Engineer assistant internship report

Tests of several concepts on the behavior of automotive water pumps

Jean-Paul LE : Etudiant Ingénieur EMME – Mécanique des Fluides et Energétiques à Polytech Nancy

Anne TANIERE : Tutrice académique / Enseignante & chercheuse à Polytech Nancy

Anita GRENIER : Tutrice entreprise / Experte Dynamique des Fluides à Sogefi Air & Cooling Business Unit

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I - PRESENTATION OF THE INTERNSHIP

I.a. - Context

SOGEFI with the aim of always offering the best products to its customers, is in perpetual research and development of new products ensuring better cooling cycles, better filtration of the air entering the cylinders and better combustion.

In the automotive sector, there are a large number of different tests (acoustic, thermal, aging, vibration, cyclic pressure, etc.) that parts must pass to comply with standards and best meet customer requirements. The company is committed to meeting these criteria with the use of suitable test benches and machines.

During the combustion of gases in the cylinder and the combustion chamber of the engine, heat is created and needs to be evacuated. Indeed, a lack of cooling has several consequences on the mechanism such as the expansion of parts and gases, overheating of the gases, a change in material properties and many others.

The main part of my internship focuses on the cooling circuit, specifically the automotive water pump. This element is essential to ensure the circulation of the coolant in the circuit. Using an engine and heat transfer fluid, the pump cools the engine block. In our study, the fluid used is glycol water. The company wants to improve the efficiency of the pumps, thereby reducing CO2 emissions and fuel consumption.

The design of a pump is based on customer needs which is based on the concept of design point. This is a characteristic point of water pumps through which the company must pass to comply with the rest of the cooling circuit imposed by the manufacturer. The design point is composed of the flow rate of the fluid Q, a pressure delta ΔP and the speed of rotation of the pump.

In order to optimize performance, while taking into account space constraints, we must size and propose new water pump concepts.

Problem

As an intern, my problem is to test new concepts on the behavior of water pumps by a study on the volutes and turbines. These tests make it possible to record the performance curves (efficiency and pressure drops) for different pump models such as designs of volutes with adjustable (variable) and fixed height or turbines with blades of various shapes.

I.b. - Objectives

To answer the problem, we must achieve these objectives:

- Initially, we focused on bibliographic research on automotive water pumps. We will study its components and how they work. In addition, we will understand the influence of the volute nozzle, splitters, back blades, flange and other parts of the impeller and volute having an influence on the performance of the pump.

- On a test bench, we must first take note of the pressure drop curves and the efficiency of the new volutes (volute at fixed height and adjustable height) of the water pump. There is no design phrase, the prototypes are already designed.

- Numerical models are to be carried out on the CF Turbo software. They make it possible to obtain correlations (1D calculations) between computer simulation and reality. They give by, calculations, the impacts on the performances in the event of modifications on the parts. This saves time and money because it eliminates the need to design a product and perform tests on it.

The results (measurement curves) and bibliographic research will be located in the appendix.

II - PUMP STUDY

II.a. - Role of the water pump

As the objectives of the internship show, my work focuses on the study of the water pump. On the company site, we focus on water pumps or more precisely in our case "mixed flow pump". The main function of the water pump is to circulate coolant through an engine. This technology is made up of two main elements:

- - An impeller (moving part or rotor): In the form of a wheel and coupled to the motor, it will rotate the fluid and allow it to circulate.
- - A volute (static part or stator): This is the receptacle, the body of the pump which directs the fluid at its inlet but also at its outlet. We often find it in the form of a spiral. When it comes out, there are one or two diffusers.

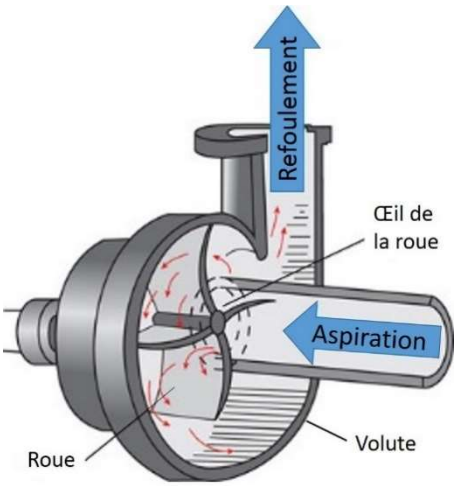


FIGURE 1 : SCHEMA D'UNE POMPE A EAU

II.b. - Impeller vocabulary

The turbines of water pumps mainly consist of the blades, a hub and possibly a flange. Before starting any design or sizing, it is essential to know the vocabulary associated with this system. The main characteristics of the water pump turbines that we are going to study are:

• d2 or Dext: This is the outside diameter of the turbine

• dS: This is the suction diameter. It also represents the inside diameter of the flange or inlet duct.

• Dhub: This is the diameter of the hub

Regarding the blades, we will also talk about:

• Attack side

• Drag side

• Blade outlet height: b2

• Blade length

• Blade entry angle: $\beta 1$

• Blade exit angle: $\beta 2$

• The winding angle of the blades: $\delta\varphi$

• The Lean angle: λ which corresponds to the angle of inclination of the blades in the case where we are dealing with 3D blades

II.c. - Volute vocabulary

The volute consists of a spiral-shaped cavity in which the fluid will circulate and a diffuser that straightens the velocities of the fluid before exiting the water pump. Regarding this piece, we will mainly talk about:

- • Volute inlet diameter: dln which is the diameter of the volute at the spout (i.e. the smallest diameter)

- • Volute height: bln
- • Volute nozzle: This is the angle between the spiral and the diffuser
- • Coefficient of enlargement ks: This is the numerical way of enlarging the spiral of the volute, we can have a fine magnification (ks = 0.8 for example) or a thick magnification (ks = 0.2).

III - COURSE OF THE INTERNSHIP

III.a. - The chronology of the project

My internship went as follows:

- Study of the characteristics of the water pump by bibliographic research (tip clearance, spout width, splitter, back blade, etc.).

- Training on CFTurbo software.

- Study of the influence of splitters on 2 pump models using CFTurbo software.

- Installation of a pump circuit to measure its performance (efficiency and DP) by varying the engine speed and flow.

I. Pumps testing

As stated in the course objectives, we must read the pressure at different locations in a circuit, the motor torque, the flow rate and the temperature of the fluid. The company asked us for measurements for 5 different engine speeds and for each speed, 5 different flow rates. This makes 25 measurements for each “turbine - volute” pair.

The initial goal was to test 3 volutes and for each volute there are 6 turbines. Since a pump consists of a volute and a turbine, we had to do a total of 18 tests. As the test bench was not available throughout my internship, I might not be able to do all the necessary testing.

Electric pump

We installed the first pump, which is an electric pump, on the test bench. The pump torque being too low, we had to install a 1N.m torque meter which was more suitable for the situation.

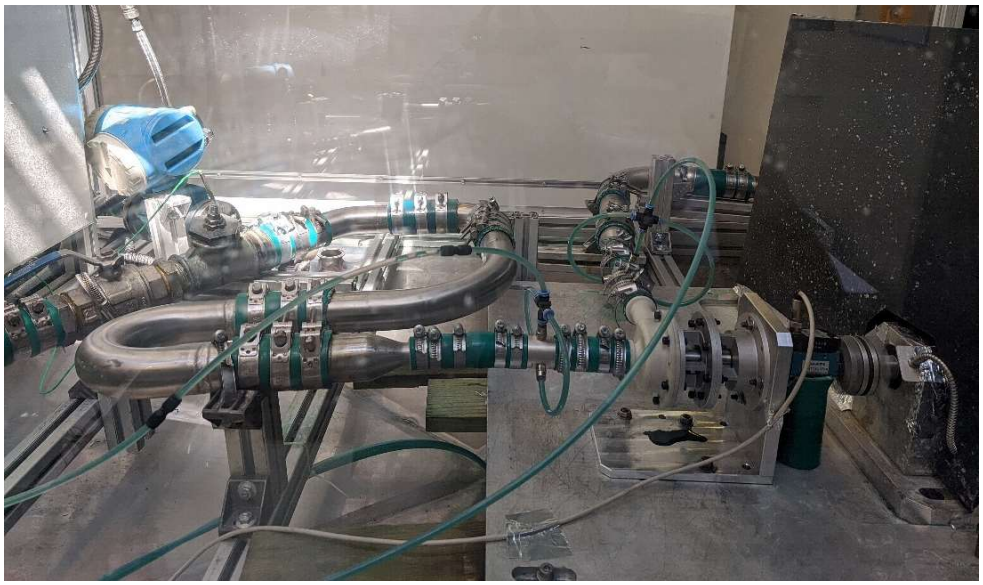


FIGURE 2 : CIRCUIT AVEC LA POMPE ELECTRIQUE

After installing the circuit and taking the measurements, we found that the torque measurements at 3000 rpm were incorrect. Initially, we had taken an instantaneous value of this one but we noticed afterwards that the curve of the torque of this mode had a big fluctuation. We restarted the measurements for this speed and this time took the average value of the torque.

For this circuit, it was necessary to measure the no-load torque for each speed. From 6000 rpm, the part malfunctioned due to excess play in the turbine shaft, which caused a loss of stability. We still got the measurement at 6000 rpm but there is no measurement for 8000 rpm because the probability of damaging the part was too great.

The next measurements were made on a pump in which we change the turbine and the volute. As stated previously, there are 6 turbines and 3 volutes. For confidentiality reasons, we will not detail their characteristics. For this pump, we will use a torque meter of 5N.m.

FIGURE 3 : CIRCUIT AVEC LA POMPE MODELE A

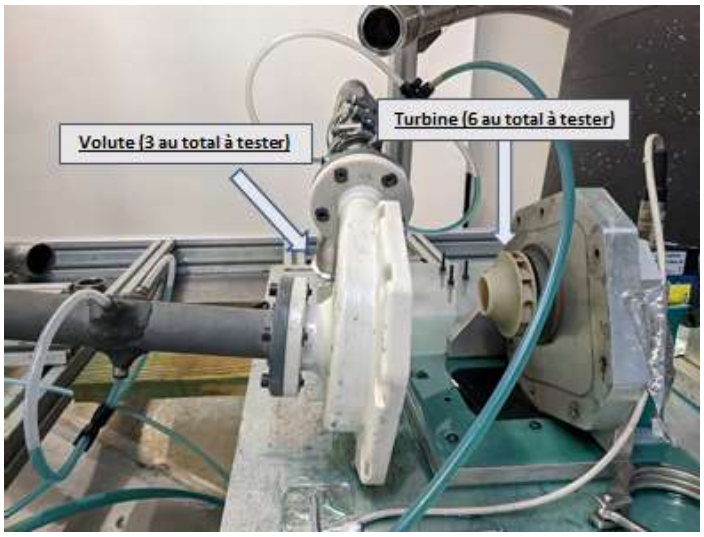
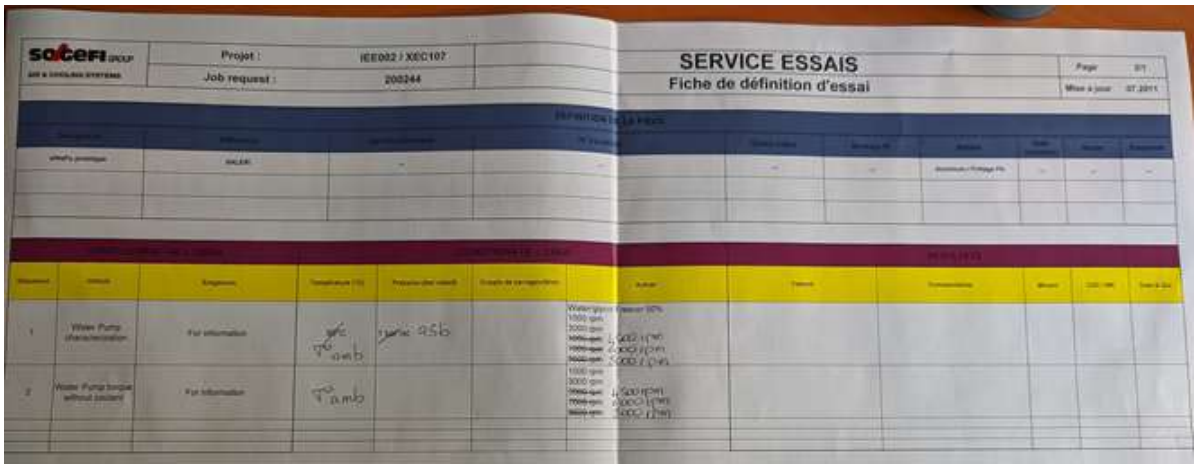


