75	106.25	128.13	150.31	189.06	0.9484	1.41406	0.30757	0.69845	0.53181	Generation=15/Individual=2
228	0.1813	0.1156	0.225	0.3625	0.4742	-15.703	106.88	126.72	147.97	189.06	0.8938	1.22656	0.3005	0.6064	0.59559	Generation=15/Individual=3
229	0.1695	0.0875	0.225	0.3844	0.4867	-15.703	106.25	128.13	151.25	186.88	0.8313	1.15625	0.28196	0.55909	0.56876	Generation=15/Individual=4
230	0.1789	0.1156	0.225	0.3625	0.4742	-18.75	106.88	126.72	147.97	189.06	0.9016	1.15625	0.30093	0.61277	0.59097	Generation=15/Individual=5
231	0.1391	0.1094	0.1828	0.3156	0.4633	-18.75	106.25	128.13	151.25	187.81	1.2453	1.32031	0.28214	1.20793	-0.07935	Generation=15/Individual=6
232	0.1789	0.1156	0.225	0.3625	0.4688	-17.734	106.25	116.88	157.81	187.19	0.8625	1.22656	0.26301	0.49968	0.55236	Generation=15/Individual=7
233	0.1578	0.1375	0.225	0.3719	0.4742	-18.75	106.88	126.72	157.81	190.63	0.8078	1.34375	0.27399	0.50239	0.59355	Generation=15/Individual=8
234	0.1789	0.1156	0.2414	0.3875	0.4742	-19.766	96.25	123.91	143.28	187.5	0.8391	0.73438	0.26025	0.52009	0.52093	Generation=15/Individual=9

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
235	0.1508	0.1125	0.2438	0.3625	0.4742	-19.766	102.5	140.31	150.78	185.63	0.8391	1.15625	0.26837	0.57391	0.49956	Generation=15/Individual=1
236	0.1391	0.1063	0.2977	0.3844	0.4617	-11.641	73.125	130.94	154.06	180.94	0.8	1.20313	0.25816	0.435	0.59764	Generation=15/Individual=1
237	0.1813	0.0844	0.293	0.375	0.4672	-3.5156	76.25	126.72	150.31	189.06	0.8	1.08594	0.25641	0.42044	0.60521	Generation=15/Individual=1
238	0.1789	0.0813	0.293	0.3125	0.4734	-19.766	103.13	125.31	150.31	189.06	0.9172	1.08594	0.2389	0.45789	0.49771	Generation=15/Individual=1
239	0.1461	0.1594	0.2602	0.3375	0.475	-16.719	100	126.25	159.22	187.5	0.8	1.20313	0.25267	0.45278	0.5579	Generation=15/Individual=1
240	0.1391	0.1063	0.2953	0.3719	0.4734	-18.75	96.875	128.13	152.66	190.63	0.8078	1.32031	0.26927	0.4242	0.65289	Generation=15/Individual=1
241	0.1391	0.1063	0.2953	0.3719	0.4734	-21.797	100	126.25	159.22	190.63	0.8078	1.32031	0.25859	0.38896	0.64541	Generation=16/Individual=0
242	0.1461	0.1594	0.2531	0.3375	0.4742	-19.766	91.875	123.91	157.34	187.5	0.8	0.52344	0.20171	0.49076	0.31607	Generation=16/Individual=1
243	0.1391	0.1063	0.293	0.375	0.4664	-19.766	102.5	125.31	142.81	185.63	0.9094	1.10938	0.28655	0.55258	0.59363	Generation=16/Individual=2
244	0.1789	0.0625	0.2953	0.3719	0.4734	-11.641	96.875	128.13	152.66	190.63	0.8078	1.32031	0.25658	0.41909	0.60723	Generation=16/Individual=3
245	0.1391	0.1063	0.2977	0.3844	0.4617	-17.734	106.25	128.59	150.31	188.44	0.8	1.20313	0.27333	0.42456	0.66878	Generation=16/Individual=4
246	0.1438	0.1063	0.2602	0.3625	0.4719	-19.766	102.5	125.78	151.25	185.63	0.8391	0.94531	0.2719	0.47263	0.61498	Generation=16/Individual=5
247	0.1789	0.1094	0.2625	0.3594	0.4742	-26.875	92.5	124.38	143.28	187.19	0.8391	0.99219	0.27808	0.49161	0.62072	Generation=16/Individual=6
248	0.1461	0.1156	0.225	0.3719	0.4719	-18.75	106.88	126.72	152.19	190.63	0.8	1.34375	0.28005	0.4917	0.62849	Generation=16/Individual=7
249	0.1461	0.1125	0.2648	0.2844	0.4625	-17.734	106.25	116.88	158.28	187.19	0.8625	0.89844	0.16785	0.4886	0.1828	Generation=16/Individual=8
250	0.1391	0.1156	0.225	0.3625	0.4688	9.6875	106.25	128.13	158.28	192.81	0.8469	1.32031	0.27082	0.61246	0.47082	Generation=16/Individual=9
251	0.1719	0.0906	0.225	0.3344	0.4633	-18.75	101.25	130	151.25	186.56	0.8391	1.15625	0.28641	0.54408	0.60156	Generation=16/Individual=1
252	0.1719	0.0906	0.225	0.3844	0.4625	-18.75	106.25	128.13	151.25	186.88	0.8781	0.94531	0.29551	0.61061	0.57144	Generation=16/Individual=1
253	0.1695	0.0906	0.225	0.3625	0.4742	-14.688	106.88	126.72	147.97	183.13	0.9016	1.41406	0.2955	0.64524	0.53676	Generation=16/Individual=1
254	0.1813	0.1156	0.232	0.3813	0.4625	-18.75	106.25	128.13	151.25	186.56	0.8156	1.41406	0.28883	0.50491	0.65039	Generation=16/Individual=1
255	0.1555	0.1688	0.1898	0.3406	0.4969	-11.641	105.63	128.13	150.31	189.06	0.9406	1.41406	0.22314	0.72764	0.16494	Generation=16/Individual=1
256	0.1789	0.1156	0.2063	0.3625	0.4805	-20.781	101.88	135.63	168.59	177.81	0.8391	0.94531	0.23428	0.64694	0.29017	Generation=16/Individual=1
257	0.1766	0.1156	0.2227	0.375	0.4805	-18.75	106.25	128.13	150.31	189.06	1.1516	0.85156	0.29643	0.99848	0.18722	Generation=17/Individual=0
258	0.1555	0.1688	0.2578	0.3406	0.4523	14.766	77.5	131.41	168.59	177.81	0.8234	1.41406	0.20789	0.60137	0.23018	Generation=17/Individual=1
259	0.1813	0.1063	0.225	0.3625	0.4742	-18.75	108.13	130	151.25	185.63	0.9016	1.41406	0.30367	0.63054	0.58413	Generation=17/Individual=2
260	0.1719	0.1156	0.225	0.3625	0.4742	-15.703	106.88	126.72	147.97	186.56	0.9016	1.41406	0.30049	0.62373	0.57823	Generation=17/Individual=3
261	0.1672	0.0906	0.225	0.3844	0.4625	-18.75	73.125	128.13	151.25	183.13	0.8781	0.94531	0.27533	0.58978	0.51153	Generation=17/Individual=4
262	0.1719	0.0563	0.225	0.3625	0.4633	-18.75	106.25	143.13	151.25	186.88	0.8391	1.15625	0.29083	0.59392	0.5694	Generation=17/Individual=5
263	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	106.25	128.13	150.78	186.88	0.8469	1.32031	0.29424	0.54902	0.62795	Generation=17/Individual=6
264	0.1789	0.1156	0.225	0.3625	0.4719	-18.75	95.625	129.53	151.25	186.88	0.8156	1.41406	0.27634	0.5141	0.59124	Generation=17/Individual=7
265	0.1461	0.1094	0.2602	0.3625	0.4742	-19.766	98.125	123.44	157.34	189.06	0.8	1.34375	0.26693	0.43121	0.63649	Generation=17/Individual=8
266	0.1461	0.1313	0.225	0.3719	0.4719	-18.75	106.88	126.25	143.28	187.5	0.8391	0.99219	0	0	-3E+41	Generation=17/Individual=9
267	0.1086	0.1063	0.2977	0.3844	0.4617	-17.734	93.125	128.59	151.25	185.63	0.8391	1.15625	0.26824	0.46357	0.6094	Generation=17/Individual=1
268	0.132	0.1063	0.2953	0.3844	0.4617	-18.75	106.25	123.91	151.25	188.44	0.8	1.20313	0.25702	0.37724	0.65085	Generation=17/Individual=1
269	0.1391	0.1063	0.2953	0.3719	0.4734	-21.797	96.25	128.13	149.38	190.63	0.8078	1.32031	0.27239	0.43196	0.65761	Generation=17/Individual=1
270	0.1836	0.1031	0.2953	0.3469	0.4734	-15.703	100	126.25	159.22	190.63	0.8078	1.32031	0.25204	0.43178	0.57638	Generation=17/Individual=1
271	0.1461	0.2375	0.2602	0.3469	0.4734	-16.719	104.38	126.25	159.22	187.5	0.8	1.20313	0.20121	0.49726	0.30758	Generation=17/Individual=1
272	0.1391	0.1063	0.2953	0.3625	0.4742	-19.766	96.875	123.91	149.38	190.63	1.0344	1.32031	0.26882	0.62464	0.45065	Generation=17/Individual=1
273	0.1391	0.1063	0.2273	0.35	0.4547	-17.734	102.5	126.25	143.28	187.5	0.8391	0.99219	0.28291	0.52247	0.60915	Generation=18/Individual=0
274	0.1461	0.1313	0.225	0.3719	0.4719	-18.75	105	126.25	159.22	187.5	0.8	1.17969	0.27064	0.48069	0.60186	Generation=18/Individual=1
275	0.1391	0.1063	0.2953	0.3719	0.4633	-22.813	100	126.25	159.22	190.94	0.8	1.20313	0.2432	0.41307	0.55975	Generation=18/Individual=2
276	0.1297	0.1063	0.2648	0.3844	0.4617	-18.75	106.25	135.63	151.25	188.13	0.8078	1.32031	0.27926	0.51647	0.60058	Generation=18/Individual=3
277	0.1391	0.1156	0.2813	0.3844	0.4617	-16.719	106.25	128.59	150.31	188.44	0.8078	1.25	0.28332	0.4608	0.67246	Generation=18/Individual=4
278	0.1391	0.1063	0.2953	0.3719	0.4734	-18.75	104.38	128.13	141.88	190.63	0.8	1.27344	0.28009	0.43803	0.68232	Generation=18/Individual=5
279	0.1391	0.1094	0.2977	0.3844	0.4609	-18.75	106.25	128.13	152.66	185.63	0.8391	1.15625	0.27397	0.47374	0.62215	Generation=18/Individual=6
280	0.1391	0.1063	0.2602	0.3594	0.4742	-19.766	96.875	135.63	151.25	182.19	0.8391	0.99219	0.27198	0.53518	0.55272	Generation=18/Individual=7
281	0.1789	0.1094	0.232	0.3156	0.4625	-18.75	105.63	128.13	151.25	185.63	0.8	1.34375	0.26998	0.49117	0.58875	Generation=18/Individual=8
282	0.1461	0.1156	0.2227	0.3719	0.4648	-18.75	106.88	126.72	152.19	191.56	0.8156	1.41406	0.28135	0.51446	0.61095	Generation=18/Individual=9
283	0.1719	0.0563	0.225	0.4344	0.4641	-19.766	106.25	130	147.5	186.88	0.8469	1.32031	0.29103	0.62866	0.53547	Generation=18/Individual=1
284	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	108.13	128.13	151.25	186.56	0.8781	1.15625	0.29918	0.58846	0.60826	Generation=18/Individual=1
285	0.1977	0.1094	0.2977	0.3594	0.45	-2.5	107.5	126.72	147.97	186.56	1.1906	1.41406	0.22139	1.01159	-0.12602	Generation=18/Individual=1
286	0.1742	0.1156	0.225	0.3625	0.4742	-15.703	106.25	130	151.25	184.06	0.9016	1.39063	0.29331	0.63364	0.53961	Generation=18/Individual=1
287	0.1484	0.1688	0.1898	0.3375	0.45	-15.703	86.25	128.13	150.31	189.06	0.9484	1.41406	0.1704	0.87709	-0.1955	Generation=18/Individual=1
288	0.1789	0.1156	0.2227	0.3719	0.4781	14.766	101.88	135.63	168.59	177.81	0.8391	0.94531	0.21606	0.67239	0.19186	Generation=18/Individual=1
289	0.1789	0.0656	0.1898	0.3563	0.4523	11.719	101.88	135.63	163.44	191.88	0.8469	0.96875	0.261147	0.77788	0.2667	Generation=19/Individual=0
290	0.1555	0.2156	0.2227	0.3719	0.4805	-18.75	106.88	128.13	150.78	189.06	0.9406	1.50781	0.1962	0.70147	0.08331	Generation=19/Individual=1
291	0.1719	0.1156	0.225	0.4344	0.4742	-15.703	106.88	126.25	151.25	185.63	0.8938	1.25	0.28749	0.67473	0.47523	Generation=19/Individual=2
292	0.1813	0.1063	0.225	0.3625	0.4742	-18.75	108.13	130.47	154.06	188.13	0.9094	1.41406	0.30607	0.64454	0.57975	Generation=19/Individual=3
293	0.1789	0.1906	0.225	0.325	0.4633	-18.75	106.25	130	151.72	186.56	0.8781	0.94531	0.21269	0.64405	0.20669	Generation=19/Individual=4
294	0.1742	0.0813	0.232	0.3125	0.4625	-18.75	108.13	128.13	151.25	186.56	0.9641	1.22656	0.28283	0.69699	0.43431	Generation=19/Individual=5
295	0.1813	0.1156	0.232	0.3844	0.4625	-18.75	106.25	128.13	151.25	186.56	1.2766	1.32031	0.26647	1.27685	-0.21098	Generation=19/Individual=6
296	0.0688	0.1813	0.232	0.3813	0.4625	-18.75	106.25	128.13	150.78	186.88	0.8391	1.41406	0.23398	0.53776	0.39817	Generation=19/Individual=7
297	0.1391	0.1406	0.2953	0.3625	0.4617	-16.719	93.125	128.59	150.31	188.44	0.8078	1.25	0.26044	0.43665	0.6051	Generation=19/Individual=8
298	0.1391	0.1813	0.2813	0.375	0.4758	-18.75	104.38	128.13	141.88	190.63	0.8	1.29688	0.25438	0.4511	0.56644	Generation=19/Individual=9
299	0.1391	0.1063	0.2953	0.3719	0.4734	-18.75	96.875	128.13	150.31	188.44	0.9172	1.20313	0.28666	0.55316	0.59349	Generation=19/Individual=1
300	0.1414	0.1063	0.2625	0.3844	0.4617	-17.734	106.25	128.59	152.66	184.06	0.8547	1.32031	0.29256	0.53815	0.63208	Generation=19/Individual=1
301	0.132	0.1156	0.2273	0.3844	0.4617	-18.75	106.25	123.91	151.25	190.63	0.8078	1.32031	0.27896	0.4914	0.62445	Generation=19/Individual=1
302	0.1391	0.1906	0.2953	0.375	0.4734	-21.797	104.38	126.25	159.22	188.44	0.8078	1.20313	0.2556	0.42457	0.59783	Generation=19/Individual=1
303	0.1461	0.1313	0.225	0.3531	0.4719	-18.75	106.88	126.25	143.28	187.5	0.8	1.20313	0.26984	0.47162	0.60775	Generation=19/Individual=1
304	0.1391	0.1063	0.2953	0.3719	0.4859	-16.719	104.38	126.25	159.22	187.5	0.8156	0.99219	0.24437	0.39109	0.58641	Generation=19/Individual=1
305	0.1391	0.1406	0.2953	0.3719	0.4734	-16.719	104.38	127.66	159.22	189.69	0.8156	0.99219	0.25664	0.43334	0.59321	Generation=20/Individual=0
306	0.1016	0.1313	0.232	0.3719	0.4742	-18.75	92.5	126.25	143.75	187.5	0.8547	1.20313	0.25687	0.54807	0.47939	Generation=20/Individual=1
307	0.1367	0.1063	0.2273	0.425	0.4719	-18.75	106.25	122.5	151.25	188.44	0.8	1.20313	0.27528	0.50202	0.59912	Generation=20/Individual=2
308	0.132	0.1063	0.2953	0.3844	0.4508	-21.797	100	118.28	159.22	190.63	0.8078	1.29688	0.22751	0.38327	0.52676	Generation=20/Individual=3
309	0.1391	0.1063	0.2273	0.3719	0.4734	-18.75	104.38	128.13	141.88	179.06	1.05	1.60156	0	0	-3E+41	Generation=20/Individual=4
310	0.1391	0.0906	0.1523	0.3719	0.4734	-18.75	95	123.91	152.66	190.63	1.2844	1.29688	0.2969	1.26738	-0.0798	Generation=20/Individual=5
311	0.1883	0.1156	0.2344	0.3781	0.4625	-19.766	106.25	131.41	150.78	181.25	0.8078	1.25	0.27834	0.51219	0.60118	Generation=20/Individual=6

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
312	0.1273	0.1156	0.2813	0.3844	0.4617	-16.719	106.25	128.59	154.53	186.25	0.8156	1.83594	0.2821	0.46797	0.66045	Generation=20/Individual=
313	0.0688	0.1156	0.232	0.3813	0.4625	-18.75	106.25	128.59	152.66	184.06	0.8547	1.90625	0.28656	0.55145	0.5948	Generation=20/Individual=
314	0.1414	0.1094	0.2695	0.3844	0.4617	-17.734	106.25	128.13	150.78	186.88	0.8469	1.15625	0.289119	0.51701	0.63947	Generation=20/Individual=
315	0.1508	0.1156	0.225	0.3625	0.4742	-15.703	106.88	117.81	147.5	186.25	0.8781	1.15625	0.27345	0.52752	0.56629	Generation=20/Individual=
316	0.1719	0.1156	0.232	0.3813	0.4617	-18.75	108.13	128.13	151.72	176.56	0.9016	1.41406	0.29684	0.62958	0.55777	Generation=20/Individual=
317	0.1813	0.1063	0.225	0.3625	0.4742	-18.75	108.13	130.47	151.25	184.06	0.9016	1.41406	0.3012	0.63318	0.57163	Generation=20/Individual=
318	0.1977	0.1063	0.225	0.3625	0.4742	-18.75	101.88	130	154.06	188.13	0.9094	1.41406	0.30138	0.64094	0.56459	Generation=20/Individual=
319	0.1555	0.1688	0.1898	0.2563	0.4523	14.766	101.88	138.91	150.31	189.06	1.0734	1.41406	0.16919	1.10038	-0.42364	Generation=20/Individual=
320	0.1789	0.1313	0.2227	0.3719	0.4805	-19.766	106.25	128.13	168.59	177.81	0.8391	0.94531	0.236711	0.59266	0.35418	Generation=20/Individual=
321	0.1813	0.1156	0.2227	0.3719	0.4805	-18.75	103.13	128.13	141.88	194.06	1.05	1.60156	0.30259	0.83408	0.37626	Generation=21/Individual=
322	0.1391	0.1156	0.2273	0.3625	0.4734	-18.75	104.38	128.13	149.84	189.06	0.9484	1.4375	0.30247	0.68339	0.5265	Generation=21/Individual=
323	0.1836	0.1063	0.225	0.3656	0.4742	-18.75	106.25	130	151.25	181.56	0.9094	1.8125	0.30285	0.64385	0.56756	Generation=21/Individual=
324	0.1813	0.1063	0.225	0.3625	0.4742	-18.75	108.13	129.06	154.06	184.06	0.9016	1.41406	0.30076	0.63165	0.57139	Generation=21/Individual=
325	0.1789	0.1313	0.232	0.3813	0.4625	-3.5156	108.13	128.13	151.25	186.56	0.8781	1.41406	0.29323	0.61482	0.5581	Generation=21/Individual=
326	0.1719	0.1156	0.225	0.3625	0.4742	-18.75	106.88	129.06	148.44	176.56	0.9016	1.15625	0.27851	0.64841	0.46564	Generation=21/Individual=
327	0.1813	0.1063	0.2789	0.3844	0.4617	-4.5313	106.25	129.06	151.25	186.88	0.8469	1.32031	0.28249	0.55902	0.57092	Generation=21/Individual=
328	0.1789	0.1813	0.232	0.3125	0.4867	12.734	106.25	128.13	149.38	184.06	0.8	1.71875	0.24056	0.56143	0.40082	Generation=21/Individual=
329	0.1789	0.1156	0.232	0.3844	0.45	-17.734	106.88	128.13	150.78	186.88	0.8469	1.0625	0.29087	0.55855	0.60494	Generation=21/Individual=
330	0.1414	0.1125	0.2695	0.3906	0.4742	-18.75	106.25	128.13	151.25	182.81	0.8156	1.41406	0.27928	0.49954	0.61756	Generation=21/Individual=
331	0.1391	0.1063	0.293	0.3625	0.4617	-16.719	106.25	128.59	150.31	188.44	0.8078	1.25	0.25933	0.44038	0.59693	Generation=21/Individual=
332	0.1273	0.1813	0.2813	0.375	0.4633	-18.75	104.38	128.13	141.88	190.63	0.8	1.39063	0.255	0.47212	0.5479	Generation=21/Individual=
333	0.1391	0.1063	0.2953	0.3688	0.4734	-21.797	104.38	127.66	152.66	190.63	0.9094	1.32031	0.27823	0.55082	0.56209	Generation=21/Individual=
334	0.1391	0.1063	0.2648	0.3719	0.4734	-18.75	96.875	129.53	159.22	189.06	0.8	1.32031	0.27102	0.45159	0.63251	Generation=21/Individual=
335	0.1461	0.1313	0.225	0.375	0.4719	-16.719	104.38	126.25	159.22	187.5	0.8	1.20313	0.27065	0.48243	0.60016	Generation=21/Individual=
336	0.1391	0.1063	0.2953	0.3719	0.4734	-18.75	106.88	126.25	143.28	187.81	0.8391	0.99219	0.27	0.4617	0.6183	Generation=21/Individual=
337	0.1836	0.1063	0.2953	0.3719	0.4734	-13.672	104.38	126.25	159.22	187.5	0.8156	0.99219	0.25392	0.42426	0.59143	Generation=22/Individual=
338	0.1391	0.1313	0.225	0.3719	0.4719	-15.703	106.88	126.25	140	187.5	0.8234	1.20313	0.26028	0.50588	0.53523	Generation=22/Individual=
339	0.1391	0.1063	0.2977	0.325	0.4742	-18.75	96.875	126.25	159.22	190.63	0.8078	1.32031	0.22285	0.39942	0.49197	Generation=22/Individual=
340	0.1391	0.1406	0.2953	0.3719	0.4734	-21.797	100	127.66	152.66	190.63	0.8078	1.53125	0.26587	0.44796	0.61554	Generation=22/Individual=
341	0.1391	0.1156	0.2414	0.3125	0.4617	-16.719	106.25	128.59	141.88	190.63	0.8	1.27344	0.27225	0.48022	0.60876	Generation=22/Individual=
342	0.1391	0.0906	0.2953	0.3719	0.4734	-15.703	104.38	127.66	150.31	188.75	0.8078	1.25	0.26393	0.4178	0.63794	Generation=22/Individual=
343	0.1414	0.1063	0.232	0.3813	0.4625	-15.703	106.25	128.13	151.72	193.13	0.8156	1.41406	0.28232	0.55281	0.57647	Generation=22/Individual=
344	0.1813	0.1125	0.2695	0.3844	0.45	-20.781	106.25	116.41	150.78	186.56	0.8469	1.13281	0.24811	0.42901	0.56342	Generation=22/Individual=
345	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	106.25	128.13	150.78	186.88	0.8469	1.34375	0.29473	0.55073	0.6282	Generation=22/Individual=
346	0.1063	0.1063	0.2625	0.3813	0.4617	-4.5313	106.25	128.59	152.66	184.06	0.8469	1.90625	0.28131	0.52691	0.59833	Generation=22/Individual=
347	0.1719	0.1156	0.225	0.3625	0.4742	-15.703	106.88	127.66	151.25	188.13	0.8781	1.15625	0.2934	0.58858	0.58503	Generation=22/Individual=
348	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	108.13	129.06	150.31	186.56	0.9016	1.41406	0.30662	0.63625	0.59024	Generation=22/Individual=
349	0.1813	0.1063	0.225	0.3625	0.4742	-18.75	108.13	136.56	154.06	189.06	0.9094	1.41406	0.2993	0.6708	0.5264	Generation=22/Individual=
350	0.1813	0.1125	0.225	0.425	0.4742	-18.75	108.13	130	151.25	186.56	0.9094	1.0625	0.2887	0.68465	0.47017	Generation=22/Individual=
351	0.1391	0.1063	0.2953	0.35	0.4734	-18.75	103.13	128.13	149.38	189.06	0.9484	1.0625	0.27779	0.58618	0.52497	Generation=22/Individual=
352	0.1789	0.0813	0.2227	0.3719	0.4805	-18.75	76.875	128.59	141.88	175.63	1.1672	1.60156	0.27732	1.110114	-0.00085	Generation=22/Individual=
353	0.1789	0.1156	0.1523	0.3719	0.4805	-18.75	106.25	127.66	150.31	180.63	0.9484	1.78906	0.27282	0.75311	0.33819	Generation=23/Individual=
354	0.1391	0.1063	0.2273	0.325	0.4742	-18.75	104.38	128.13	141.88	179.06	1.05	1.41406	0.30071	0.84587	0.35696	Generation=23/Individual=
355	0.1719	0.1156	0.225	0.35	0.4625	-18.75	108.13	129.06	150.31	186.56	0.9016	1.97656	0.31263	0.62308	0.62746	Generation=23/Individual=
356	0.1789	0.1156	0.232	0.3813	0.45	-15.703	92.5	126.72	147.97	193.13	0.8781	1.41406	0.26448	0.66685	0.39108	Generation=23/Individual=
357	0.1438	0.1156	0.2344	0.3813	0.4625	-17.734	106.25	128.59	149.38	185	0.8469	1.32031	0.28801	0.54484	0.6072	Generation=23/Individual=
358	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	108.13	128.13	151.25	188.13	0.8703	1.03906	0.29728	0.58043	0.60869	Generation=23/Individual=
359	0.1414	0.1	0.2695	0.3844	0.4617	-17.734	106.25	128.13	150.78	186.25	1.2375	1.90625	0.2605	1.16886	-0.12686	Generation=23/Individual=
360	0.1414	0.1063	0.2625	0.3625	0.4617	-17.734	106.25	128.59	152.66	184.06	0.8469	0.57031	0.24799	0.49845	0.4935	Generation=23/Individual=
361	0.1391	0.1188	0.2813	0.3813	0.4625	-18.75	106.25	128.13	151.25	186.56	0.8156	1.41406	0.28262	0.4689	0.66159	Generation=23/Individual=
362	0.1883	0.1156	0.2344	0.3844	0.4609	-16.719	103.13	115.94	150.31	188.44	0.8078	1.29688	0.26845	0.44061	0.63318	Generation=23/Individual=
363	0.1391	0.1063	0.2836	0.3625	0.4758	-18.75	92.5	128.13	141.88	190.63	0.8	1.27344	0.27204	0.4406	0.64757	Generation=23/Individual=
364	0.1391	0.1063	0.2953	0.3719	0.4734	-18.75	104.38	131.41	152.66	190.63	0.8	1.32031	0.26714	0.45735	0.61123	Generation=23/Individual=
365	0.1391	0.1063	0.2953	0.3719	0.4734	-24.844	100	126.25	159.69	193.75	0.8078	1.25	0.24439	0.42361	0.55395	Generation=23/Individual=
366	0.1391	0.0906	0.2953	0.3875	0.4508	-15.703	104.38	127.66	150.31	189.06	0.8	1.32031	0.26675	0.42708	0.63994	Generation=23/Individual=
367	0.1461	0.1313	0.225	0.3719	0.4523	-18.75	106.88	126.25	140	189.69	0.8469	1.01563	0.265	0.55165	0.50835	Generation=23/Individual=
368	0.1391	0.1063	0.2953	0.3719	0.4734	-16.719	104.38	126.25	159.22	187.5	0.8	1.20313	0.24894	0.36887	0.62691	Generation=23/Individual=
369	0.1391	0.1094	0.2953	0.3719	0.4734	-16.719	104.38	126.25	159.22	186.25	0.8156	0.99219	0.24614	0.37774	0.60681	Generation=24/Individual=
370	0.1461	0.1313	0.225	0.3719	0.4719	-11.641	106.88	126.25	143.28	191.88	0.8547	1.22656	0.27998	0.56096	0.55897	Generation=24/Individual=
371	0.1391	0.1063	0.2953	0.3719	0.4734	-21.797	79.375	126.25	159.22	190.63	0.8078	1.20313	0.25086	0.40313	0.60032	Generation=24/Individual=
372	0.1391	0.1063	0.2953	0.3719	0.4734	-5.5469	104.38	126.25	159.22	187.5	0.8	1.32031	0.24058	0.38085	0.58148	Generation=24/Individual=