FIGURE 4 : LES CONFIGURATIONS DE LA POMPE

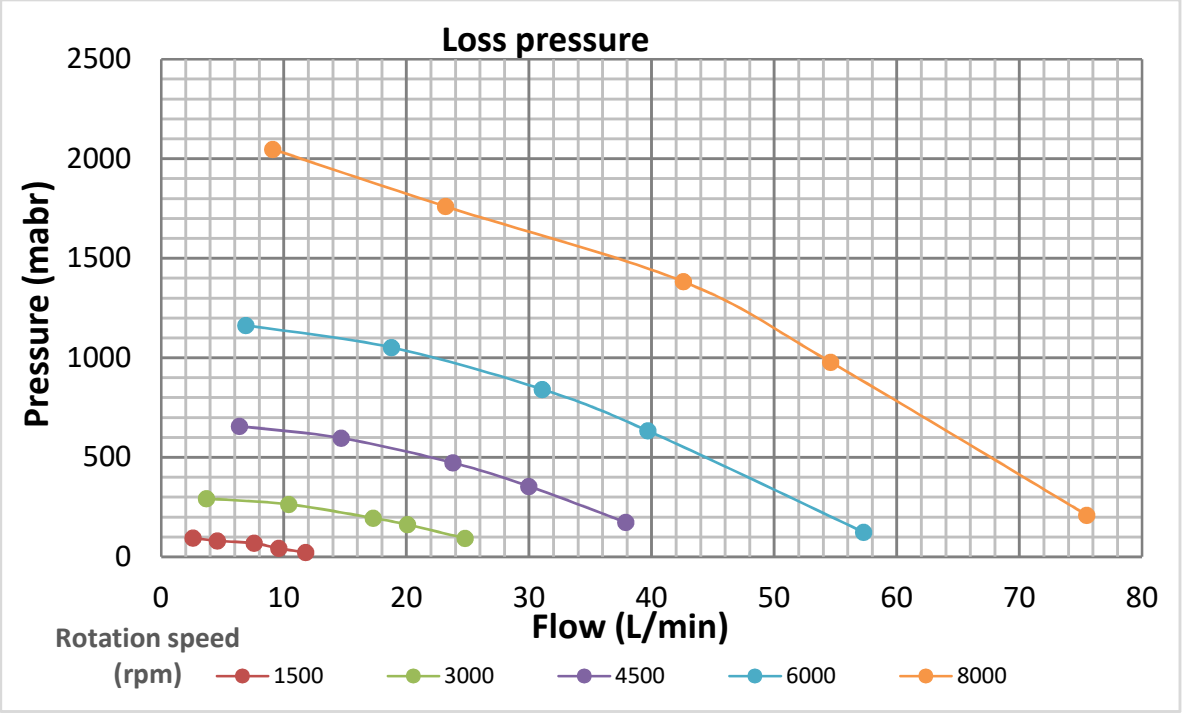
During the 4th test, a turbine could not withstand excess pressure and therefore broke. In addition, the remaining turbines are mounted on a part but the company no longer has the tools to dismantle them. There are therefore in the end, 3 volutes and 3 turbines to test which makes a total of 9 tests.

I. Handling on the test bench

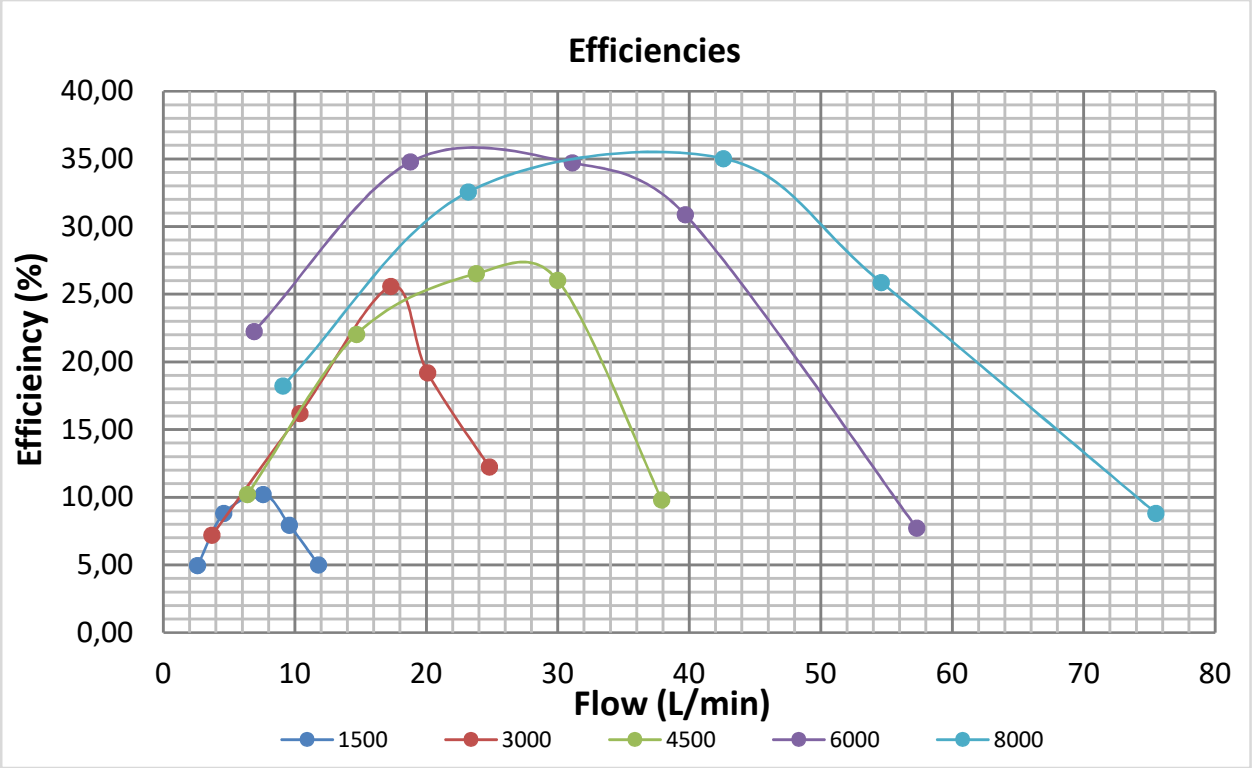


EXEMPLE DE FICHE DE DEFINITION D'ESSAI

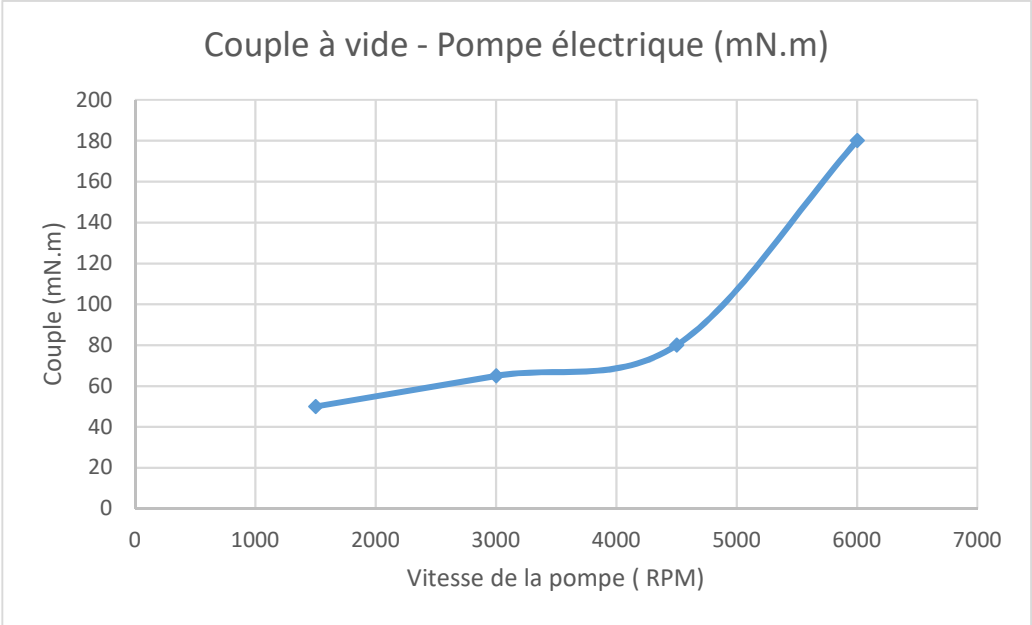
1) Electric pump



GRAPHE 4 : DP DE LA POMPE ELECTRIQUE



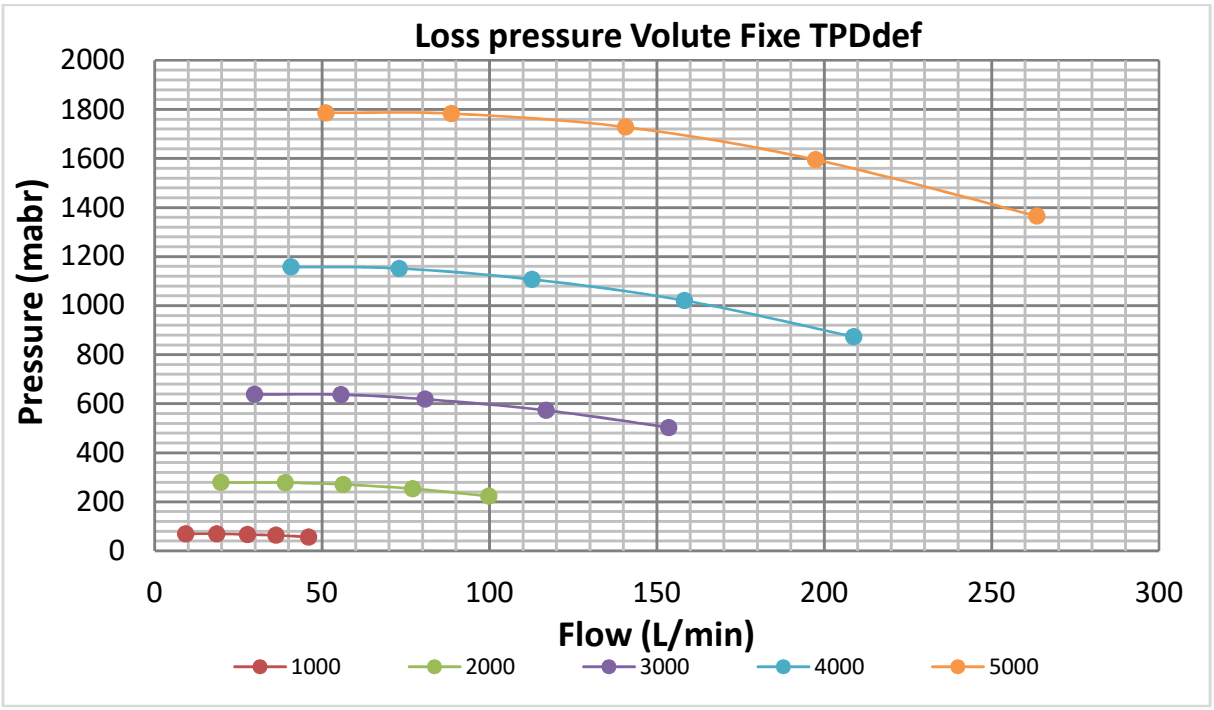
GRAPHE 5 : RENDEMENT DE LA POMPE ELECTRIQUE