373	0.1391	0.1031	0.2648	0.3719	0.4734	12.734	95	127.66	150.31	188.75	0.8078	1.27344	0.25852	0.49419	0.5399	Generation=24/Individual=
374	0.1391	0.0906	0.2953	0.325	0.4734	-15.703	102.5	127.66	152.66	190.63	0.8078	1.32031	0.24237	0.39766	0.57183	Generation=24/Individual=
375	0.1391	0.0813	0.2813	0.3844	0.4617	-16.719	106.25	128.59	141.88	190.31	0.8	1.27344	0.27983	0.49557	0.62375	Generation=24/Individual=
376	0.1391	0.1063	0.293	0.325	0.4734	-18.75	104.38	128.13	150.31	188.44	0.8078	1.25	0.24392	0.41108	0.56461	Generation=24/Individual=
377	0.1414	0.1	0.2695	0.3625	0.4617	-18.75	106.25	128.13	151.25	192.81	0.8156	1.03906	0.26381	0.45164	0.60358	Generation=24/Individual=
378	0.1789	0.1156	0.2977	0.3813	0.4617	-17.734	106.25	128.13	150.78	186.88	0.8469	0.94531	0.27538	0.48335	0.61816	Generation=24/Individual=
379	0.0688	0.1156	0.2344	0.4156	0.4625	-18.75	105.63	128.13	151.25	186.56	0.8547	1.32031	0.27047	0.60021	0.48166	Generation=24/Individual=
380	0.1344	0.1063	0.2625	0.3844	0.4563	-17.734	106.25	128.59	152.66	184.38	0.8078	1.34375	0.28315	0.47536	0.65722	Generation=24/Individual=
381	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	101.88	127.66	151.25	186.25	0.8781	1.03906	0.29161	0.58398	0.58244	Generation=24/Individual=
382	0.1789	0.1156	0.232	0.3813	0.4625	-18.75	108.13	116.41	154.53	188.13	0.8703	1.15625	0.2666	0.49935	0.56704	Generation=24/Individual=
383	0.1391	0.1063	0.2273	0.3719	0.4734	-17.734	105	128.13	141.88	179.06	0.9016	1.25	0.27408	0.60817	0.48813	Generation=24/Individual=
384	0.1719	0.1156	0.225	0.35	0.4625	-18.75	91.25	129.06	150.31	186.56	1.05	1.60156	0.28496	0.83863	0.30122	Generation=24/Individual=
385	0.1719	0.1156	0.225	0.3969	0.4633	-15.703	104.38	129.53	141.88	190.63	1.0578	1.60156	0	0	-3E+41	Generation=25/Individual=
386	0.1391	0.1031	0.2578	0.3719	0.4742	-18.75	108.13	129.06	150.31	183.13	0.9016	1.8125	0.30183	0.61527	0.59203	Generation=25/Individual=
387	0.1789	0.1156	0.2297	0.3813	0.4648	-18.75	108.13	128.59	151.25	187.81	0.8781	0.57031	0.2648	0.58569	0.47351	Generation=25/Individual=
388	0.1789	0.1156	0.2906	0.3813	0.4625	-3.5156	101.25	128.13	151.25	186.56	0.8703	1.4375	0	0	-3E+41	Generation=25/Individual=

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif	Obj. Penalty	TechniqueData
389	0.1414	0.0906	0.2625	0.3625	0.4617	-17.734	106.25	128.59	143.28	186.88	0.9953	1.50781	0.30283	0.73321	0.47811	Generation=25/Individual=
390	0.1789	0.0813	0.157	0.3813	0.4617	-18.75	105.63	128.13	150.78	184.06	0.8547	1.32031	0.2966	0.59926	0.58713	Generation=25/Individual=
391	0.1813	0.1156	0.232	0.3781	0.4625	-18.75	106.25	128.13	151.25	186.56	0.8078	1.15625	0.28247	0.49553	0.63436	Generation=25/Individual=
392	0.1063	0.1125	0.2695	0.3844	0.4617	-20.781	106.25	128.13	147.5	188.13	0.8391	1.34375	0.28105	0.50899	0.61522	Generation=25/Individual=
393	0.1414	0.1063	0.2953	0.3844	0.4617	10.703	106.25	128.13	150.31	188.44	0.8078	1.25	0.24378	0.45975	0.51537	Generation=25/Individual=
394	0.1391	0.1156	0.2813	0.425	0.4633	-18.75	104.38	128.13	141.88	190.63	0.8	1.57813	0.2674	0.51057	0.55902	Generation=25/Individual=
395	0.1836	0.0906	0.2953	0.3719	0.4734	-15.703	104.38	127.66	150.78	190.63	0.8469	1.15625	0.27001	0.48985	0.5902	Generation=25/Individual=
396	0.1391	0.1063	0.2953	0.3719	0.4727	-18.75	92.5	128.13	152.19	188.75	0.8078	1.25	0.2664	0.42607	0.63955	Generation=25/Individual=
397	0.1391	0.1406	0.2953	0.3719	0.4734	-16.719	100	126.25	159.22	190.63	0.8078	1.27344	0	0	-3E+41	Generation=25/Individual=
398	0.1391	0.1063	0.2953	0.3719	0.4734	-21.797	77.5	125.78	159.22	190.63	0.8078	1.15625	0.25014	0.40034	0.60021	Generation=25/Individual=
399	0.1461	0.1344	0.2836	0.3719	0.4734	-16.719	75	126.25	158.75	187.5	0.8	1.20313	0.24825	0.40679	0.58622	Generation=25/Individual=
400	0.1391	0.1063	0.225	0.325	0.4523	-18.75	106.88	129.53	166.25	187.5	0.8391	0.99219	0.24075	0.54262	0.42037	Generation=25/Individual=

Third optimization process

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
1	0.1719	0.1156	0.225	0.35	0.4625	-18.75	108.13	129.06	150.31	186.56	0.9015	1.976	0.31253322	0.6224773
2	0.2209622	0.2309227	0.2179869	0.3870544	0.4949038	-18.41602	93.63003	140.3121	168.7964	179.5186	1.2397954	1.2079341	-0.0325691	1.658812
3	0.1532999	0.1482871	0.2285769	0.3688158	0.466236	11.621294	109.1908	127.0642	160.8213	183.394	0.8670403	1.0734441	0.26268411	0.5917317
4	0.2411476	0.1847831	0.1566558	0.4294643	0.4886458	1.6544655	89.17617	136.412	151.4739	183.894	0.9461672	1.5595674	0.13913071	0.8939745
5	0.0650992	0.2426732	0.2552855	0.4301745	0.4474558	17.117819	100.1046	134.9524	153.1729	184.2419	1.0778319	0.7482201	0.05589483	1.0052812
6	0.0674669	0.1173056	0.1886077	0.3968241	0.476516	-17.22138	97.8693	115.26	168.729	192.3603	1.2553476	0.8219889	0.15190856	1.1306758
7	0.0885864	0.1577404	0.2609671	0.3996635	0.4822941	22.535403	93.33724	142.7217	159.4454	192.895	1.1512002	1.846635	0.22845637	1.0184976
8	0.1197691	0.2209427	0.1784599	0.255929	0.4577488	7.1660876	118.0653	125.9543	167.8905	191.4737	1.2295934	0.7768842	-0.1514786	1.5066131
9	0.0965171	0.0525822	0.1665363	0.3080137	0.4150858	-27.19616	84.03673	132.6229	164.2199	194.9827	0.9682151	1.5528911	0.13882914	1.4609616
10	0.1162364	0.0725978	0.1643682	0.3691472	0.4188026	29.475485	91.24715	117.523	142.9934	193.6436	1.1140461	1.3464651	0.10147803	1.3146717
11	0.2383874	0.1950903	0.2448972	0.32172	0.4404384	14.780959	92.76382	134.4893	153.1843	182.4719	1.1580345	1.6517283	0.14197489	1.2322163
12	0.1893157	0.2215543	0.2249993	0.3349852	0.4682193	12.434662	117.8531	133.6922	148.8306	187.1145	1.14897	0.9254838	0.10508578	1.084223
13	0.1483484	0.0500889	0.186904	0.4328328	0.4083534	-20.18591	105.9475	138.2479	146.1297	186.3189	0.8772277	0.99468	0.21070247	0.878114
14	0.2073918	0.11153525	0.2688959	0.2919672	0.4910484	-23.82597	92.84585	124.765	140.1198	178.0739	1.0107074	0.6587359	0.20129751	0.7842009
15	0.1664013	0.1313706	0.2620769	0.3488423	0.4102764	-14.23711	102.5722	123.8448	144.0686	194.8779	1.1169794	1.4652312	0.11419611	1.304212
16	0.2167438	0.2128918	0.2424115	0.4121664	0.4597462	-10.37878	94.94388	134.9402	146.7624	185.1981	0.933217	1.9909734	0.17315943	0.7821784
17	0.0605626	0.116385	0.2928787	0.34815	0.4922133	29.422035	98.01522	133.0229	169.7692	190.9675	1.267041	0.7744388	0.16104098	1.0091791
18	0.1755574	0.1786088	0.2839788	0.2687329	0.4998879	-33.17804	113.2903	128.8221	161.9507	176.3468	0.9121568	1.5480783	0.17330469	0.7258227
19	0.1417898	0.0693959	0.2093573	0.4090096	0.4509181	-33.4042	78.77586	122.9683	143.8057	180.8302	0.8200791	1.2833159	0.2703859	0.5209573
20	0.1527412	0.2442634	0.2043847	0.338519	0.4923293	-4.587765	93.6261	124.1032	167.2053	193.3839	0.9779468	0.7809115	0.07742036	0.9636373
21	0.0674669	0.1173056	0.1869778	0.3968241	0.476516	-19.81307	97.69367	115.26	168.729	185.8577	0.9265349	0.8219889	0.23939641	0.6069987
22	0.1315271	0.0500889	0.188534	0.4328328	0.4083534	-17.59422	106.1231	138.2479	146.1297	192.8215	1.2060403	0.99468	0.16725738	1.6467403
23	0.1664013	0.0689347	0.2149174	0.3488423	0.4213146	-31.84957	83.26992	123.8448	143.8276	194.8779	0.8082492	1.4652312	0.18252771	0.7790646
24	0.1417898	0.1318318	0.2565168	0.4090096	0.4398799	-15.79174	100.7035	122.9683	142.9855	180.8302	1.1288094	1.2833159	0.26947318	0.9602532
25	0.1755574	0.1210402	0.2846924	0.2687329	0.4921261	-33.17804	113.2903	128.8221	162.8324	175.0208	0.9026594	1.5480783	0.15942084	0.6504629
26	0.0605626	0.1739536	0.2921651	0.34815	0.4999751	29.422035	98.01522	133.0229	168.8875	192.2508	1.2765384	0.7744388	0.1227664	1.0356476
27	0.1450763	0.1950903	0.2448972	0.3250158	0.4404384	-27.07538	77.72048	124.3538	153.1843	182.4719	0.9111043	1.6517283	0.18533703	0.8021875
28	0.2351009	0.0693959	0.2062155	0.4057138	0.4509181	8.452136	93.81919	133.1037	143.8057	180.8302	1.0670093	1.2833159	0.26310452	1.0658525
29	0.1417898	0.0751397	0.2093573	0.4090096	0.4509181	-34.24941	75.41318	122.98	143.8057	180.8302	0.8200791	1.2833159	0.26801817	0.5199939
30	0.1664013	0.1256268	0.2620769	0.3488423	0.4102764	-13.39189	102.5722	124.1669	144.0686	194.8779	1.1169794	1.4652312	0.11517392	1.3039495
31	0.1399512	0.0653704	0.2099453	0.4090096	0.4438393	-33.4042	80.8425	122.6714	143.8057	181.3825	0.8200791	1.2979884	0.27272547	0.5282076
32	0.1737386	0.1196254	0.2244119	0.35	0.4695788	-18.75	106.0634	129.3569	150.31	186.0077	0.9015	1.9613275	0.30514943	0.6184083
33	0.0965171	0.0525822	0.1665363	0.3080137	0.4150858	-27.19616	84.03673	132.6229	164.2199	194.9827	0.9682151	1.5528911	0.13882914	1.4609616
34	0.0965171	0.0525822	0.1665363	0.3080137	0.4150858	-27.19616	86.19179	132.6229	164.2199	194.9688	0.9682151	1.5528911	0.13984768	1.4635228
35	0.0691767	0.0865916	0.1886077	0.3968241	0.476516	-33.20399	78.8806	115.26	144.3014	192.3603	0.8274784	0.8219889	0.25002404	0.4859148
36	0.1382059	0.1143368	0.2093573	0.4090096	0.4509181	-17.42159	97.76456	122.9683	168.2332	180.8302	1.2479482	1.2833159	0.26402133	1.1622348
37	0.1532999	0.0529243	0.2285769	0.3688158	0.40903	11.621294	105.5726	127.0642	147.347	183.394	0.8670403	1.0734441	0.20759448	0.7579553
38	0.1483484	0.1454516	0.1914358	0.4328328	0.4655594	-20.18591	108.182	138.2479	159.604	186.3189	0.8645104	0.99468	0.2169895	0.7058801
39	0.1719	0.1156	0.225	0.35	0.4625	-20.70027	91.3017	129.06	150.31	186.7401	0.9015	1.8405439	0.29465571	0.6224084
40	0.0885864	0.1577404	0.2609671	0.3996635	0.4822941	24.485677	110.1655	142.7217	159.4454	192.7148	1.1512002	1.9820911	0.26075615	1.0550041
41	0.0788234	0.11511173	0.1827559	0.3418625	0.4601836	-20.7167	91.3017	115.1524	150.31	186.0842	0.9163255	1.8405439	0.27953567	0.6197092
42	0.1605435	0.1177939	0.2292219	0.3966158	0.4785274	-19.79665	97.69367	129.1676	168.729	186.7415	0.9265349	0.8219889	0.26791503	0.6352881
43	0.0674669	0.0538402	0.189427	0.3968241	0.445364	-19.81307	97.69367	115.26	147.4556	182.1337	0.840188	0.822825	0.24875932	0.4980983
44	0.1399512	0.1288358	0.2074961	0.4090096	0.4749914	-33.30025	80.8425	122.6714	165.079	185.1064	0.9068534	1.2971523	0.23115408	0.6500657
45	0.0631885	0.1178041	0.1869778	0.3971825	0.4437508	-19.81307	97.82132	115.26	168.729	181.3479	0.9063829	0.8302646	0.23504571	0.5935011
46	0.1417898	0.1313333	0.2565168	0.4086513	0.4726452	-15.79174	100.5759	122.9683	142.9855	185.34	1.1489614	1.2750403	0.27702549	0.9810445