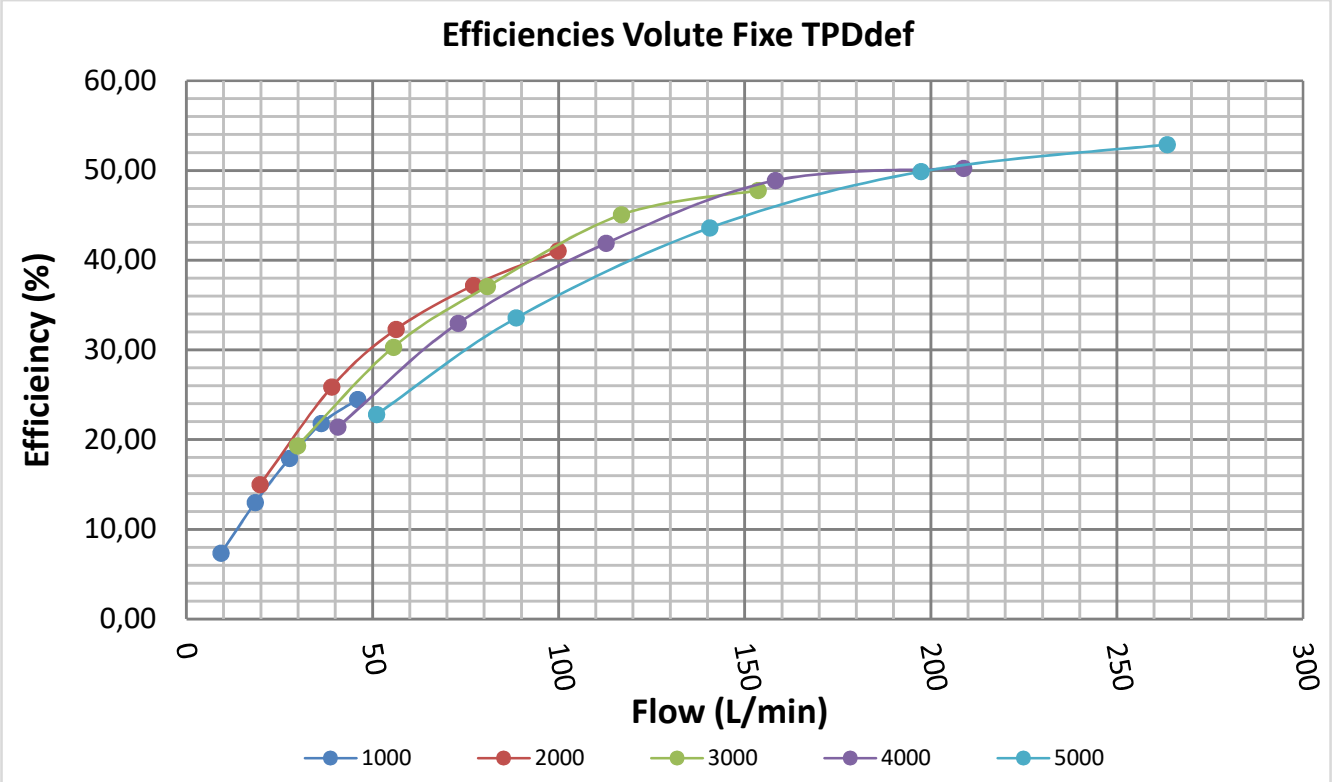
GRAPHE 6 : MESURE DU COUPLE A VIDE DE LA POMPE ELECTRIQUE

2) Fixed volute pump

a. Straight blades impeller

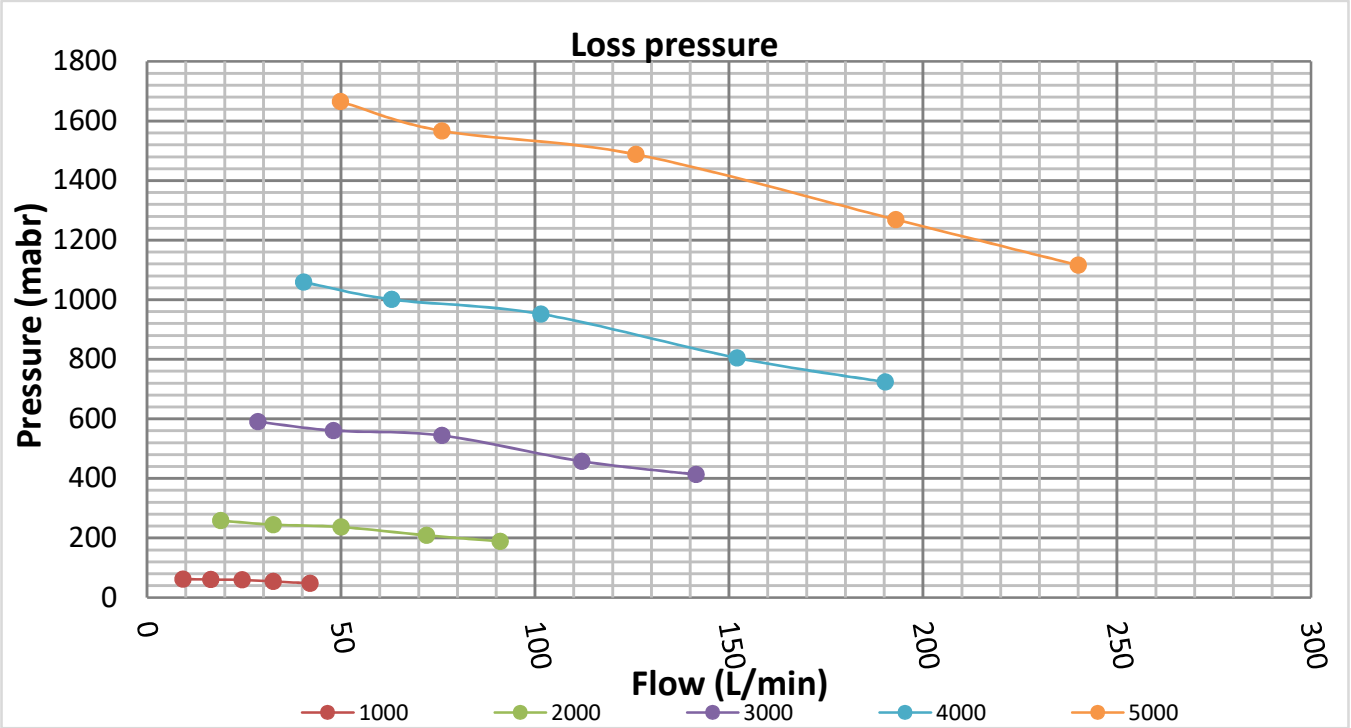


GRAPHE 7: DP DE LA POMPE AVEC VOLUTE FIXE ET PALE DROITES

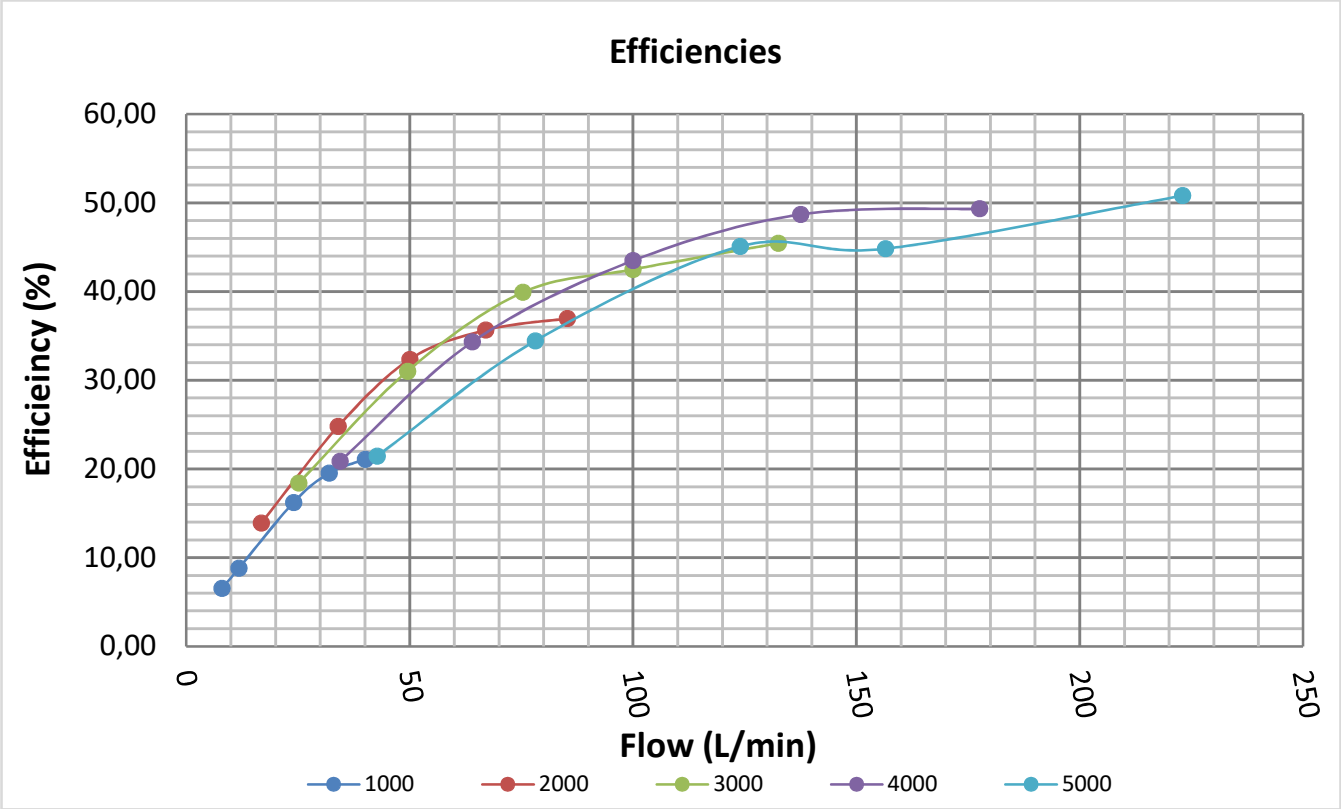


GRAPHE 8 : RENDEMENT DE LA POMPE AVEC VOLUTE FIXE ET PALE DROITES

b. Curved blades impeller

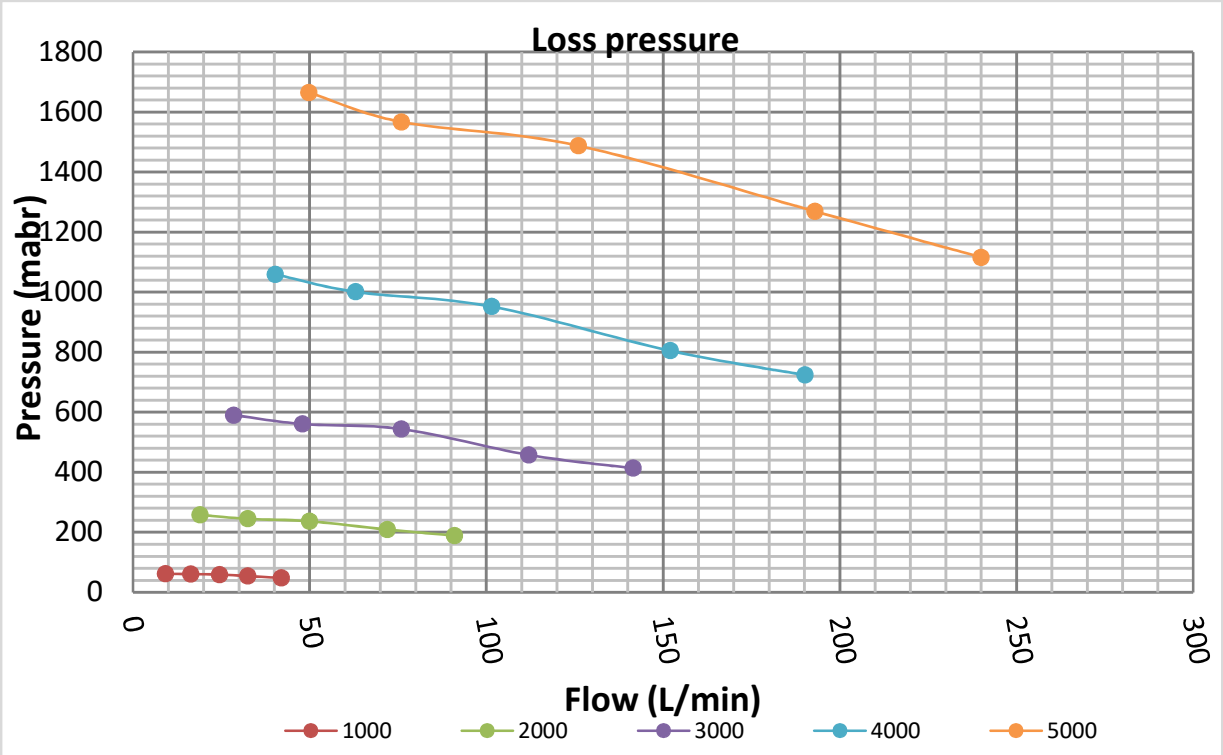


GRAPHE 9: DP DE LA POMPE AVEC VOLUTE FIXE ET PALE COURBES

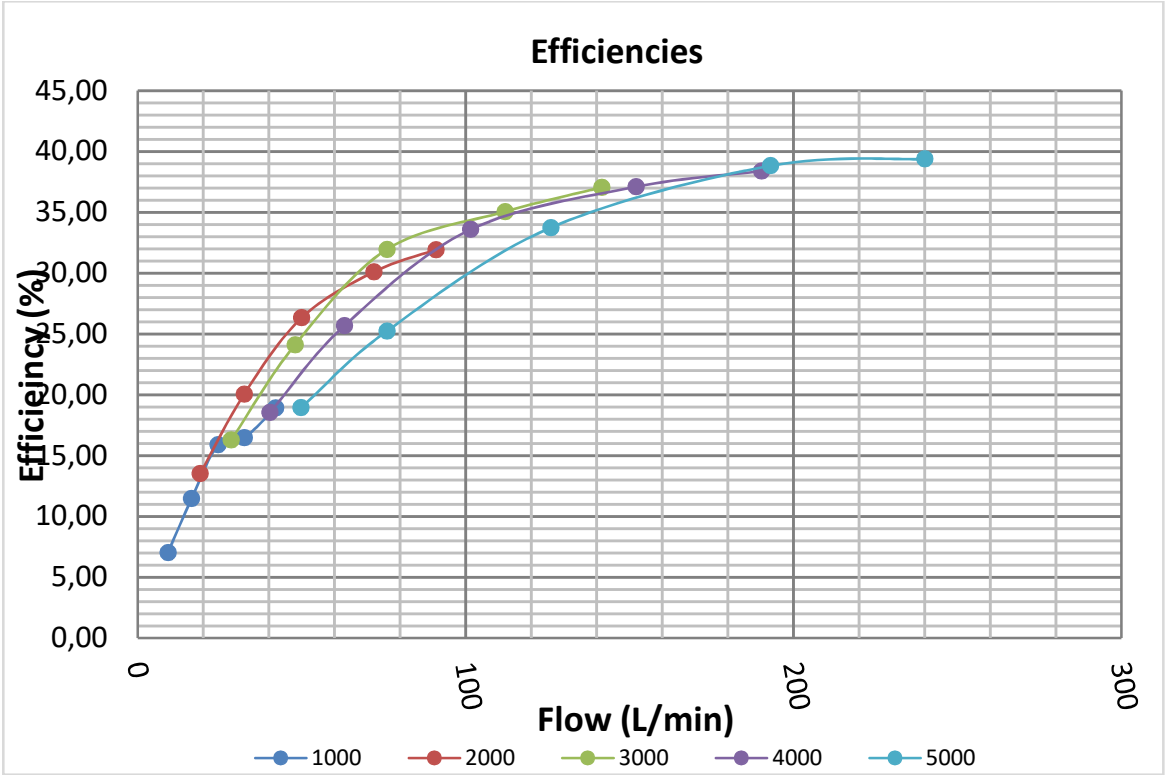


GRAPHE 10 : RENDEMENT DE LA POMPE AVEC VOLUTE FIXE ET PALE COURBES

c. Bucket blades impeller without shroud

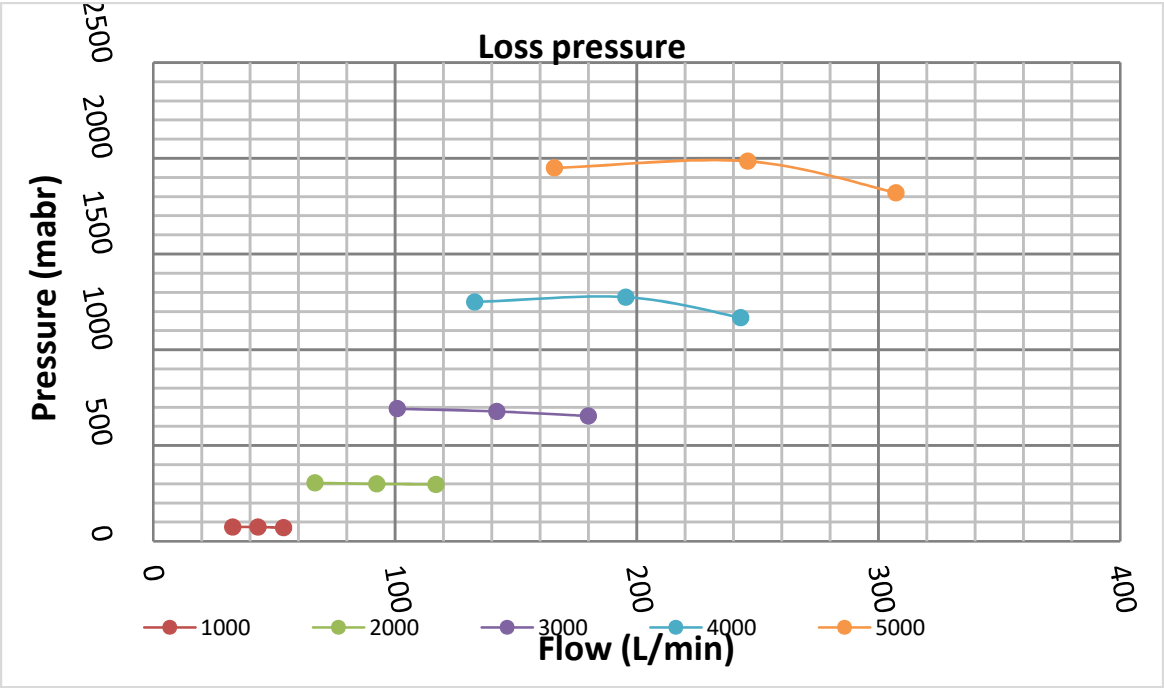


GRAPHE 11 : DP DE LA POMPE AVEC VOLUTE FIXE ET PALE GODET

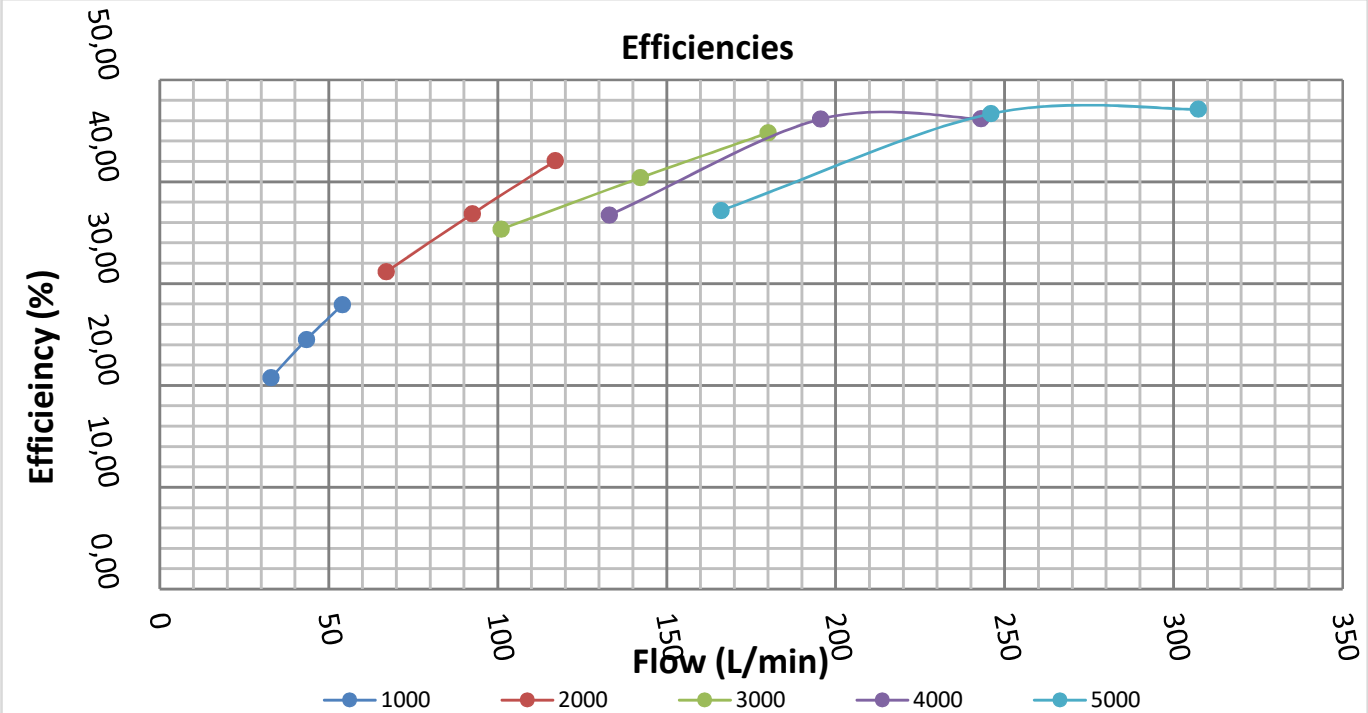


GRAPHE 12 : RENDEMENT DE LA POMPE AVEC VOLUTE FIXE ET PALE GODET

d. Bucket blades impeller with shroud



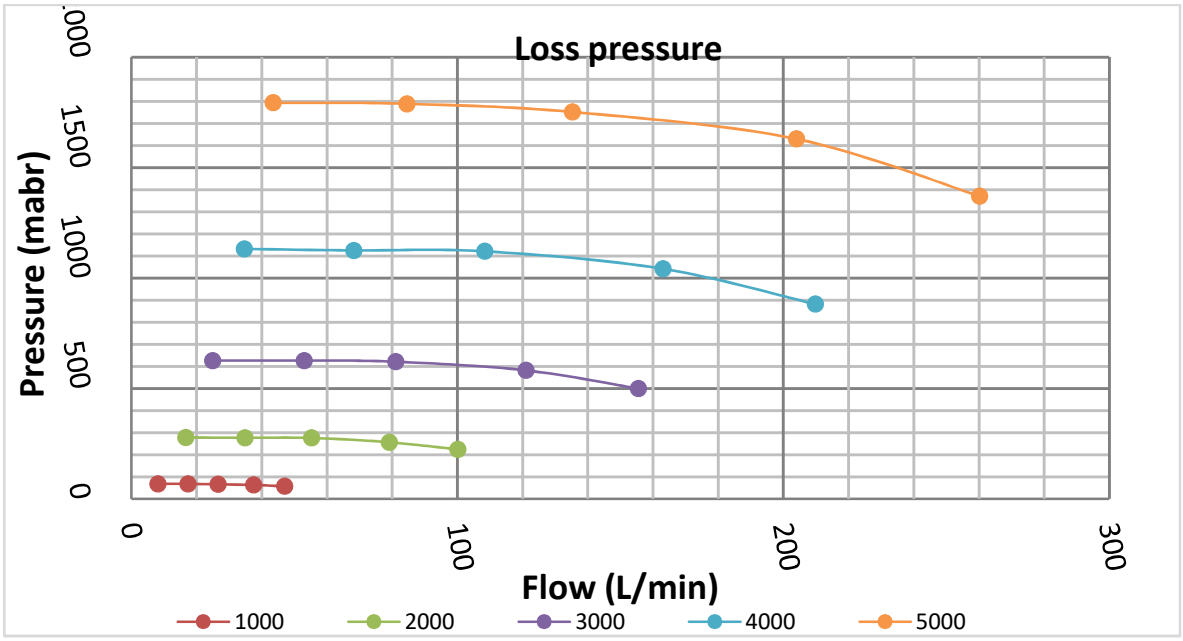
GRAPHE 13 : DP DE LA POMPE AVEC VOLUTE FIXE ET PALE GODET FLASQUEE



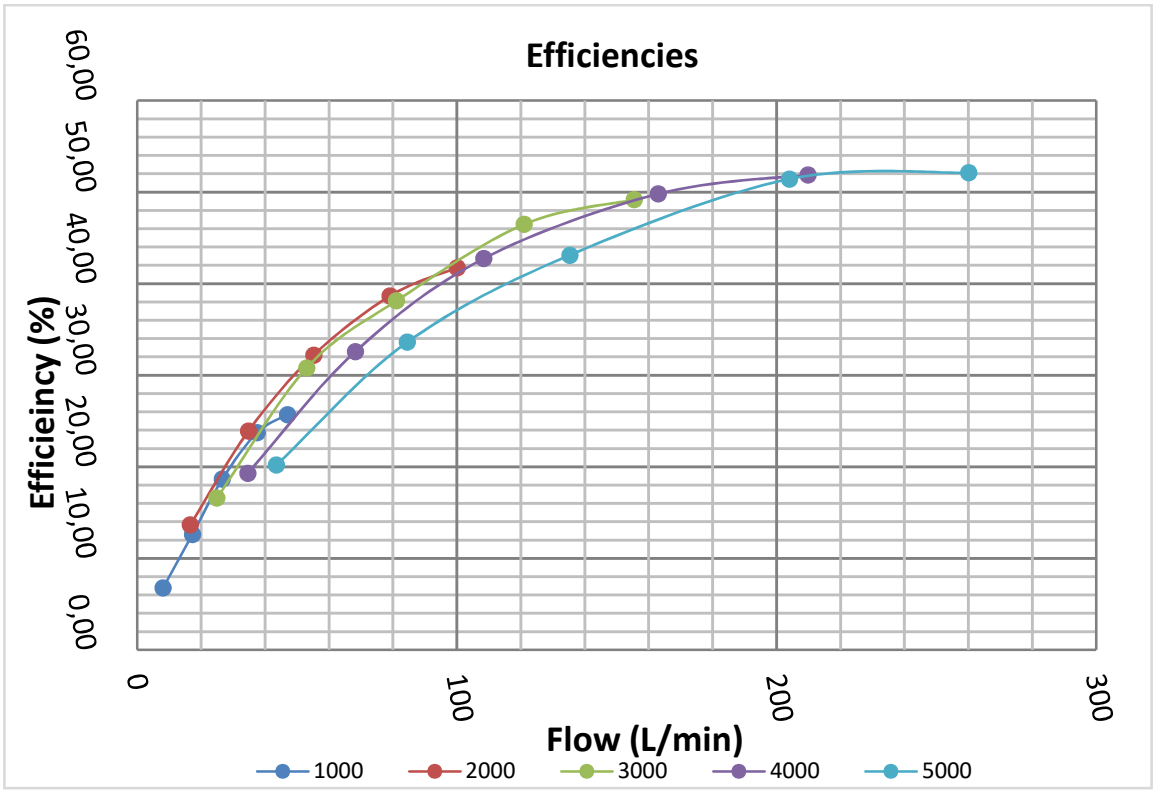
GRAPHE 14 : RENDEMENT DE LA POMPE AVEC VOLUTE FIXE ET PALE GODET FLASQUEE

3) Scalable volute pump