47	0.1468476	0.0693959	0.2062155	0.4057138	0.4509181	-29.43695	77.54893	133.1037	143.8057	180.8302	1.0670093	1.2833159	0.28929821	0.9193513
48	0.2300431	0.0693959	0.2093573	0.4090096	0.4509181	4.484888	95.04612	122.9683	143.8057	180.8302	0.8200791	1.2833159	0.25162576	0.5913266
49	0.1417898	0.0703036	0.2092836	0.4090096	0.4509181	-33.4042	78.75748	122.696	143.8057	180.7669	0.8200791	1.2833159	0.27056099	0.5195308
50	0.1399512	0.0653704	0.210019	0.4090096	0.4438393	-33.4042	80.86088	123.8567	143.8057	181.4457	0.8178662	1.3202191	0.27244183	0.5303187
51	0.1416991	0.0693959	0.2093573	0.4090096	0.4510772	-32.54632	83.39378	122.9683	142.5257	180.8302	0.8200791	1.2801654	0.27018314	0.5196897
52	0.1738293	0.1196254	0.2244119	0.35	0.4694198	-19.60788	101.4454	129.3569	150.3051	186.0077	0.9015	1.964478	0.29907297	0.6203282
53	0.0766824	0.1446538	0.1898574	0.3640993	0.4652644	11.621294	109.1908	115.7929	160.8213	183.394	0.8263898	1.0734441	0.24307133	0.4690777
54	0.1457942	0.0865916	0.2324848	0.4015406	0.4762205	-33.20399	78.8806	126.5312	144.3014	192.3603	0.8258619	0.8219889	0.25760499	0.519823

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
55	0.1382059	0.1143368	0.2085789	0.4090096	0.4509181	-18.70131	97.76456	122.7044	150.1352	180.8302	1.2479482	1.2833159	0	0
56	0.1737386	0.1196254	0.2251903	0.3318365	0.4695788	-17.47028	106.0634	129.6208	168.408	186.134	0.9015	1.9613275	0.25958467	0.6481582
57	0.1451198	0.0751397	0.2073762	0.4090096	0.4509265	-34.24941	77.26402	122.98	142.8659	181.1863	0.8274477	1.2833159	0.2690608	0.5315968
58	0.16857	0.1156	0.226981	0.35	0.4624916	-18.75	106.2792	129.06	151.2497	186.2039	0.8890834	1.976	0.30683612	0.6035422
59	0.1654449	0.0700004	0.2106326	0.4040922	0.451911	-19.43712	94.92265	133.1037	143.9038	181.5632	0.9038599	1.2833159	0.28970854	0.6776627
60	0.2387842	0.1177272	0.2244119	0.35	0.4685859	9.1392588	104.9599	129.3569	150.2119	185.2747	1.0646494	1.9613275	0.27963132	0.9658506
61	0.1719	0.1156	0.225	0.3403665	0.4635791	-20.07434	100.7287	123.0843	150.31	185.1724	0.925272	1.976	0.30308771	0.6227212
62	0.1417898	0.1313333	0.2565168	0.4182848	0.4715661	-14.4674	107.9772	128.944	142.9855	186.7276	1.1251894	1.2750403	0.28766558	0.9996891
63	0.1410561	0.1156	0.226981	0.3488646	0.4624916	-18.88601	100.5857	129.06	140.3293	186.2039	0.9035325	1.976	0.29297732	0.6146108
64	0.1693037	0.1313333	0.2565168	0.4097867	0.4726452	-19.23681	106.2693	122.9683	152.2786	185.34	1.1345123	1.2750403	0.29483937	0.9123544
65	0.1782557	0.1147926	0.2244119	0.35	0.469628	-18.91878	106.0634	129.3569	142.103	186.0077	0.9015	1.2876533	0.29561299	0.6159674
66	0.1417898	0.1329936	0.2565168	0.4086513	0.472596	-15.62295	100.5759	122.9683	151.1925	185.34	1.1489614	1.9487145	0.28671234	0.9544458
67	0.1302313	0.0693959	0.2070394	0.4090096	0.4495569	-32.54632	83.39378	122.8085	142.6332	180.8178	0.8259762	1.2801654	0.26971054	0.533805
68	0.1730562	0.1196254	0.2352454	0.35	0.4710991	-18.75	106.0634	129.5166	150.2026	185.3284	0.8956029	1.9613275	0.30303396	0.6037368
69	0.1654449	0.0740414	0.2159723	0.4040922	0.451911	-19.43712	94.92265	129.7845	144.493	181.5632	0.9016417	1.2833159	0.29704467	0.6596417
70	0.1738293	0.1155844	0.2234926	0.35	0.4694198	-19.60788	101.4454	132.6761	149.7159	186.0077	0.9037182	1.964478	0.29742224	0.6353064
71	0.1678137	0.1156	0.2074434	0.35	0.450398	-20.78463	91.35588	129.06	150.31	186.7401	0.9015	1.2912913	0.27823012	0.6531663
72	0.1719597	0.0700004	0.2281892	0.4040922	0.4589422	-19.35276	95.04117	133.1037	143.9038	181.5632	0.9038599	1.8325685	0.30099245	0.6695472
73	0.1592164	0.0751397	0.2029161	0.4090096	0.4509265	-34.24941	72.0161	122.98	143.204	181.1863	0.8246884	1.2833159	0.26971702	0.5257279
74	0.1748382	0.1196254	0.228872	0.35	0.4695788	-18.75	113.7503	129.3569	149.9719	186.2273	0.9112634	1.9613275	0.3141023	0.6433531
75	0.1430949	0.0751397	0.2119148	0.4090096	0.4509181	-34.24941	75.41318	122.8644	143.8057	181.021	0.8200791	1.2833159	0.26869454	0.5181723
76	0.1724335	0.1196254	0.2218544	0.35	0.4695788	-18.75	106.0634	129.4725	150.31	185.8169	0.9015	1.9613275	0.30370516	0.6212548
77	0.1468476	0.0693959	0.2062155	0.4057138	0.4509181	-29.43695	77.54893	133.1037	143.8057	180.8302	1.1064748	1.2833159	0.29071209	0.9798175
78	0.1468476	0.0693959	0.2062155	0.4057138	0.4509181	-29.43695	77.54893	133.1037	143.8057	180.8302	1.0670093	1.2833159	0.28929821	0.9193513
79	0.0873952	0.066549	0.210019	0.3119887	0.4438393	-33.4042	79.88645	115.3555	143.8057	181.4457	0.8178662	1.3618681	0.25026178	0.4484512
80	0.1313794	0.11393311	0.1827559	0.4388833	0.4601836	-20.7167	92.27613	123.6536	150.31	186.0842	0.9163255	1.7988949	0.269927	0.733677
81	0.171642	0.1156	0.225	0.35	0.4625	-20.70027	91.9544	129.06	150.31	186.032	0.9015	1.8405439	0.29347003	0.6212001
82	0.1739966	0.1196254	0.2244119	0.35	0.4695788	-18.75	105.4107	129.3569	150.31	186.7159	0.9015	1.9671713	0.30457129	0.6185487
83	0.1656864	0.0788463	0.2159723	0.4040922	0.451911	-19.43712	94.92265	129.7845	144.4678	181.3905	0.9014844	1.2685322	0.29280164	0.659377
84	0.172192	0.1175814	0.2218544	0.35	0.4695788	-18.75	106.0634	129.0341	150.3352	185.9896	0.9016572	1.9761112	0.30612416	0.6187697
85	0.1724335	0.1196254	0.2228963	0.35	0.4695788	-18.75	106.0634	129.4725	150.33	185.8169	0.8891419	1.9613275	0.30137914	0.6030656
86	0.16857	0.1156	0.2259391	0.35	0.4624916	-18.75	106.2792	129.06	151.2297	186.2039	0.9014415	1.976	0.3093358	0.617717
87	0.1719	0.1156	0.225	0.3403975	0.4583014	-19.99112	104.6386	123.0843	150.31	185.1889	0.9115098	1.9601204	0.30177289	0.6046159
88	0.1748382	0.1196254	0.228872	0.349969	0.4695788	-18.83321	113.7503	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31630398	0.6619067
89	0.1685761	0.1156	0.2280271	0.3490546	0.4598327	-18.75	106.2792	129.06	151.2497	184.7443	0.8890834	1.2686764	0.29548814	0.5989308
90	0.1692977	0.1313333	0.2554707	0.4107321	0.477506	-19.23681	106.2693	122.9683	152.2786	186.0957	1.1345123	1.9823639	0.29772804	0.9473258
91	0.1725717	0.1196254	0.2218544	0.35	0.4695832	-18.75	106.0634	129.4725	142.4373	185.8466	0.9015	1.2889609	0.29044489	0.6164294
92	0.1781175	0.1147926	0.2211251	0.35	0.4696236	-18.91878	106.0634	129.3569	149.9756	185.9781	0.9015	1.9600199	0.30732556	0.6209318
93	0.1762466	0.1144396	0.2244119	0.362841	0.4696217	-25.10642	106.0634	129.3569	141.8739	185.3317	0.8962737	1.3324352	0.28904809	0.6064826
94	0.1635604	0.1199785	0.2352454	0.35	0.4711054	-18.75	106.0634	129.5166	151.0518	186.0045	0.9008291	1.9165456	0.30277122	0.6105413
95	0.1786888	0.11558511	0.2236837	0.3404113	0.4619186	-19.60788	100.7089	122.7356	149.7159	185.0192	0.9037182	1.9650354	0.30105381	0.592898
96	0.1719	0.1155993	0.2248089	0.3499552	0.4710802	-20.07434	101.4653	133.0248	150.31	186.1609	0.925272	1.9754427	0.30189866	0.6628614
97	0.16857	0.1098328	0.2249863	0.35	0.4575829	-18.75	106.2792	129.06	150.3478	186.2039	0.889842	1.9746936	0.310813	0.6080333
98	0.1719	0.1156	0.2269947	0.35	0.4625003	-18.75	108.13	129.06	151.212	186.56	0.9007413	1.976	0.31196047	0.6221199
99	0.1737386	0.1196254	0.2244119	0.35	0.4695788	-21.06427	106.0634	129.3569	150.31	185.4101	0.9015	1.9613275	0.3038741	0.6195569
100	0.1700519	0.1196254	0.2352454	0.35	0.4710991	-18.75	106.0634	129.5166	150.2026	185.926	0.8956029	1.9613275	0.30376484	0.6032616
101	0.1690075	0.1098328	0.2197869	0.35	0.4550257	-18.75	106.2792	129.0985	150.3478	186.2039	0.889842	1.9745995	0.30980215	0.6088835
102	0.1744008	0.1196254	0.228872	0.349969	0.472136	-18.83321	113.7503	129.3183	149.9719	186.2109	0.9250256	1.9773012	0.31455283	0.6624863
103	0.1730562	0.1196254	0.2248545	0.35	0.4578178	-18.75	106.051	129.0631	150.2026	185.3799	0.8896352	1.9613275	0.30574365	0.6043718
104	0.16857	0.1098328	0.2353772	0.35	0.4726343	-18.75	106.2915	129.901	150.3478	186.1524	0.8958097	1.9746936	0.30709653	0.608413
105	0.1781175	0.1144227	0.2211077	0.35	0.4696236	-18.91878	106.3771	129.3569	149.9756	185.9781	0.9015	1.9600199	0.30756727	0.620719
106	0.1719	0.11597	0.2250174	0.35	0.4625	-18.75	108.5346	129.06	150.31	186.56	0.9015	1.976	0.31255338	0.6222195
107	0.1663113	0.1199785	0.2352454	0.35	0.4695653	-21.46912	106.0634	129.5166	149.4947	186.0045	0.9342102	1.9180592	0.31208927	0.6563286
108	0.1737386	0.11911833	0.2244119	0.35	0.471119	-18.34515	106.0634	129.3569	151.0686	185.4101	0.9015	1.9598139	0.30342592	0.6172643
109	0.1724335	0.1094435	0.2217331	0.35	0.4575745	-18.75	106.0634	128.9919	150.3071	185.8372	0.9015	1.9613275	0.31366845	0.6254642
110	0.16857	0.1200147	0.2251076	0.35	0.4695872	-18.75	106.2792	129.5406	150.3507	186.1836	0.889842	1.9746936	0.30170036	0.6041968
111	0.1722741	0.1196254	0.2219298	0.3499707	0.4695788	-18.75	106.4815	129.4725	149.9108	185.7891	0.8958479	1.9613275	0.30325903	0.6118118
112	0.1749976	0.1196254	0.2287967	0.3499982	0.4695788	-18.83321	113.3322	129.3569	150.3711	186.2387	0.9529726	1.9772071	0.31937433	0.7015675
113	0.1748382	0.1228434	0.2291718	0.3913579	0.4695788	-18.83321	113.7503	127.1726	149.9719	186.2109	0.9250256	1.9722393	0.31781474	0.6745099
114	0.1765844	0.1196254	0.228872	0.349969	0.4695788	-18.83321	112.8077	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31581838	0.6608119
115	0.1683843	0.110673	0.2250174	0.349969	0.4572445	-18.82906	113.7503	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31517502	0.6693505
116	0.1750239	0.1187853	0.2348835	0.35	0.4699172	-18.75415	106.2792	129.06	150.3478	186.2039	0.889842	1.9746936	0.30467414	0.5962821
117	0.1719	0.1156	0.225	0.35	0.4621768	-18.75	101.0818	124.3067	150.31	184.9642	0.903666	1.976	0.30359826	0.6003595
118	0.1719	0.1156	0.225	0.3403665	0.4639023	-20.07434	107.7769	127.8376	150.31	186.7682	0.923106	1.976	0.31310003	0.6476712
119	0.1715225	0.118597	0.2252262	0.3403975	0.4572894	-19.99112	104.6386	121.0947	149.8175	185.1889	0.9115098	1.9601204	0.30044033	0.5963395
120	0.1752156	0.120714	0.2286458	0.3402975	0.4705909	-18.75	113.7503	129.3569	151.9367	186.2273	0.9112634	1.9613275	0.30910587	0.6373724
121	0.1748382	0.1196254	0.2288026	0.3499982	0.4695788	-18.75	113.2673	129.3569	149.9719	186.2273	0.9161608	1.957868	0.31452443	0.6462108