a. Straight blades impeller

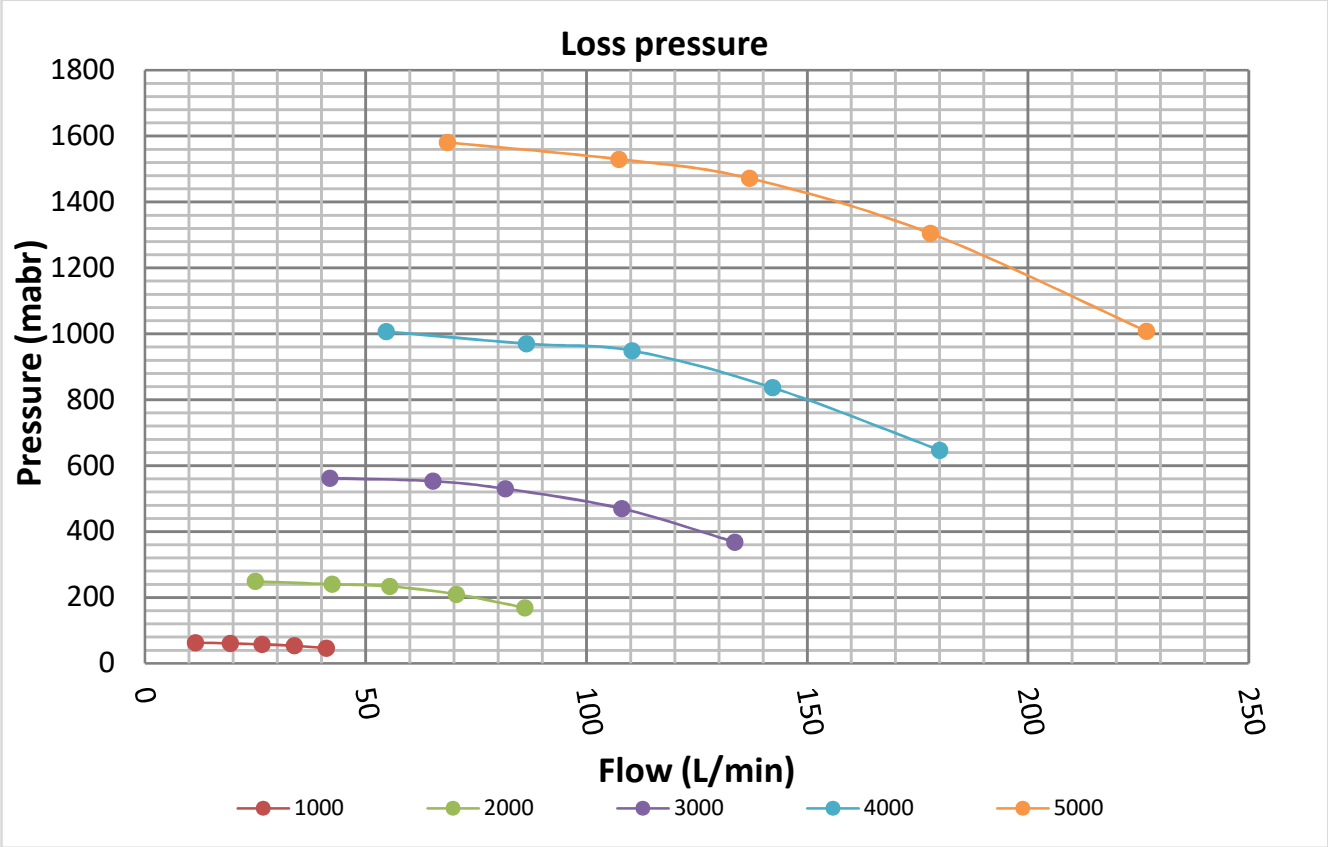


GRAPHE 15 : DP DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE DROITES

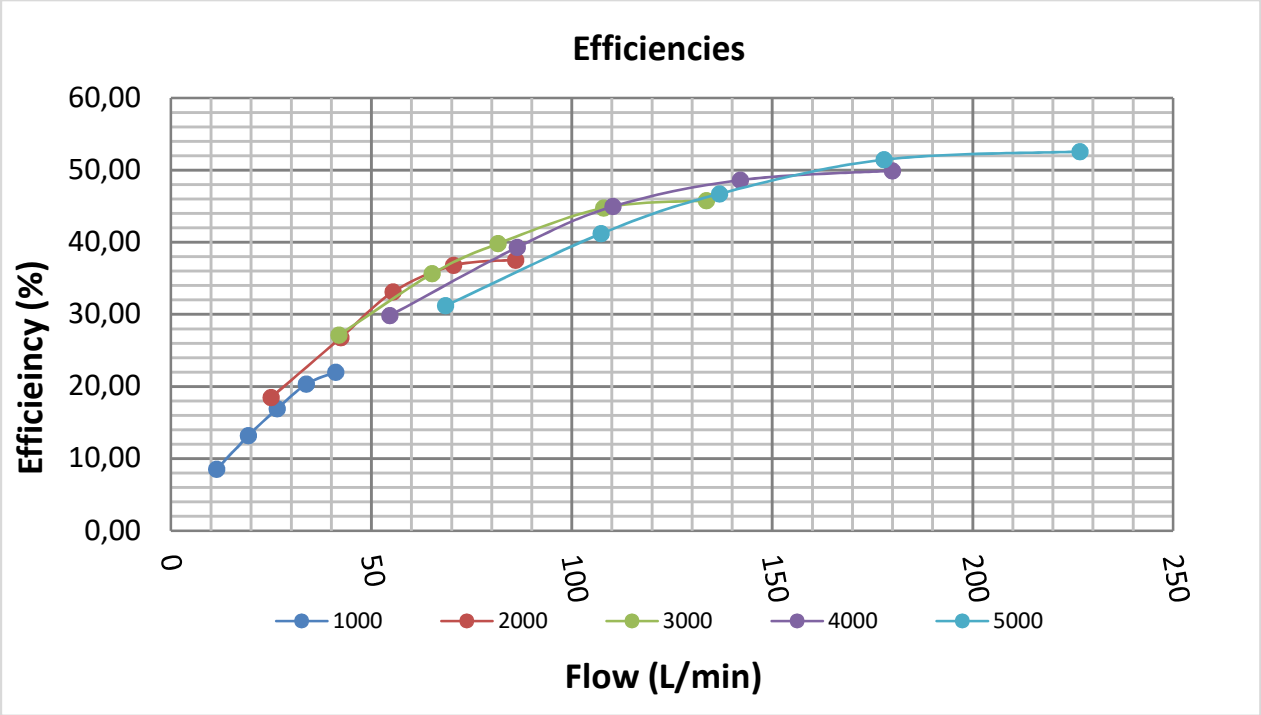


GRAPHE 16 : RENDEMENT DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE DROITES

b. Curved blades impeller

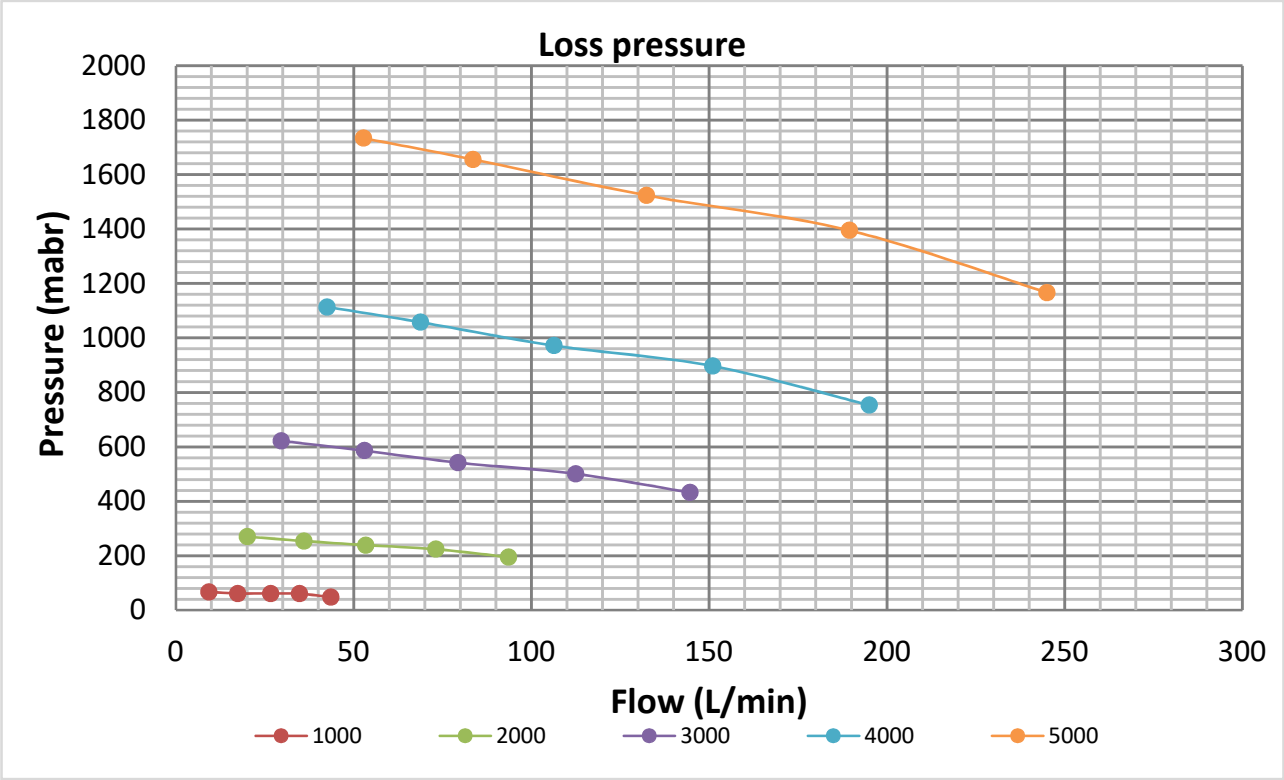


GRAPHE 17 : DP DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE COURBEES

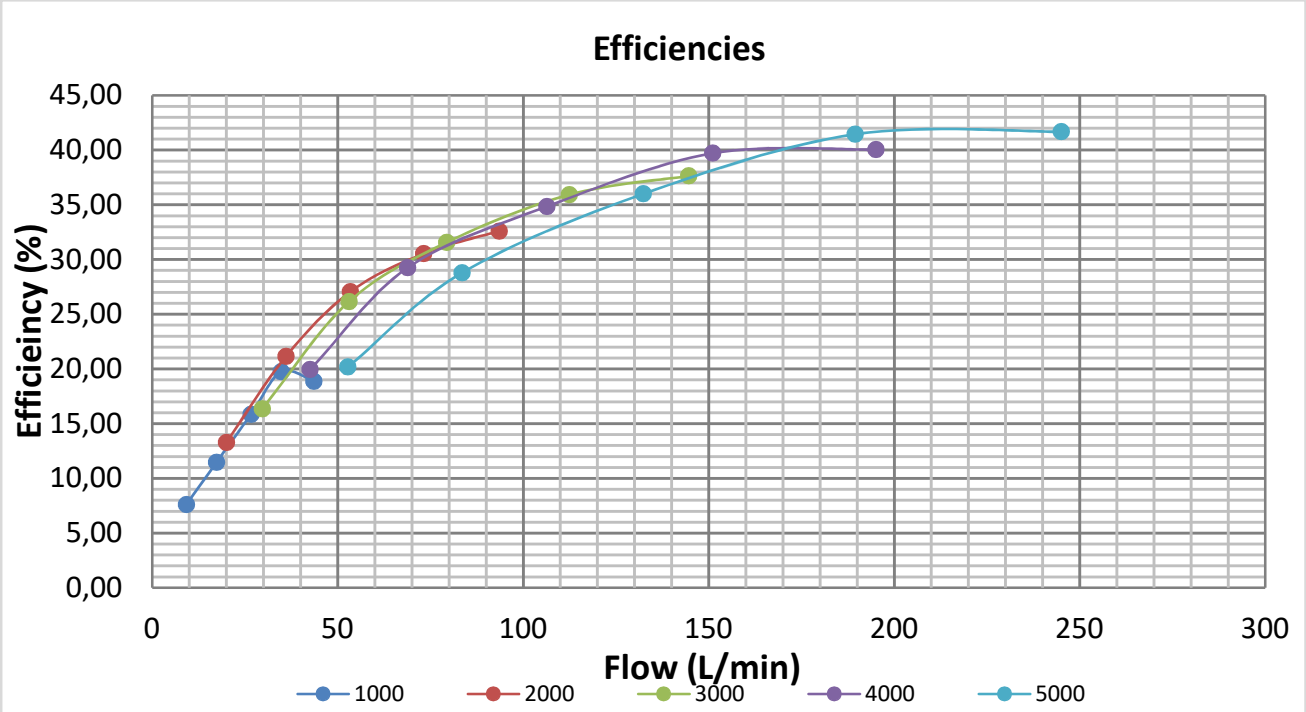


GRAPHE 18 : RENDEMENT DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE COURBEES

c. Bucket blades impeller



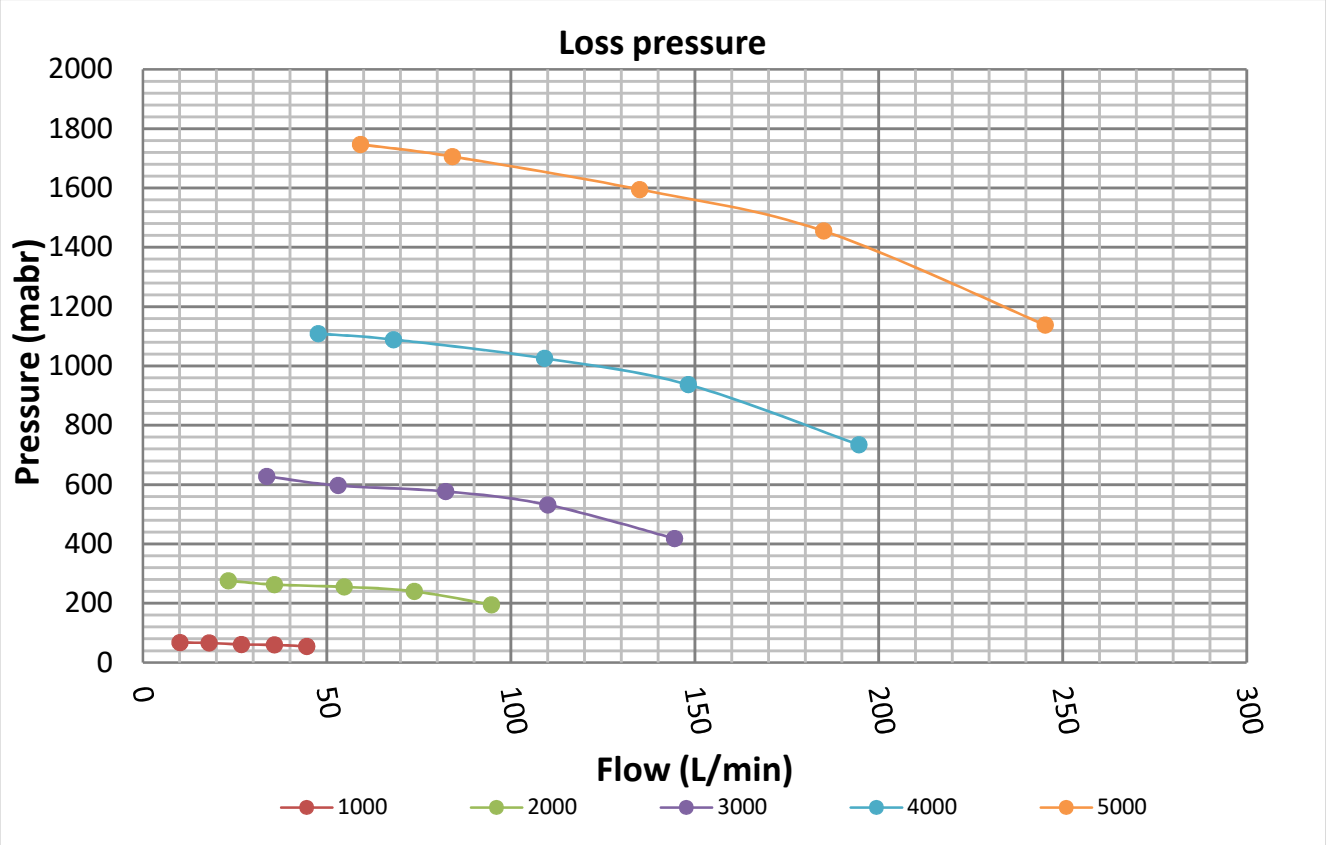
GRAPHE 19 : DP DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE GODET



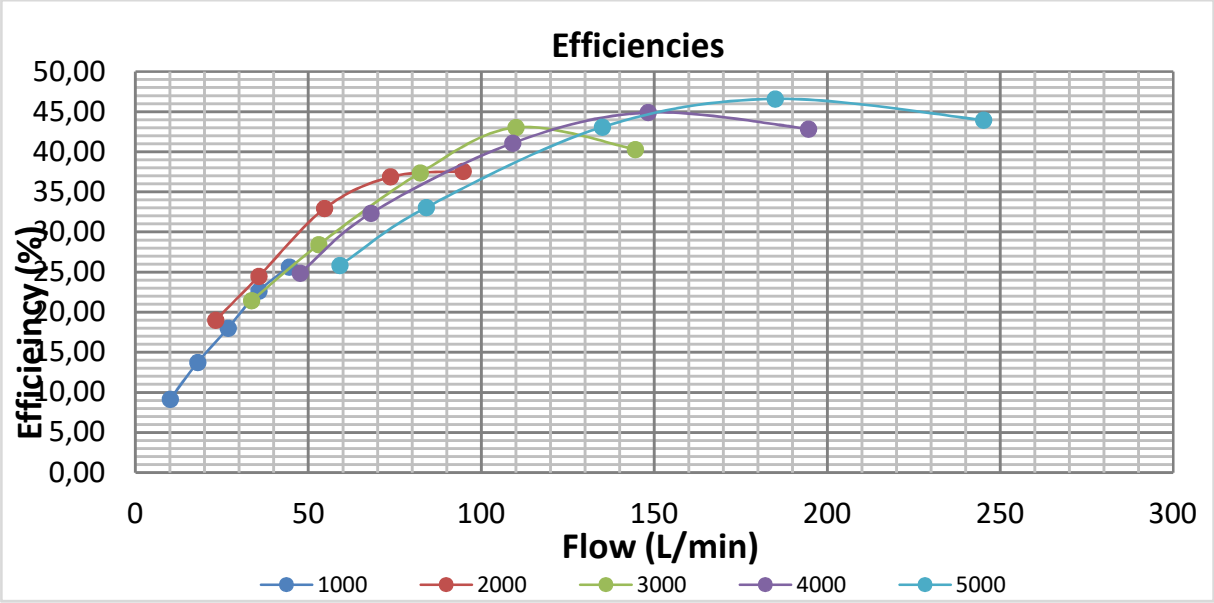
GRAPHE 20 : RENDEMENT DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE GODET