122	0.1749976	0.1196254	0.2288661	0.3334943	0.4695788	-18.83321	113.8151	129.3569	150.3711	186.2387	0.9480752	1.9806667	0.31412438	0.6917752
123	0.1692963	0.109866	0.2252722	0.349969	0.4581772	-16.04559	113.7503	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31605663	0.6705193
124	0.1756724	0.1204324	0.2286172	0.349969	0.4695807	-18.83321	112.8077	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31652725	0.658426
125	0.1724335	0.109035	0.2217331	0.35	0.4582521	-18.83727	106.0634	128.9919	150.3071	185.8372	0.9357298	1.9613275	0.31766199	0.671183
126	0.1765844	0.120034	0.228872	0.349969	0.4689013	-18.74594	112.8077	129.3569	149.9719	186.2109	0.9245286	1.9772071	0.31580289	0.6564416
127	0.171889	0.1196254	0.228872	0.349969	0.4621811	-18.83321	108.9088	129.3183	149.9719	186.1391	0.9014481	1.9773012	0.31298895	0.6190238
128	0.1744118	0.11597	0.2250174	0.35	0.4724549	-18.75	113.3761	129.06	152.0021	186.6317	0.9250776	1.976	0.31367661	0.6618977
129	0.1725434	0.1086123	0.2273934	0.3499691	0.4577126	-18.84175	106.2971	128.9964	149.9558	185.7992	0.8815658	1.9588135	0.30945214	0.5943025
130	0.1742908	0.1204567	0.228872	0.3499999	0.4752259	-18.74146	113.5165	129.3138	150.3231	186.2489	0.9366972	1.9972983	0.31599392	0.6775316
131	0.1748382	0.1228434	0.2291718	0.3913579	0.4720786	-18.83321	113.3168	127.1726	150.0647	185.9834	0.9293318	1.9722393	0.31732249	0.6806645

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
132	0.1749976	0.11711109	0.2287967	0.3499982	0.4695788	-18.83321	113.7657	129.3569	150.2782	186.2351	0.9486665	1.9772071	0.31877679	0.6965072
133	0.1684758	0.1098459	0.2206112	0.3552333	0.4549621	-18.75	106.0036	129.0573	150.31	186.2039	0.889842	1.9745995	0.31023631	0.6123482
134	0.1724317	0.1159569	0.224193	0.3707026	0.4625636	-18.75	108.8102	129.1012	150.3477	186.56	0.9015	1.976	0.31397547	0.6255131
135	0.1765844	0.1196254	0.2246305	0.349969	0.4695788	-18.83321	107.6371	129.3569	150.0052	186.2109	0.9250256	1.9757397	0.31212878	0.649183
136	0.1719	0.1156	0.2292415	0.3403665	0.4639023	-20.07434	112.9475	127.8376	150.2766	186.1741	0.923106	1.9774674	0.31032639	0.6480454
137	0.1748382	0.11526	0.2268249	0.349969	0.4695788	-18.83321	113.7503	129.3569	149.9681	186.2109	0.9250256	1.9772071	0.31589678	0.665291
138	0.1719	0.1199655	0.2314762	0.35	0.4571008	-18.75	108.13	129.06	151.2158	186.56	0.9007413	1.976	0.31095923	0.6211545
139	0.1750222	0.1156201	0.228872	0.3563514	0.4641882	-18.83321	107.9884	127.7951	149.9719	186.2131	0.9250256	1.9773012	0.3158682	0.6519107
140	0.1742168	0.1234271	0.225	0.3403665	0.4720221	-20.07434	113.5388	129.3608	150.31	186.7682	0.923106	1.976	0.31361935	0.6543039
141	0.171853	0.1102822	0.2215004	0.349973	0.4581628	-18.83731	106.0634	128.9422	149.9869	185.8506	0.9357298	1.9608745	0.31736837	0.6755727
142	0.1771649	0.1183782	0.2291047	0.3499959	0.4696681	-18.83318	111.4841	129.4065	150.292	186.1975	0.9204612	1.9776601	0.31476137	0.6521741
143	0.1725232	0.1204324	0.2286172	0.349969	0.4695786	-18.83321	112.7949	129.3569	149.968	186.2109	0.9250256	1.9772071	0.31528497	0.6596519
144	0.1748382	0.11526	0.2268249	0.349969	0.4695808	-18.83321	113.763	129.3569	151.4527	186.2109	0.9250256	1.9772071	0.31499255	0.6604519
145	0.1748382	0.1196254	0.228872	0.349969	0.4695788	-18.83321	112.8499	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.3162814	0.6580905
146	0.1756724	0.1204324	0.2286172	0.349969	0.4695806	-18.83321	113.7081	126.458	149.9719	186.2109	0.9250256	1.9772071	0.3100832	0.6505379
147	0.1749694	0.11611226	0.2285901	0.349969	0.4695807	-18.83321	112.8346	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31553179	0.6617485
148	0.1757006	0.1214312	0.2288237	0.3499982	0.4695788	-18.83321	113.7388	129.3569	150.2782	186.2351	0.9486665	1.9772071	0.32004323	0.7005518
149	0.173727	0.1196254	0.2287874	0.3499985	0.4695788	-18.75	113.7507	129.3569	149.9908	186.2275	0.9112634	1.959963	0.31326254	0.6408969
150	0.1749976	0.11711109	0.2288813	0.3499997	0.4695788	-18.83321	113.7653	129.3569	150.2593	186.235	0.9486665	1.9785716	0.3187398	0.6935213
151	0.1748438	0.1196254	0.228872	0.3499707	0.4693957	-18.83321	113.4045	129.3569	150.0973	186.203	0.928387	1.9772071	0.31713598	0.6665101
152	0.174992	0.1196254	0.2287967	0.3499965	0.4695788	-18.83321	113.6779	129.3569	150.2457	186.2465	0.9025737	1.9772071	0.31167147	0.6271145
153	0.1748382	0.11526	0.2267652	0.3474146	0.4693209	-18.83321	113.3167	129.3569	149.9681	186.2109	0.9250256	1.9716314	0.31624867	0.663525
154	0.1748382	0.11511397	0.2292314	0.3939122	0.4723365	-18.83321	113.7504	127.1726	150.0647	188.6612	0.9293318	1.977815	0.31945985	0.6840039
155	0.1748504	0.1196254	0.2288665	0.3318139	0.4695788	-24.69164	113.7452	129.3569	150.3711	186.2387	0.9480752	1.9771573	0.31344311	0.6884789
156	0.1749853	0.1196254	0.2288717	0.3516494	0.4695788	-18.83321	113.8202	129.3569	149.9719	186.2109	0.9250256	1.9919917	0.31566369	0.6615778
157	0.1748382	0.1228434	0.2287654	0.3913579	0.4695788	-18.83321	113.7694	127.1726	149.9719	186.2125	0.9250256	1.9722393	0.31732318	0.672422
158	0.1816726	0.1196254	0.2292031	0.3499982	0.4695788	-18.83321	113.3322	129.3569	150.3711	186.237	0.9529726	1.9772071	0.31954404	0.7018254
159	0.1724314	0.1096149	0.2268249	0.3729437	0.4695788	-18.83691	113.7503	129.3569	149.9444	186.2109	0.9208847	1.9596509	0.31980289	0.664929
160	0.1748403	0.11468	0.2217331	0.35	0.4582521	-18.83358	106.0634	128.9919	150.3307	185.8372	0.9398707	1.9788837	0.31783554	0.681446
161	0.1749976	0.11711109	0.2287856	0.3499982	0.4695788	-18.83321	112.9686	129.3569	150.2782	186.235	0.9486665	1.9772944	0.31890652	0.6980101
162	0.1749976	0.11711109	0.2288924	0.3499998	0.4695788	-25.09237	113.7653	129.3569	150.2593	186.2351	0.9486665	1.9784843	0.31897642	0.6916228
163	0.1748382	0.123844	0.2287654	0.3913579	0.4695788	-18.83321	113.7694	127.1726	149.9719	186.2125	0.9250256	1.9722393	0.31755919	0.6743337
164	0.1753074	0.1254108	0.2287654	0.3913579	0.4695788	-18.83321	113.7694	127.1726	149.9719	186.2125	0.9250256	1.9722393	0.31560241	0.6714403
165	0.1748028	0.1207334	0.2287663	0.3913579	0.4695788	-18.83321	113.7694	126.8222	149.9719	185.6373	0.9250256	1.9722393	0.31728287	0.6752458
166	0.175736	0.1214312	0.2288228	0.3499982	0.4695788	-18.83321	113.7388	129.7073	150.2782	186.2351	0.9486665	1.9985211	0.31941898	0.6925753
167	0.1750278	0.1197042	0.2287963	0.3499982	0.4695788	-18.83321	113.2452	129.3569	150.2826	187.2866	0.9529726	1.9772071	0.3196962	0.7020291
168	0.1756704	0.1213525	0.2288241	0.3499982	0.4695788	-18.83321	113.8258	129.3569	150.3667	186.2388	0.9486665	1.9772071	0.31905307	0.6963997
169	0.171853	0.1062172	0.2215004	0.348838	0.4581628	-18.83735	106.0634	127.1627	151.2699	185.8842	0.9357298	1.9810426	0.31550809	0.6710722
170	0.1748382	0.1269084	0.2291718	0.3924929	0.4720786	-18.83317	113.3168	128.9521	150.0645	185.9498	1.0014651	1.9720692	0.32170103	0.7998936
171	0.1756724	0.1196295	0.2286172	0.349969	0.4746743	-18.83321	112.9471	129.3569	149.9719	186.2109	0.9250256	1.9812356	0.31366084	0.6621841
172	0.1748382	0.1204283	0.228872	0.349969	0.4695788	-18.83321	113.6109	129.3569	149.9719	186.2109	0.9250256	1.9772071	0.31657287	0.6601018
173	0.1749976	0.11711109	0.2288813	0.3499731	0.4695788	-18.8381	105.9888	129.3569	150.0084	185.8918	0.9486665	1.9612651	0.31638546	0.6848615
174	0.1850419	0.1102822	0.2215004	0.3499997	0.4581628	-18.83242	113.8399	128.9422	150.2378	185.8506	0.9357298	1.978181	0.31843258	0.6901522
175	0.1748382	0.1228434	0.2291718	0.3436024	0.4598235	-18.83321	113.3168	126.8308	150.0283	185.9834	0.9223934	1.9720063	0.30910473	0.6449735
176	0.1757006	0.1214312	0.2288237	0.3938161	0.4721087	-18.83321	113.7388	129.3569	150.3147	186.2351	0.9556048	1.9774401	0.32188085	0.7266336
177	0.172598	0.1101441	0.2292314	0.3939122	0.4766877	-18.83321	113.7503	127.4201	150.0647	188.6612	0.9182405	1.977815	0.31600197	0.6690192
178	0.1746716	0.1145847	0.2223884	0.3729437	0.4719526	-18.83691	113.7504	129.1324	149.9444	186.2109	0.931976	1.9596509	0.32009276	0.6810629
179	0.1748382	0.1151477	0.2267652	0.3474146	0.4693209	-18.83321	113.3818	129.3569	149.9681	186.2107	0.9250256	1.9716431	0.31586074	0.6609678
180	0.1748382	0.1229557	0.2287654	0.3913579	0.4695788	-18.83321	113.7042	127.1726	149.9719	186.2127	0.9250256	1.9722276	0.31729001	0.6731026
181	0.1599426	0.1214312	0.2288228	0.3499982	0.4711266	-18.83321	113.7388	129.7073	150.2789	186.2351	0.9493289	1.9985211	0.31751792	0.6902254
182	0.1757006	0.1214312	0.2288237	0.3938161	0.4717885	-18.83321	113.7388	129.3569	150.3141	186.2351	0.9549424	1.9774401	0.32212812	0.7264193
183	0.1750278	0.1197042	0.2287963	0.3499982	0.4586746	-18.83321	113.2308	129.3569	150.2826	186.1929	0.9529726	1.9772071	0.31858885	0.7063841
184	0.1749976	0.11711109	0.2287967	0.3499982	0.4695788	-18.83321	113.78	129.3569	150.2782	187.3969	0.9486665	1.9772071	0.3185325	0.7002578
185	0.1724335	0.1120274	0.2217331	0.349998	0.4582278	-18.83727	106.0634	128.9919	150.3071	185.9132	0.9357298	1.9613275	0.3177938	0.6754252
186	0.1750278	0.1205142	0.2287963	0.3500002	0.4789831	-18.83321	113.2452	129.3569	150.2826	187.2106	0.9529726	1.9772071	0.31718851	0.7027321
187	0.1723882	0.1099604	0.2270674	0.3437234	0.4695788	-18.83321	113.3132	129.3569	149.9423	187.2866	0.9209088	1.956661	0.3149119	0.6560319
188	0.1750709	0.1193587	0.2285538	0.3729437	0.4695788	-18.83691	113.6822	129.3569	150.2847	186.2109	0.9529485	1.9801969	0.32167248	0.7094725
189	0.1757006	0.1214312	0.2288237	0.3938161	0.4681513	-18.83321	113.7388	129.3569	150.3147	186.2351	0.9556048	1.9774401	0.32363877	0.7255429
190	0.1757006	0.1214312	0.2288237	0.3499982	0.4721677	-18.83321	113.7388	129.3569	150.2782	186.2351	0.9486665	1.9772071	0.3183693	0.6943989
191	0.1864554	0.1035511	0.2205995	0.3499998	0.4549906	-25.9589	113.7624	128.9791	150.2356	186.2351	0.9381076	1.9780424	0.31746114	0.6947138
192	0.1847288	0.1329464	0.2297933	0.3499997	0.4727509	-17.9659	113.8428	129.32	150.2615	185.8506	0.9462886	1.9786229	0.31713167	0.683679
193	0.1749982	0.1176058	0.2287846	0.3499982	0.4695788	-25.05229	113.2644	127.7857	150.2826	186.0518	0.948782	1.9773027	0.31560508	0.6880251
194	0.1750272	0.1192095	0.228904	0.3718323	0.4695788	-18.87329	113.7461	129.3569	150.2593	187.4699	0.9528571	1.9783886	0.32220377	0.7110926