4) Project volute

a) Straight blades impeller

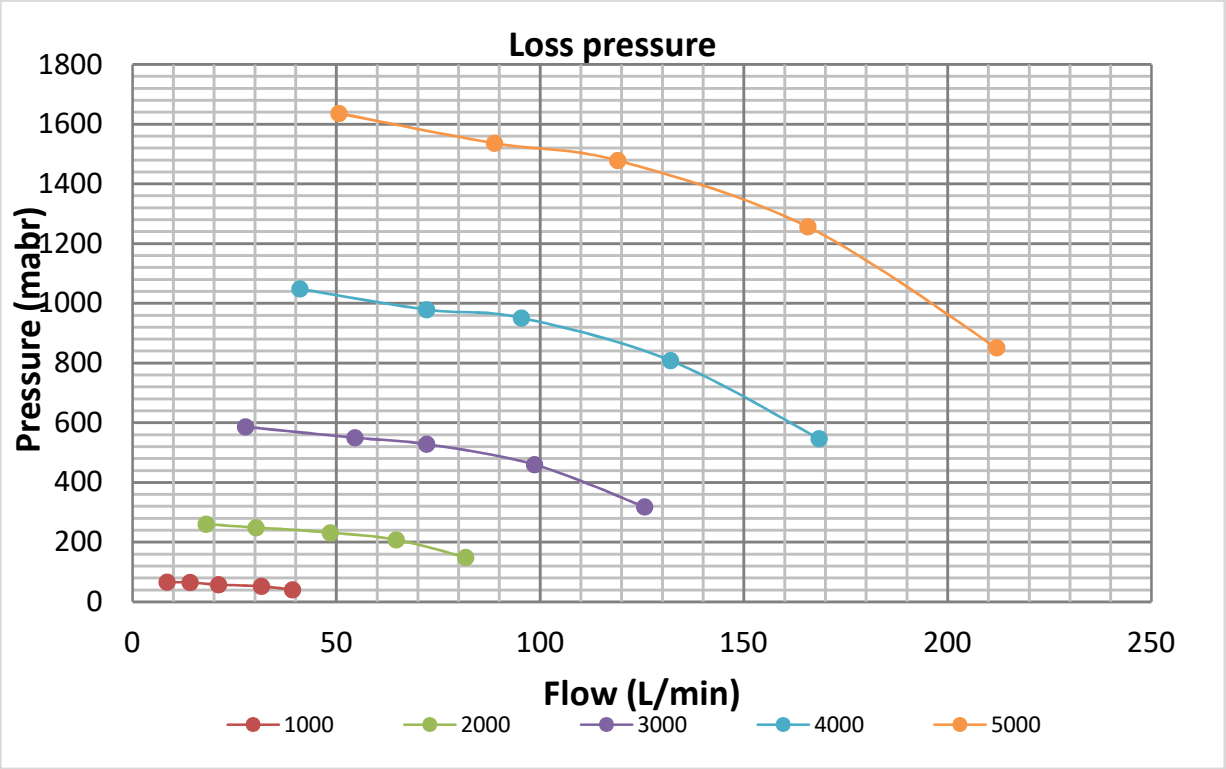


GRAPHE 21 : DP DE LA POMPE AVEC VOLUTE VP ET PALE DROITE

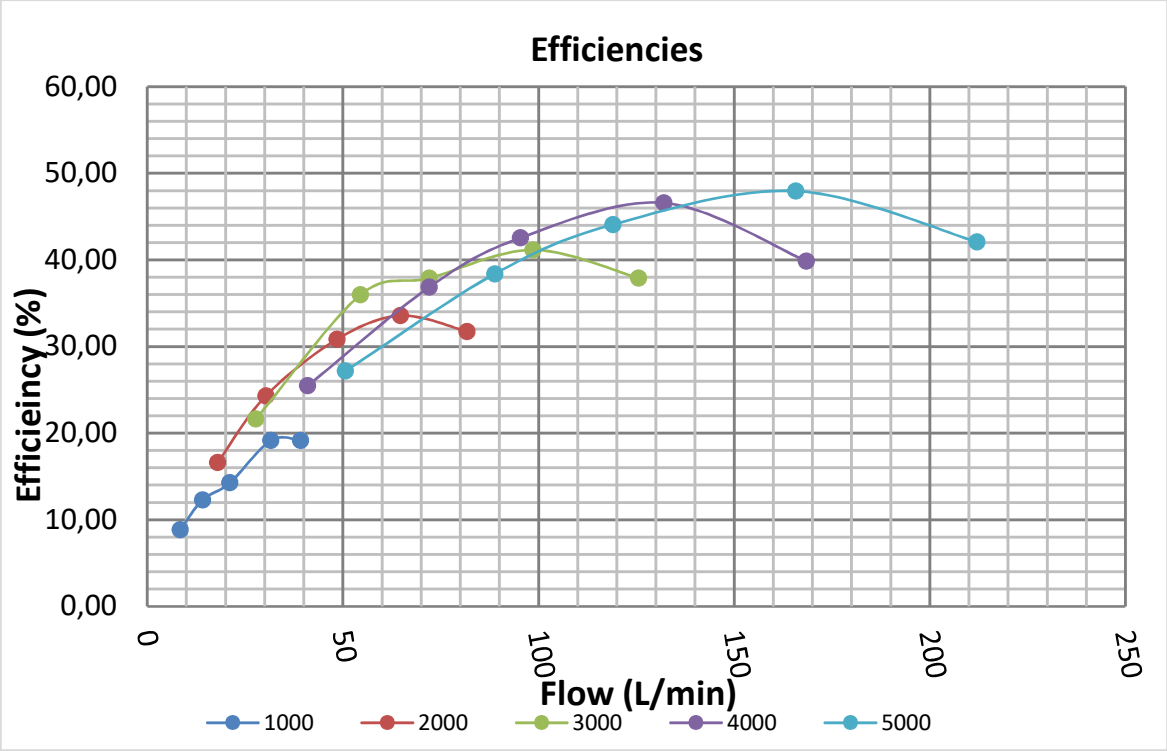


GRAPHE 22 : RENDEMENT DE LA POMPE AVEC VOLUTE EVOLUTIVE ET PALE GODET

b) Curved blades impeller

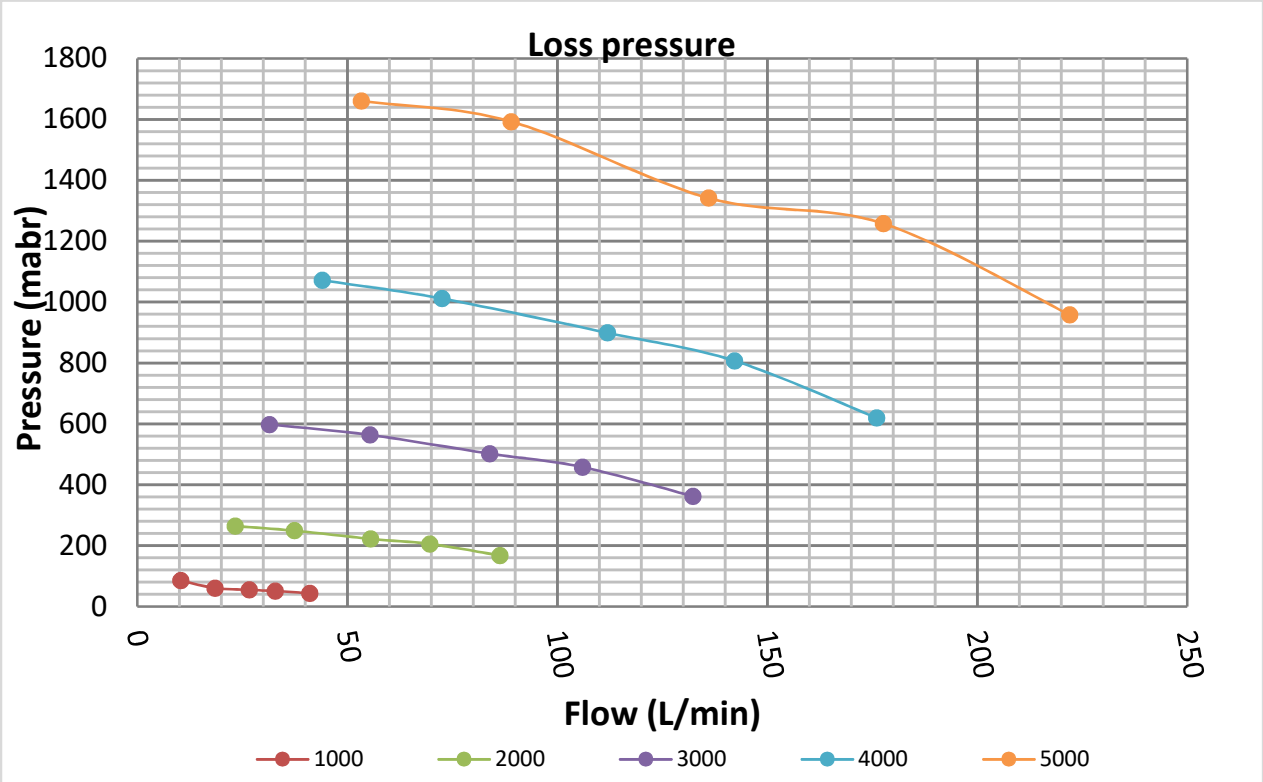


GRAPHE 23 : DP DE LA POMPE AVEC VOLUTE VP ET PALE COURBEES

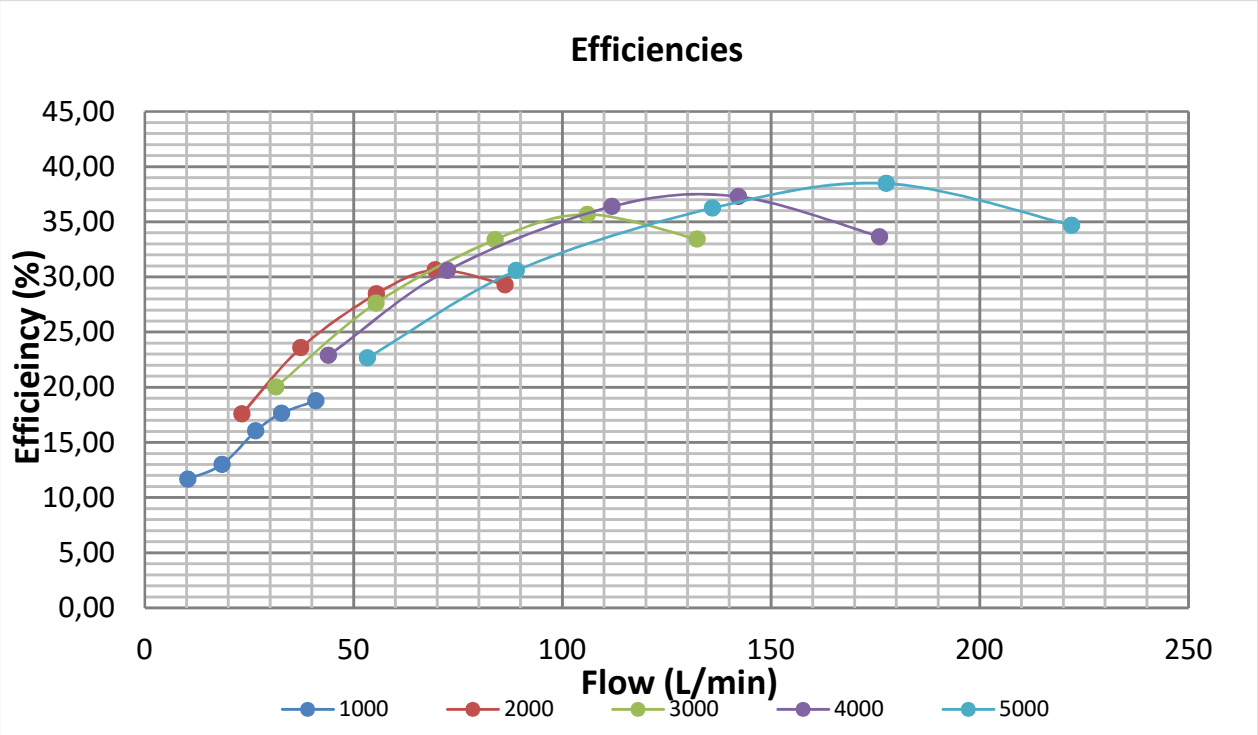


GRAPHE 24 : RENDEMENT DE LA POMPE AVEC VOLUTE VP ET PALE COURBEES

b) Bucket blades impeller



GRAPHE 25 : DP DE LA POMPE AVEC VOLUTE VP ET PALE GODET



GRAPHE 26 : RENDEMENT DE LA POMPE AVEC VOLUTE VP ET PALE GODET

III.b. - The CF TURBO software

III.b.i. - Presentation of the digital tool

The second major part of my internship focuses on the correlation of results under CF TURBO. It is used in many industries for various tasks, we find it in the automotive industry, aerospace, equipment technology, chemical engineering, construction etc ...

The CF TURBO software is a software for pre-sizing systems for driving fluids using a wheel (impeller or turbine). These systems can be water pumps (this can be water or another liquid like glycol), fans and compressors. Its role is to predict the performance of these 1D systems.

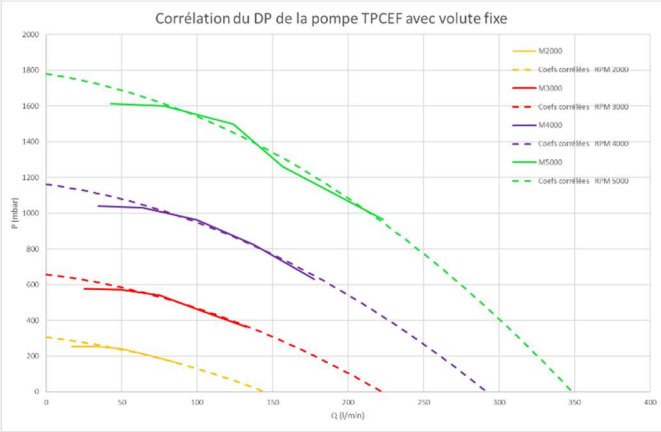
CF TURBO provides a fast and reliable approximation of the performance of a pump or turbine. The results it provides are less precise but it allows a significant saving of time compared to a 3D calculation which can require one to two days of calculation (24h of calculation for 1 flow and a speed of rotation or RPM). This type of software is mainly used to make pre-sizing for customers during calls for tenders (whose response times are very short) and where it is necessary to respond to the offer without delay.

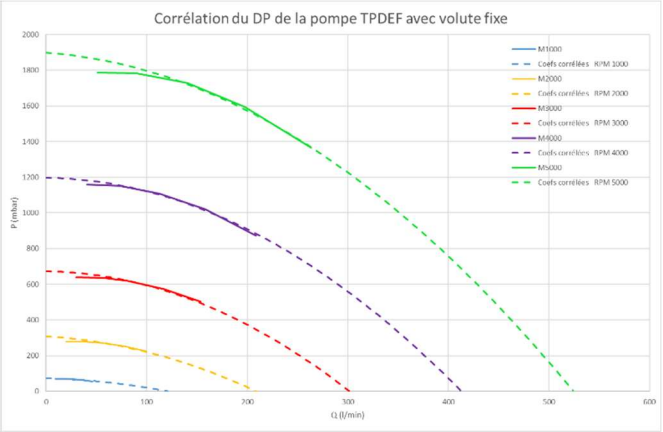
III.b.ii. - Corrélation

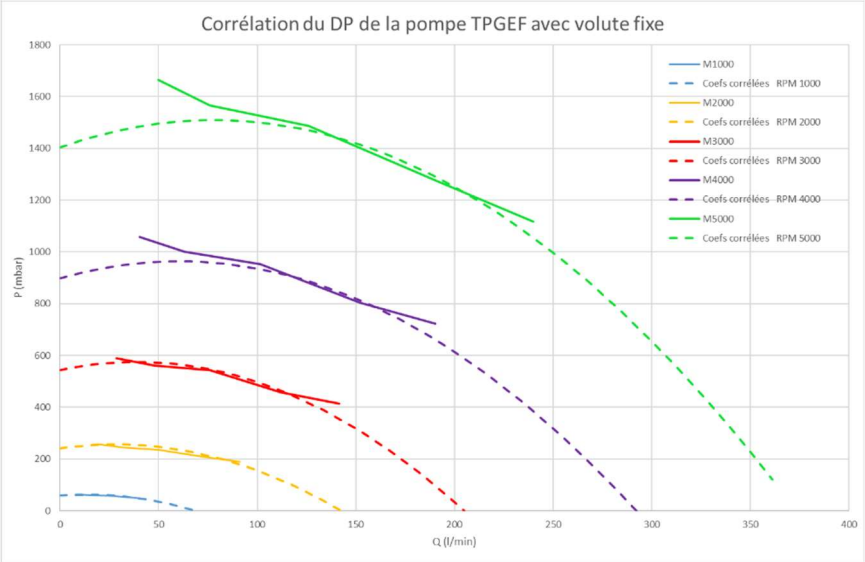
During my internship, my corporate tutor, trained me in this software. The final objective is to find the loss coefficients which made it possible to obtain the correlation. This pump will thus be added to an existing database, and will make it possible to respond to future calls for tenders. At the same time, I also used CFTurbo to study the influence of new elements in the pump.

The tested impeller :

The results :







We can see that for small flow rates (<75 l / min at 5000RPM), it is very difficult to correlate the calculation and the tests; On the other hand, for RPMs <3000, it is quite possible.

III.c. - Study of the characteristics of operating parameters of pumps

In a water pump, we can identify many elements each having an influence on the characteristics of the pump. The aim of this research is to better understand the functioning of the pump elements in order to improve their performance and to propose as a test subject to future trainees. We looked in detail at the splitters.

a . The splitters

In an impeller, it is possible to meet several different configurations. A turbine can essentially consist of main blades or else of blades and splitters. The main blades have the greatest length while the splitters are only portions of the blades.

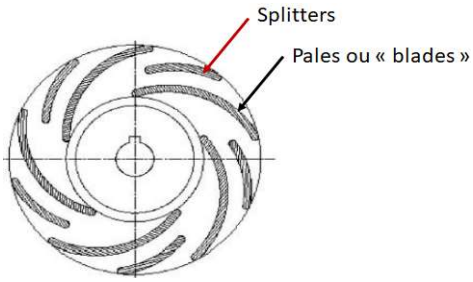


FIGURE 5 : VUE EN FACE D'UNE TURBINE EQUIPEE DE SPLITTERS

Several studies show that replacing certain blades with splitters improves pump performance. It is possible to optimize their efficiency by varying their length, number and position relative to the blades. For example, if we increase the number of splitters, the head will also increase, but this decreases the efficiency.