195	0.1748403	0.11468	0.2217331	0.35	0.4595014	-16.07495	106.4275	128.9462	150.3307	185.8393	0.9398707	1.9788837	0.31804944	0.6823527
196	0.1748382	0.1269084	0.2278891	0.3924929	0.4708292	-18.83317	112.9527	128.9978	150.0645	185.8769	1.0014651	1.9720692	0.32161848	0.7973035
197	0.1748382	0.1269084	0.2289258	0.3431581	0.4720786	-18.83321	112.9124	128.9521	150.0645	185.9498	0.9482798	1.9720692	0.31677383	0.6882876
198	0.1749976	0.11711109	0.2291273	0.3993345	0.4695788	-18.83317	113.7653	129.3569	150.2593	186.235	1.0018518	1.9785716	0.32564614	0.8069415
199	0.1749976	0.1196254	0.228749	0.3499982	0.4709313	-18.83321	113.3322	129.3569	150.3711	186.2387	0.9529726	1.9797921	0.31846998	0.7046983
200	0.177184	0.1188015	0.2292508	0.3499982	0.4695788	-18.83321	113.3322	129.3569	150.3711	186.237	0.9529726	1.9772071	0.31923485	0.7011974
201	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
202	0.1724314	0.1309149	0.2278537	0.3729437	0.470826	-18.83691	113.7503	129.3473	149.9444	186.2109	0.9208847	1.9596509	0	0
203	0.1757006	0.1214312	0.2288237	0.3938161	0.4717885	-18.83321	113.7388	129.3569	150.3141	186.2351	0.9549424	1.9774401	0.32212812	0.7264193
204	0.1757006	0.1214312	0.2288237	0.3938161	0.4717885	-18.83321	113.7388	129.3569	150.3141	186.2351	0.9549424	1.9774401	0.32212812	0.7264193
205	0.1750272	0.1192095	0.228904	0.3718323	0.4695788	-18.87329	113.7461	129.3569	150.2568	186.1298	0.9528571	1.9785285	0.32151128	0.7106541
206	0.1750709	0.1346291	0.2285538	0.3729437	0.4695788	-18.83691	113.6822	128.9962	150.2872	187.5509	0.9529484	1.980057	0.32206269	0.6993877
207	0.1749976	0.1147185	0.2291232	0.393858	0.4696233	-18.83317	113.251	129.3569	151.1973	185.9429	1.0014754	1.9785716	0.32534124	0.8003166
208	0.1748382	0.129301	0.2291759	0.3979695	0.4720341	-18.83316	113.8311	128.9521	150.0645	186.2419	1.0018414	1.9720692	0.32022275	0.8068594

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
209	0.1749677	0.1172821	0.2288237	0.3939398	0.4721087	-18.83321	113.7388	128.4174	150.2578	186.235	0.9556048	1.9774212	0.32182823	0.7305676
210	0.1757305	0.1212602	0.2291273	0.3992109	0.4695788	-18.83317	113.7653	129.3569	150.3161	186.2351	1.0018518	1.9692799	0.32278093	0.8072969
211	0.1756704	0.1213508	0.2288241	0.3499982	0.4695274	-18.83321	113.8258	129.3569	150.3667	186.2357	0.9486665	1.9772283	0.31909178	0.6969122
212	0.164166	0.1214329	0.2288237	0.3938161	0.4718399	-18.83321	113.7388	129.3569	150.3141	186.2383	0.9549424	1.9774189	0.32028573	0.728875
213	0.1747747	0.1214312	0.2288237	0.3938161	0.4721046	-18.83321	113.7388	127.3686	150.0065	185.7926	0.9556048	1.9774426	0.31994971	0.7261654
214	0.1757641	0.11511397	0.2292314	0.3939122	0.4723406	-18.83321	113.7504	129.1609	150.3729	189.1038	0.9293318	1.9778126	0.31985232	0.6909599
215	0.1749884	0.1012949	0.2288318	0.351852	0.4695788	-26.94839	114.5632	129.3569	150.2601	186.2351	0.9491273	1.9784843	0.31748862	0.7015473
216	0.1757098	0.1214312	0.2288842	0.3919639	0.4681513	-16.97719	113.7388	129.3569	150.3138	186.2351	0.9571161	1.9774401	0.32260831	0.7298356
217	0.1757006	0.1214312	0.2288237	0.3938161	0.4717885	-19.1938	113.7388	129.3569	150.3141	186.2351	0.9549424	1.9774401	0.32238027	0.7254908
218	0.1757006	0.1214312	0.2288237	0.3938161	0.4717885	-18.83321	113.7388	129.3569	150.3141	186.2915	0.9549424	1.9774401	0.32209114	0.727751
219	0.1952961	0.1214312	0.2288237	0.3938161	0.4697845	-18.8332	113.7388	129.3569	150.2608	186.2351	0.9504511	1.9774401	0.32257966	0.7225268
220	0.1749976	0.11711109	0.2291273	0.3993345	0.4715828	-18.83318	113.7653	129.3569	148.5758	186.235	1.006343	1.9785716	0.32339217	0.8186449
221	0.1749976	0.1146515	0.2291234	0.3939115	0.4695801	-17.25193	113.7653	129.3569	150.2593	185.9745	1.0013569	1.9785716	0.32525586	0.8050076
222	0.1749976	0.1171781	0.2291271	0.3992811	0.4696219	-18.83317	113.251	129.3569	151.1973	186.2034	1.0019703	1.9785716	0.32468431	0.8064961
223	0.1759521	0.1214312	0.2265037	0.3938161	0.4698391	-14.89959	113.7388	129.3569	150.3141	186.2351	0.9505504	1.9774401	0.32003036	0.7286811
224	0.1950447	0.1214312	0.2357474	0.3961418	0.4717338	-18.8332	113.7388	129.3569	150.2608	186.2351	0.9548432	1.9774401	0.32143859	0.7313617
225	0.1752708	0.1214312	0.2288237	0.3938161	0.468045	-18.83321	113.7388	128.5013	150.2705	186.2351	0.9478563	1.9774401	0.32028789	0.7137209
226	0.1957259	0.1214312	0.2288237	0.3938161	0.4698908	-18.8332	113.7388	129.3569	150.305	187.4719	0.9581997	1.9774401	0.32397698	0.7371969
227	0.1757006	0.1214312	0.2288237	0.3938161	0.4681528	-18.83321	113.7388	129.3569	150.314	186.2351	0.9549424	1.9774401	0.3231239	0.7237212
228	0.1757006	0.1214312	0.2288237	0.3938161	0.471787	-18.83321	113.7388	129.3569	150.3147	186.2351	0.9556048	1.9774401	0.32232912	0.7288112
229	0.1749976	0.11711109	0.2291273	0.3993345	0.4695788	-18.83317	113.7653	129.3569	150.2593	185.9686	1.0014613	1.9785716	0.32497044	0.8087568
230	0.1749976	0.1147185	0.2268792	0.393858	0.4696233	-18.83317	113.251	129.0538	151.7468	186.2093	1.0018658	1.9785716	0.32487205	0.8029187
231	0.1750272	0.1055652	0.228904	0.3718323	0.4695788	-18.8716	113.7461	129.03	150.0769	187.4699	0.9528571	1.9783886	0.32163481	0.7161574
232	0.1748382	0.1305053	0.2268603	0.3795112	0.469582	-18.83486	112.9527	129.3342	150.2469	185.8769	1.0014651	1.9720692	0.32316116	0.7875001
233	0.1842582	0.1050873	0.2291232	0.393858	0.4696233	-18.83317	112.9371	129.0114	150.1074	185.8752	1.0014653	1.9719105	0.32517997	0.8072106
234	0.1749952	0.1152397	0.2268603	0.3795112	0.469582	-18.83317	113.2666	129.3528	151.1544	185.9446	1.0014752	1.9787303	0.32493944	0.7941153
235	0.1749976	0.112948	0.2291273	0.3932443	0.4695788	-18.83317	113.7653	129.3569	150.2593	186.235	0.9526273	1.977119	0.32300086	0.7281898
236	0.1757006	0.1214312	0.2288237	0.3999063	0.4681513	-18.83321	113.7388	129.3569	150.3147	186.2351	1.0048292	1.9788927	0.32308254	0.8150194
237	0.1757006	0.1214312	0.2288237	0.3938161	0.4687196	-19.1897	113.7388	129.3569	150.3138	186.2351	0.9429612	1.9774401	0.32221228	0.7045738
238	0.1757006	0.1214312	0.2288237	0.3938161	0.4712202	-18.83732	113.7388	129.3569	145.9155	184.9927	0.9549424	1.9774401	0.31730599	0.733422
239	0.1749976	0.1147163	0.2291237	0.393858	0.4698389	-19.96363	113.322	129.3569	150.2418	185.9429	0.9956638	1.9785716	0.32610103	0.7929316
240	0.1749976	0.11711326	0.2302741	0.3993345	0.4695767	-18.83317	113.6944	129.3569	151.2148	186.235	1.0018096	1.9785716	0.324119	0.8076438
241	0.1749976	0.1140127	0.2268792	0.3938141	0.4696233	-18.83317	113.251	129.0538	151.7468	186.2045	1.0018791	1.9785716	0.32528222	0.8020218
242	0.1749976	0.11186827	0.2291271	0.3989534	0.4696219	-18.83317	113.251	129.3569	151.1973	186.2082	1.001957	1.9785716	0.3254951	0.8084082
243	0.1757006	0.1214312	0.2288237	0.3938161	0.4683633	-18.83321	112.9876	129.3569	150.043	186.2351	0.9549424	1.9774401	0.32315826	0.7243998
244	0.1748382	0.1056084	0.2268603	0.3795112	0.4693715	-18.83317	113.7038	129.0074	150.3355	185.1555	1.0014651	1.9720692	0.32665867	0.7907102
245	0.17487	0.1147185	0.2291232	0.393858	0.4696233	-18.83317	112.9814	129.0777	150.4536	185.8821	1.0014622	1.9785716	0.32547255	0.8014829
246	0.1749657	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	113.2223	129.2866	151.0433	186.4311	1.0014783	1.9720692	0.3262443	0.7922913
247	0.1749976	0.1171781	0.2291271	0.3992811	0.4696219	-18.83317	113.251	129.3569	151.1973	186.2034	0.971821	1.9785716	0.32416073	0.758717
248	0.1749976	0.1171781	0.2291271	0.3992811	0.4696219	-18.83317	113.251	129.3569	151.1973	186.2034	1.0019703	1.9785716	0.32468431	0.8064961
249	0.1751067	0.1175286	0.2291273	0.3938841	0.4695788	-18.83321	113.7653	129.3569	150.2593	186.183	1.0018518	1.9785716	0.32474797	0.8032286
250	0.1755915	0.1210138	0.2288237	0.3992666	0.4681513	-18.83317	113.7388	129.3569	150.3147	185.2356	0.9556048	1.9774401	0.32245463	0.7299112
251	0.1749976	0.1171781	0.2291271	0.3992811	0.4696219	-18.83317	113.251	129.3569	151.1973	186.2034	1.0019703	1.9785716	0.32468431	0.8064961
252	0.1749976	0.1147163	0.2291237	0.393858	0.4698389	-19.96363	113.322	129.3569	150.2418	185.9429	0.9956638	1.9785716	0.32610103	0.7929316
253	0.1749976	0.1164901	0.2291234	0.3939115	0.4695801	-17.25193	113.7653	129.3569	150.2593	185.9832	1.0013569	1.9785716	0.32549383	0.8045481
254	0.1749976	0.112948	0.2291273	0.3932443	0.4695788	-18.83317	113.7653	129.3569	150.2593	186.2262	0.9526273	1.977119	0.32294245	0.7288669
255	0.1749976	0.1146972	0.2291236	0.3947001	0.4696211	-20.16412	113.3464	129.3569	150.2418	185.9456	0.9975087	1.9785716	0.32629932	0.798184
256	0.1749976	0.1171303	0.2291274	0.3984925	0.4697966	-18.63267	113.7409	129.3569	150.2593	186.2323	1.0018518	1.9785716	0.32508638	0.8085134
257	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
258	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
259	0.1748382	0.1046502	0.2268603	0.3752455	0.469582	-18.83317	112.9527	129.0007	150.0645	185.8883	1.0014651	1.9720692	0.32570906	0.7893711
260	0.1749976	0.1181363	0.2291271	0.4035467	0.4696219	-18.83317	113.251	129.3636	151.1973	186.192	1.0019703	1.9785716	0.32571934	0.8132727
261	0.1749976	0.11191899	0.2291237	0.3919854	0.46964	-19.96363	113.2547	127.4861	150.2418	185.9429	0.9955416	1.9785716	0.32363119	0.7800097
262	0.1749976	0.1146656	0.2291271	0.3988045	0.4698208	-18.83317	113.3183	129.3569	151.1973	186.2082	1.0020791	1.9785716	0.32598554	0.8083112
263	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9932153	0.3274309	0.7943634
264	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
265	0.1748452	0.1024575	0.2291274	0.3984925	0.4693692	-18.63267	113.7409	129.004	150.2606	186.2323	1.0018518	1.9722114	0.32490623	0.8021802
266	0.1749906	0.1202811	0.2268603	0.3795112	0.4697988	-18.83317	113.7038	129.3603	150.3342	185.1555	1.0014651	1.9784293	0.32446055	0.7901533
267	0.1748382	0.1056084	0.2268603	0.3795112	0.4694062	-18.83317	112.9527	129.0074	150.0724	185.8769	1.0014651	1.9720692	0.32636725	0.7936134
268	0.1748382	0.1056084	0.2268603	0.3795112	0.4695473	-18.83317	113.7038	129.0074	150.3276	185.7745	0.9963634	1.9720692	0.3259674	0.7861156
269	0.1749657	0.1056084	0.2268603	0.3795112	0.4693662	-18.83317	113.2223	129.2866	150.2304	185.4343	1.0014659	1.9720692	0.32656028	0.7950341
270	0.1748382	0.0970664	0.2268603	0.3795112	0.4695873	-18.83317	113.7038	129.0074	151.1484	186.1523	1.0014774	1.9720692	0.32523896	0.7949717
271	0.1748248	0.1056084	0.2268603	0.3795112	0.4693763	-18.83317	113.1841	128.9988	150.3355	184.8096	1.0014651	1.9720692	0.32624397	0.7933069
272	0.1749791	0.1056084	0.2268603	0.3795112	0.4695772	-18.83317	113.742	129.2952	151.0433	186.777	1.0014783	1.967695	0.32472958	0.7987738
273	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	149.7425	185.8769	0.9482674	1.9720692	0.32348688	0.7140367
274	0.1748382	0.105383	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.99003	0.32628829	0.792434
275	0.1748339	0.1056084	0.2267599	0.3795112	0.4693653	-18.83317	107.9905	129.0144	150.3355	185.1555	1.0014466	1.9722107	0.32566596	0.793003
276	0.1750018	0.11186827	0.2292275	0.3989534	0.4696281	-18.83317	113.726	129.3499	151.1973	186.2082	1.0019754	1.9784301	0.32573669	0.8093083
277	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-19.64931	112.9527	129.0074	150.0645	185.8769	0.9945126	1.944292	0.32587151	0.7825354
278	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
279	0.17483	0.106266	0.2268603	0.377813	0.4693715	-18.83317	111.5955	129.0074	150.2461	185.1555	1.0014651	1.9465873	0.32584319	0.7922888
280	0.1750057	0.1164535	0.2406902	0.4010327	0.4695788	-18.83317	113.7489	129.3569	150.3487	185.7875	1.0018518	1.9778423	0.32170938	0.8028258
281	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	149.1873	185.8769	1.0014651	1.9720692	0.32652002	0.7944472
282	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.2955	150.0645	185.8769	1.0014651	1.9720692	0.3270649	0.7937605
283	0.1748382	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.9932153	0.32930468	0.8052885
284	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
285	0.1749976	0.1057979	0.2328711	0.3947001	0.4693844	-20.16412	113.3464	129.0151	150.2418	185.9456	0.9975087	1.9718577	0.32600265	0.791833

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
286	0.1748248	0.1145077	0.2268603	0.3795112	0.469613	-18.83317	113.1841	129.3405	150.3355	184.8096	1.0014651	1.9787831	0.32468266	0.7958884
287	0.1748382	0.1056084	0.2268603	0.3795112	0.4695473	-18.83317	113.7038	129.0074	150.0749	185.7815	0.9937568	1.9720692	0.32553713	0.7824834
288	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.3171	185.8699	1.0012306	1.9932153	0.32637062	0.7922941
289	0.1748382	0.1056084	0.2268603	0.3832626	0.469582	-18.83317	112.7084	129.0074	150.0645	185.8769	1.026332	1.9720692	0.32759045	0.8293625
290	0.1748382	0.109666	0.2268603	0.3795112	0.469582	-18.83317	114.897	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32598515	0.7921842
291	0.1748382	0.1061793	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32658114	0.7916554
292	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.2264	185.8769	1.0014651	1.9644969	0.3263245	0.7924647
293	0.1748382	0.1056084	0.2268603	0.3795112	0.4695561	-18.83317	113.057	129.0074	150.0645	185.8769	0.9961205	1.9720692	0.32680931	0.7842602
294	0.1748382	0.114122	0.2268603	0.3795112	0.4695732	-18.83317	113.5994	129.0074	150.3276	185.7745	1.0017079	1.9720692	0.32430045	0.7965331
295	0.1747949	0.1023259	0.2291236	0.3758281	0.4695734	-20.16412	113.3464	129.3569	150.0912	185.8755	0.9970904	1.9785716	0.32707693	0.7835255
296	0.1750409	0.1179797	0.2233928	0.3983831	0.4696297	-18.83317	112.9527	129.0074	150.2151	185.947	1.0018834	1.9932153	0.32576902	0.8114458
297	0.1749976	0.1147163	0.2263888	0.3807761	0.4695224	-20.21465	113.322	128.9982	150.0726	186.1137	0.9971275	1.9785716	0.3246466	0.7871064
298	0.1748382	0.1056084	0.2295953	0.3925931	0.4698985	-18.58214	112.9527	130.5364	150.2337	185.9336	1.0000013	1.9720692	0.32762184	0.8087888
299	0.1748382	0.1056084	0.2268603	0.3795112	0.4695476	-18.83317	112.9527	125.0616	150.0517	185.7715	0.9746865	1.9720692	0.31351503	0.7365038
300	0.1748382	0.1056084	0.2268603	0.3795112	0.4695817	-18.83317	113.7038	129.0074	150.3404	185.8798	1.0015832	1.9720692	0.32612451	0.7940645
301	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
302	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-7.639596	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9932153	0.31580966	0.8002217
303	0.1748382	0.1056084	0.2268603	0.3741737	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9546751	0.32554176	0.7899301
304	0.1748382	0.1056084	0.2268603	0.3812507	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32622467	0.7952422
305	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	128.6259	150.0645	185.8769	1.0014651	1.9696371	0.32532742	0.789404
306	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	152.0454	185.8769	1.0014651	1.9939496	0.32417669	0.8009562
307	0.1748382	0.1056084	0.2268603	0.3794588	0.469582	-18.83317	112.6842	129.0399	150.0645	185.8769	1.0042056	1.9720692	0.32666018	0.7960157
308	0.1748382	0.1056084	0.2268603	0.383315	0.469582	-18.83317	112.9768	129.263	151.0433	185.8769	1.0235915	1.9720692	0.32803283	0.8257224
309	0.1747949	0.1017527	0.2271602	0.3758281	0.4695734	-20.16412	112.9244	128.0554	150.0912	185.8755	0.9970904	1.9785716	0.32425432	0.7778693
310	0.1748382	0.1061815	0.2288238	0.3795112	0.469582	-18.83317	113.3747	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32539119	0.7898584
311	0.1806814	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32550187	0.7994847
312	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
313	0.1748382	0.1082521	0.2268603	0.3914762	0.469582	-18.83317	112.9527	129.0001	150.0645	185.1013	1.0014651	1.9753763	0.32584167	0.8025475
314	0.1748382	0.1099708	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.3028	150.0645	185.8769	1.0014651	1.9720692	0.32725293	0.7931317
315	0.1747949	0.1022562	0.2264756	0.3752706	0.4695734	-20.11894	113.1748	129.0055	150.0912	185.8756	0.9721261	1.9717558	0.32506667	0.7464136
316	0.1748382	0.105678	0.2321266	0.3800687	0.469582	-16.80173	113.3053	129.3588	150.0645	185.8768	1.0022378	1.978885	0.32463463	0.7935548
317	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	149.258	185.8769	1.0014651	1.9720692	0.32702989	0.7884971
318	0.1748382	0.1056084	0.2268603	0.3795112	0.4632903	-18.83317	112.9527	128.7647	149.9938	185.8769	1.0014651	1.9720692	0.32540849	0.7928015
319	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32696428	0.7929574
320	0.1748382	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.9932153	0.32930468	0.8052885
321	0.1748382	0.1056084	0.2268603	0.3794493	0.469582	-18.83317	112.7084	129.8553	150.0645	185.8769	1.0057856	1.9720692	0.32814715	0.8023762
322	0.1748382	0.1056084	0.2268603	0.3833246	0.4671169	-19.20636	112.9527	129.0074	150.0645	185.8769	1.0220115	1.9720692	0.32724241	0.8233203
323	0.1748382	0.1056084	0.2269474	0.3795112	0.46955	-18.83384	112.9527	129.0074	150.0645	185.8724	0.9999873	1.9676265	0.32575612	0.7889281
324	0.1748382	0.1056084	0.2295082	0.3925931	0.4699305	-18.58147	112.9527	130.5364	150.2337	185.938	1.0014791	1.9976579	0.3287819	0.808726
325	0.1748382	0.1056084	0.2268603	0.3795755	0.479455	-18.83317	112.9527	128.9586	150.0484	185.8769	1.0014651	1.9734791	0.32482649	0.7933322
326	0.1748382	0.1056084	0.2268603	0.3832506	0.469582	-18.83317	112.9768	129.3118	151.0594	185.8769	1.0499328	1.9918054	0.32782451	0.8641726
327	0.1748382	0.1056573	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.6863	150.0645	185.8769	1.0014651	1.9720692	0.32773903	0.7960628
328	0.1748382	0.1099218	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.3028	150.0645	185.8769	0.9562069	1.9720692	0.32454444	0.7259535
329	0.1748382	0.1056084	0.2154971	0.3795112	0.469582	-18.83317	112.706	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32934079	0.8016498
330	0.1748382	0.1056084	0.2268603	0.3740276	0.469582	-18.83317	112.955	129.0074	150.0645	185.8769	1.026332	1.9720692	0.32648506	0.8244425
331	0.1748382	0.1056084	0.2287628	0.3789656	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.325583	0.7912338
332	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9527	129.2955	150.0645	185.8769	1.0014651	1.9720692	0.3270649	0.7937605
333	0.1748382	0.1056084	0.2268603	0.3832626	0.4772396	-18.83317	112.7013	127.7915	150.0645	185.8769	1.026332	1.9720692	0.32303279	0.8214975
334	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.9598	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.3271403	0.7914764
335	0.1747982	0.1029019	0.2272494	0.3758281	0.4695734	-20.44018	112.9669	129.3569	150.0912	185.8755	0.9970904	1.9610202	0.32743773	0.7839319
336	0.1748348	0.1050324	0.224326	0.3795112	0.469582	-17.92551	113.3321	129.0074	150.0645	185.8769	1.0014651	1.9720692	0.32625276	0.7935328
337	0.1748382	0.1056084	0.2268603	0.3852402	0.469582	-18.82522	112.954	129.2567	153.1659	185.8769	1.0235915	1.9720692	0.32531719	0.8318488
338	0.1748382	0.1056084	0.2295953	0.3906679	0.4698985	-18.59009	112.9755	130.5428	150.2337	185.9336	1.0000013	1.9720692	0.32830305	0.8075705
339	0.1748382	0.1056084	0.2268603	0.3847444	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.9724695	0.32913336	0.8038193
340	0.1748382	0.1056084	0.2268603	0.383239	0.469582	-18.83317	112.7084	129.0074	150.0645	185.8769	1.026332	1.9928149	0.32770968	0.8294162
341	0.1748382	0.1056573	0.2268603	0.3785211	0.471884	-17.15584	112.9527	129.6863	150.0645	185.8769	1.0014651	1.9710666	0.32679739	0.7958454
342	0.1788381	0.1056084	0.2268603	0.3836011	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.9942178	0.32889954	0.8015632
343	0.1748382	0.1056086	0.2238177	0.3796606	0.469582	-18.83317	112.9527	128.1835	150.0645	185.8769	1.0014651	1.969985	0.32599087	0.790407
344	0.1748382	0.1056571	0.2268603	0.382138	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.9952994	0.3281369	0.8054357
345	0.1748382	0.1056084	0.2268603	0.3832506	0.469582	-18.83317	112.7135	129.319	150.0437	185.8769	1.0499328	1.9918054	0	0
346	0.1748382	0.1056084	0.2268603	0.3794493	0.469582	-18.83317	112.9718	129.8481	151.0802	184.8852	1.0057856	1.9720692	0.32767212	0.804098
347	0.1748382	0.1056084	0.2268603	0.3795112	0.469582	-18.83317	112.6962	129.2955	150.0645	183.4994	1.0015661	1.9720692	0.32618513	0.7936306
348	0.1748382	0.1056084	0.2268603	0.3794493	0.469582	-18.83317	112.9648	129.8553	150.0645	185.8769	1.0056845	1.9720692	0.32861335	0.8032253
349	0.1748382	0.1056084	0.2268603	0.3790394	0.469582	-18.83317	112.7084	129.9146	150.0645	185.8769	1.0029404	1.9720692	0.3278354	0.8012646
350	0.1748382	0.1231101	0.2268603	0.3837344	0.469582	-18.83317	112.9527	129.0074	150.0645	185.8769	1.0659591	1.9932153	0.32413343	0.8829759
351	0.1748382	0.1056084	0.2267608	0.3847444	0.4695847	-18.84828	112.9532	130.1563	150.0705	185.8769	1.0014651	1.9724695	0.32889944	0.8013625
352	0.1748382	0.1056084	0.2296948	0.3898358	0.4698958	-18.57498	112.975	130.5428	150.2278	185.9336	1.0000013	1.9720692	0.32861738	0.8045344
353	0.1748382	0.1056084	0.2268603	0.3847444	0.469582	-18.83317	112.9527	129.4205	150.0211	185.8769	1.0014651	1.972028	0.32778983	0.7979255
354	0.1748382	0.1056084	0.2268603	0.383315	0.469582	-18.83317	112.9768	129.9989	151.0866	185.8769	1.0235915	1.9725107	0.32968443	0.8336396
355	0.1748382	0.1056084	0.2154971	0.3796863	0.469582	-18.83317	112.706	129.0074	150.0645	185.8769	1.0014651	1.9560173	0.32867647	0.8035992
356	0.1748382	0.1056084	0.2268603	0.3824358	0.469582	-18.83317	112.9527	130.1563	150.0645	185.8769	1.0014651	1.988257	0.32905138	0.800736
357	0.1723304	0.1099708	0.2161177	0.3795112	0.469582	-18.83317	111.0247	128.3204	150.0645	185.8769	0.9898713	1.9725722	0.32658229	0.780369
358	0.1748382	0.1056084	0.2278899	0.382611	0.469582	-18.83317	112.9527	130.1873	150.0645	185.8769	1.0014651	1.9927122	0.32846751	0.8013348
359	0.1748382	0.1056084	0.2268603	0.3825932	0.469582	-18.83317	112.7084	124.613	150.0645	185.8769	1.026332	1.9743436	0.31345607	0.8016232
360	0.1748382	0.1056084	0.2268603	0.3832804	0.469582	-18.83317	112.9527	130.1563	150.0645	184.7765	1.0014651	1.9909409	0.32894114	0.8008492
361	0.1748382	0.099343	0.2268603	0.3824728	0.469582	-18.83317	112.9768	129.9998	150.0008	185.8769	1.0235915	1.9703555	0.3289604	0.8310628
362	0.1748382	0.1056084	0.2268603	0.4013177	0.469582	-18.83317	112.4499	130.1554	151.1503	185.8769	1.0014651	1.9904123	0.32704892	0.8175479

Run	l1	l2	l3	l4	l5	a1	a2	a3	a4	a5	TSR	DIAMETER	CP	CPdif
363	0.1748382	0.1056084	0.2268603	0.3847444	0.469582	-18.851	112.9526	130.1563	150.0645	185.8769	1.0014651	1.9724695	0.32861348	0.8041073
364	0.1748382	0.1056084	0.2267608	0.3847444	0.4695848	-18.83044	110.8648	130.1563	150.8022	185.8769	1.0014651	1.9724695	0.32823085	0.8026924
365	0.1748382	0.1056084	0.2268603	0.383315	0.469582	-18.83317	112.9768	129.263	150.6111	185.8769	1.0235915	1.9720788	0.32794644	0.8274267
366	0.1748382	0.0947679	0.2244558	0.383315	0.469582	-18.83317	112.9768	129.9989	151.0866	185.8769	1.0235915	1.972501	0.33028648	0.8330235
367	0.1748382	0.1056084	0.2146677	0.383315	0.469582	-18.83317	112.7099	129.0109	150.9486	185.8769	1.0675924	1.9720692	0.3306919	0.8963836
368	0.1748382	0.1056084	0.2276897	0.3796863	0.4682664	-18.83317	112.973	129.2376	150.0645	186.0142	1.0014651	1.9560173	0.3276015	0.7933162
369	0.1788381	0.1056084	0.2268603	0.3833067	0.469582	-18.83317	112.5514	130.1563	150.0806	185.8769	1.0030216	1.9680151	0.32867422	0.8075395
370	0.1748382	0.1056084	0.2220813	0.3679254	0.469582	-18.83317	112.9768	129.263	148.371	186.4154	1.0220349	1.9982719	0.32797655	0.8204767
371	0.1748382	0.1056084	0.2268603	0.383315	0.4652821	-18.83317	112.9479	129.9864	151.0866	185.8769	0.9994131	1.9725107	0.32833066	0.7999367
372	0.1748382	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9816	130.1688	150.0645	185.8769	1.0256435	1.9932153	0.32988994	0.8382287
373	0.1748382	0.1056084	0.215296	0.3803668	0.469582	-20.7072	112.706	126.4611	150.0645	185.8769	1.0014651	1.97196	0.32492966	0.7866574
374	0.1743275	0.1056084	0.2270613	0.3817553	0.469582	-18.83317	112.9527	130.1189	150.0645	184.5633	1.0014651	1.9894463	0.32819137	0.8003106
375	0.1748382	0.1036356	0.2154971	0.3795112	0.4695088	-18.83317	112.7127	129.003	150.0674	185.8769	1.0014653	1.973715	0.32947074	0.8020192
376	0.1750895	0.1056084	0.2295082	0.3925931	0.4700038	-18.58147	112.946	130.5408	150.2308	185.938	1.0014789	1.9960121	0.32893868	0.8115298
377	0.1748382	0.1056084	0.2268603	0.382611	0.4696064	-18.83317	112.9522	129.9994	150.0798	185.8769	1.0001197	1.9726008	0.32788575	0.800843
378	0.1748382	0.1056084	0.2296948	0.3898358	0.4698714	-18.57498	112.9755	130.5623	150.2124	185.9336	0.9912066	1.9926837	0.32803547	0.7948592
379	0.1748382	0.1056084	0.2268603	0.3832299	0.469582	-18.83317	112.9527	130.1563	149.9406	185.8769	1.0014651	1.97247	0.32883567	0.8035683
380	0.1748382	0.1056084	0.2268603	0.393678	0.469582	-18.83317	112.9768	129.9989	151.2106	185.8769	1.0235915	1.993764	0.32901304	0.8413108
381	0.1748382	0.1056084	0.2155543	0.3793037	0.469582	-18.83317	112.7076	128.6826	150.0645	185.8769	1.0014651	1.9720692	0.32891183	0.7989497
382	0.1748382	0.1056084	0.226803	0.3828184	0.469582	-18.83317	111.2137	130.4811	150.0645	185.8769	1.0014651	1.9932153	0.32894781	0.8041366
383	0.1752429	0.1056084	0.2270192	0.388974	0.4700038	-18.58147	112.9471	130.1743	150.2308	185.8746	1.0014656	1.9943237	0.32836903	0.8050873
384	0.1786847	0.0888229	0.2285983	0.3925279	0.469582	-18.272	112.9516	130.5229	150.0645	185.9403	1.0014783	1.9959062	0.32796296	0.8077721
385	0.1748449	0.1056084	0.2295082	0.3925931	0.4700038	-18.58147	112.7042	129.1134	150.2308	184.3903	1.0015029	1.9960121	0.32523083	0.7990962
386	0.1750828	0.1056084	0.2146677	0.383315	0.469582	-18.83317	112.9517	130.4383	150.9486	185.8769	1.0675684	1.9720692	0.33318457	0.90699
387	0.1748382	0.1056084	0.215715	0.3796863	0.469582	-18.83317	112.6894	129.0074	150.0645	185.8769	1.0014651	1.9560173	0.32911982	0.8004414
388	0.1748382	0.1056084	0.228845	0.382611	0.469582	-18.83317	112.9693	130.1563	150.0645	185.8769	1.0086006	1.9932153	0.32930072	0.8112042
389	0.1748382	0.1056084	0.2146677	0.3870662	0.469582	-18.83317	112.7224	128.9403	150.1577	185.8769	1.0046244	1.9720692	0.32901675	0.8118819
390	0.1748382	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9401	130.2269	150.8555	185.8769	1.0644331	1.9932153	0.33087744	0.8878622
391	0.1748382	0.1121361	0.2144875	0.3799672	0.4705098	-18.83317	112.706	128.9434	150.0645	185.8769	1.0014651	1.9720692	0.32920113	0.8009876
392	0.1748382	0.1056084	0.2278699	0.3842883	0.469582	-19.73471	112.9527	130.2203	150.0645	185.8769	1.0014651	1.9724695	0.32946755	0.8020853
393	0.1749594	0.1056084	0.2268603	0.383315	0.469582	-18.83317	112.9768	129.9989	149.8567	185.8769	1.0026743	1.9725107	0.32882104	0.8042428
394	0.1748382	0.1056084	0.2268603	0.3847444	0.469582	-18.83317	112.9527	130.1563	151.2944	185.8769	1.0223822	1.9724695	0.32957176	0.8342067
395	0.18376	0.1036513	0.2150667	0.3847444	0.4695053	-18.83317	112.7178	130.1563	150.0645	185.8769	1.0014651	1.9724695	0.33048826	0.8124688
396	0.1748382	0.1055927	0.2272907	0.3795112	0.4695855	-18.83317	112.9476	129.003	147.9987	186.3545	1.0014653	1.9823346	0.3277018	0.7917415
397	0.1748382	0.1031536	0.2144762	0.3795112	0.4695088	-18.83317	112.7127	129.003	150.0674	185.9376	1.0014653	1.973715	0.32865165	0.8015341
398	0.1748382	0.1060905	0.2278812	0.383315	0.469582	-18.83317	112.9768	129.9989	151.0866	185.8769	1.0235915	1.9703258	0.32889234	0.8318524
399	0.1748382	0.0943131	0.2161982	0.383315	0.469582	-18.83317	112.6811	129.9989	151.0866	185.8769	1.0235915	1.9720528	0.33134296	0.8405187
400	0.1748382	0.1060632	0.2229253	0.383315	0.469582	-20.05241	113.0056	129.0109	150.9486	185.8769	1.0675924	1.9725175	0.32851644	0.8853723
401	0.1846764	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9816	129.991	150.0645	185.8769	1.0286298	1.9716175	0.32783786	0.8458658
402	0.1704766	0.1056084	0.2268603	0.383315	0.4718826	-19.1631	112.9768	130.1767	151.0866	185.8769	1.0235915	1.9941085	0.32947365	0.8363833
403	0.1748294	0.1056084	0.2160234	0.3824816	0.4700561	-18.83317	107.964	130.2005	150.9486	185.8769	1.0675684	1.9720692	0.33152674	0.898433
404	0.1750916	0.1098871	0.2155152	0.3834444	0.469582	-18.83317	112.9511	130.4648	150.8555	185.8769	1.0644331	1.9929054	0.33309531	0.9015589
405	0.1748758	0.0946363	0.2134621	0.3833413	0.4695073	-19.66209	112.9768	129.9989	150.1254	185.1489	1.00475	1.972501	0.33102435	0.8141599
406	0.1837223	0.103783	0.2260604	0.3847181	0.46958	-18.83317	112.7178	130.1563	151.0257	185.8769	1.0203066	1.9724695	0.32873865	0.8374247
407	0.1756586	0.1056084	0.2153314	0.383315	0.4695153	-18.83317	112.9768	129.9989	151.0866	185.8769	1.0030619	1.9725107	0.33056084	0.8115008
408	0.1829396	0.1036513	0.2265956	0.3828253	0.469572	-16.57837	112.7178	130.1563	150.0645	185.8769	1.0219946	1.9724695	0.32767247	0.8364933
409	0.1748382	0.1056084	0.2268603	0.3847444	0.469582	-18.83317	112.9527	129.1143	149.941	185.8769	1.0228306	1.9724695	0.32721551	0.8274592
410	0.1748382	0.1056084	0.2268603	0.382611	0.469582	-18.83317	112.9816	130.1688	151.4179	185.8769	1.0251951	1.9932153	0.32814191	0.8375278
411	0.1748382	0.1036356	0.2161657	0.3795112	0.4695092	-18.83317	112.7127	128.9409	150.0674	185.8769	1.0014653	1.9730009	0.3288231	0.8015533
412	0.1748382	0.1056084	0.2261917	0.382611	0.4695816	-18.83317	112.9527	130.2185	150.0645	185.8769	1.0014651	1.9939294	0.32909437	0.8019002
413	0.1750828	0.1056084	0.2161256	0.3826697	0.469582	-18.83317	112.9397	130.204	150.9486	185.8769	1.0675684	1.9720692	0.33178122	0.9023943
414	0.1748382	0.1056084	0.2254024	0.3832562	0.469582	-18.83317	112.9521	130.4613	150.8555	186.0688	1.0644331	1.9932153	0.33032582	0.8931921
415	0.1748382	0.1056084	0.2044481	0.3847444	0.469582	-18.83317	112.9527	128.9521	150.1532	185.8769	1.0223822	1.9753422	0.3311214	0.8449731
416	0.1748382	0.1036356	0.2258088	0.3795112	0.4695088	-18.83317	112.7127	128.6585	151.2086	187.8436	1.0014653	1.973715	0.32398696	0.7920991
417	0.1748382	0.0952152	0.2244558	0.3832475	0.469582	-18.83317	112.7339	130.0067	151.0866	185.8769	1.0235915	1.972501	0.33000789	0.8336873
418	0.18376	0.103204	0.2150667	0.3848118	0.4695053	-18.83317	112.9607	130.1485	150.0645	185.8769	1.0014651	1.9724695	0.33099989	0.8134665
419	0.1750828	0.1056084	0.2146677	0.383315	0.469582	-18.83317	112.9517	130.4383	152.2909	185.8769	1.0675684	1.9720692	0	0
420	0.1750828	0.1056084	0.2146677	0.383315	0.469582	-18.83317	112.9517	130.4383	150.9486	185.8769	1.0675684	1.9720692	0.33318457	0.90699