Replacing the blades with splitters is an effective solution for pumps. Splitters cost less to design due to their size and take up less space in a turbine. In terms of performance, this varies depending on the pump model. According to research, they generally increase the efficiency and the pressure delta DP. Otherwise, the decrease in the pressure delta is not high.

I . Study on 2 pumps

My first study on CFTurbo concerns the implementation of splitters on two pump models A and B. Indeed, the company wants to know whether changing blades by splitters improves their performance or not.

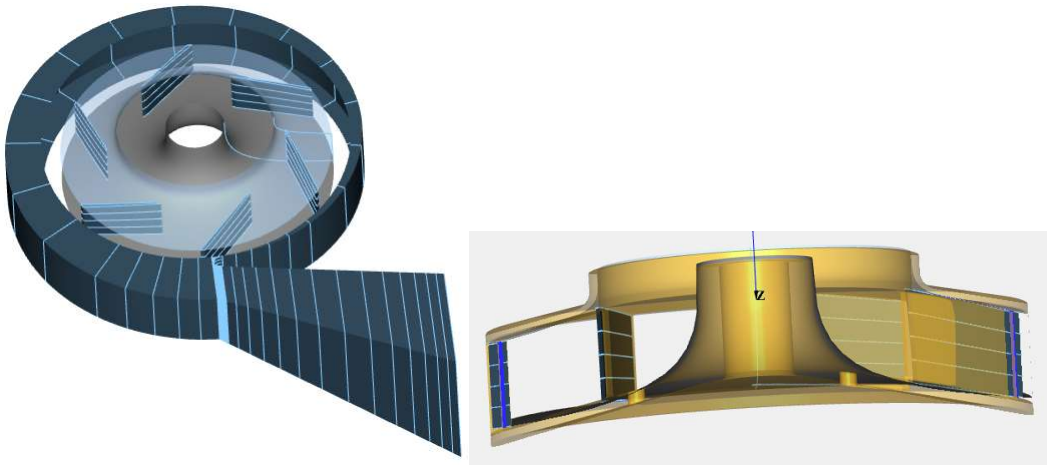


FIGURE 6 : MODELE DE LA POMPE A SANS SPLITTER

First, we defined a pump rotation speed of 6000 rpm and the fluid used is 50% glycol at a temperature of 80 ° C for the first model. The XE006 model has 6 blades and in the configuration with splitters it has 3 blades and 3 splitters.

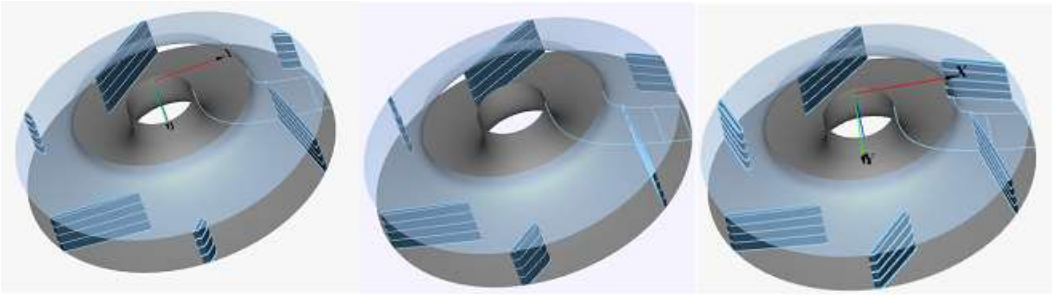


FIGURE 7 : EXEMPLE DE CONFIGURATION DE SPLITTERS (L25%/L50%/L75%)

We compared the influence of the splitters on the DP and the efficiency according to its position in relation to the blade and its length for 3 percentages 25%, 50% and 75%, so there are 9 different splitter configurations.

By observing the PD and yield curves, here is our conclusion on the splitters for this model. We have seen through research that the implementation of splitters made it possible to increase the performance of the pump, in particular at the level of the pressure delta DP, which is the present case. However, it is necessary to vary the length and the position of the splitters at the same time in order to have a change in efficiency, towards higher flow rates. The maximum yield does not vary. The best configurations in terms of efficiency and DP are the L25% / D 25% and the L75% / D75% (D x%: offset of the splitters by x% with respect to the main blade / L x%: the splitters have a length of x% relative to the main blade).

My second study concerns the model B, the peculiarities of this pump are the curved shape of the blades and the circular shape of the volute. The speed of the pump rotation is 7000 rpm and the fluid used is 50% glycol at a temperature of 30 ° C. The model without splitter has 7 blades and the model with splitter has 4 blades and 4 splitters.

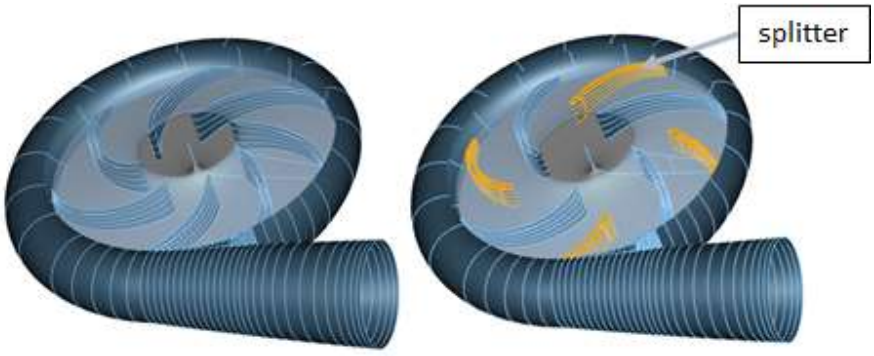


FIGURE 8 : MODELE DE LA POMPE B SANS ET AVEC SPLITTER

In this present case, we have focused only on the study of the pressure difference DP. However, the results diverge from the previous model. As you can see from the curves, adding the splitters lowered the DP of the pump. On the other hand, the DPs do not vary whatever their length and their position (see the curves in the appendix), we believe that the origin of this problem comes from the fact that the diameter of the outside of the pump is small (45mm). It is interesting to see when the company should or should not use splitters.

CONCLUSION

Over a short period, my internship as an assistant engineer was a rewarding experience on several points. Working in a research & development (R&D) department of SOGEFI allowed me to better understand the role of an engineer in the professional world. After observation, I noticed the autonomy, the team spirit and the know-how of an engineer. In addition, the automotive sector is a very exciting and very heterogeneous environment, every technical detail of a vehicle is very important because it influences the whole.

By doing an internship that brought together different issues, I was able to have a global vision of the missions requested for an engineer.

Initially, the search for technical data requires a great capacity for organization and communication. I learned to quickly identify the desired information through documents and relay it in summary form. These summaries on the mechanisms of the water pump will allow future trainees to better understand their aspects and give them experience ideas to optimize their performance.

Then, my knowledge in the field of computational fluid mechanics (CFD) deepened. Indeed, I am beginning to be familiar with the behavior of hydraulic turbomachines and the flow of fluid through pumps. In addition, I also learned to link theory and practice with this simulation software. For example, the study on splitters on CFTurbo more or less confirmed my theoretical research on the influence of these particular blades.

The biggest part of my internship is on the design of cooling circuits to test the performance of different pumps. Thanks to the support of several technicians, I became autonomous to design an unassisted circuit myself. Sometimes I had to deal with unforeseen events (leak, lack of coolant, degassing, etc.), I

would solve them on my own or in some cases, I had to ask for help. This experience allowed me to see when to make the choice between doing it on my own or asking for support from the team. Also, this part helped me in my data acquisition method in terms of speed or accuracy.

Finally, this internship gave me a better understanding of the application of fluid mechanics in the automotive industry. This gave me a better idea of what I want to do later as an engineer and I am grateful to the company for allowing me to discover this.

ANNEXE

Bibliographic search

The splitters

A group of students from Tehran's Faculty of Mechanical and Energy Engineering studied the behavior of splitters on efficiency [**OPTIMIZATION OF THE SPLITTER BLADE CONFIGURATION AND GEOMETRY OF A CENTRIFUGAL PUMP IMPELLER USING DESIGN OF EXPERIMENT**]. In this study, we find a comparison of the performances for turbine models with and without splitters (Case I: without splitters; Case II: with splitters of length equal to 33% of the main blade; Case III: with splitters of equal length at 66% of the main blade).

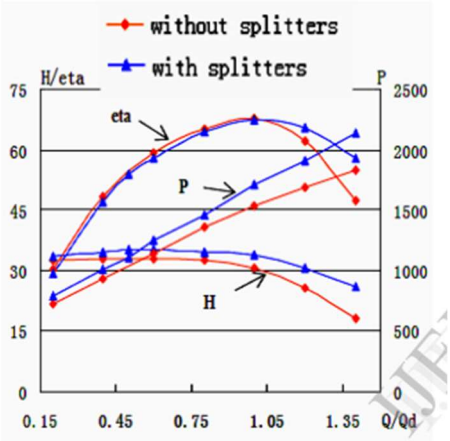
	Case I		Case II		Case III	
	η [%]	H [m]	η [%]	H [m]	η [%]	H [m]
Experimental	79.16	12.67	78.55	13.36	80.02	14.01
Numerical	82.76	12.46	81.97	13.9	82.04	14.41
Deviation [%]	4.54	1.69	4.35	3.99	2.5	2.81

Observation :

By comparing the numerical results and the experimental results, model 3 (with the largest splitters) have the greatest performances in terms of yield / height of yield ratio.

- In theory, the model with splitter is more likely to have a better height.

Here is another similar study [AN OVERVIEW OF EFFECT OF SPLITTER BLADES ON CENTRIFUGAL PUMP PERFORMANCE] which compares the performances between a turbine with and without splitters.



COMPARAISON DES POMPES AVEC ET SANS SPLITTERS

Observation :

Looking more closely, a model with splitter has better efficiency towards higher flow rates. If we start with a model of splitters, the length does not have to be necessarily very large, a similar study [EFFECTS OF SPLITTER BLADE LENGTH ON DISC PUMP PERFORMANCE] by LEONEL MARTINEZ-DIAZ on the splitters shows that there is a certain limit. For their experiment, they used a turbine with an outer diameter d2 = 272 mm and an inner diameter d1 = 110 mm with five splitters (This is certainly why we could not see any variation with and without splitters on the PAE XEC107 whose turbine diameter d2 is 47mm).

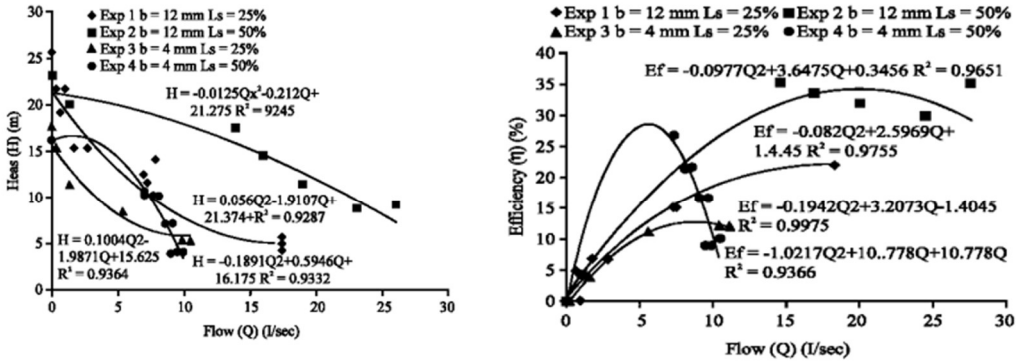


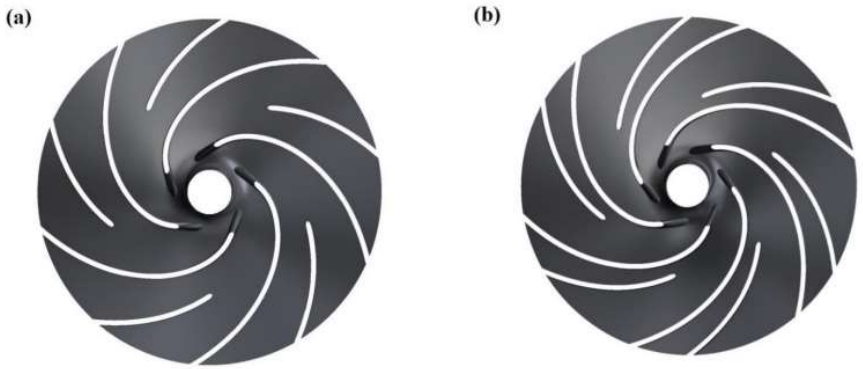
Fig. 5: The effect splitter blades lenght on the disc pump head

INFLUENCE DES SPLITTER SUR LES PERFORMANCES DE LA POMPE

Observation :

The results show on average that splitters with a length of 50% relative to the main blade have better performance. However, they failed to test 75% splitters due to high instability and high power consumption but to see if this is not a specific or general case.

We don't just limit ourselves to the length of the splitters. Indeed, the analysis [OPTIMIZATION OF CENTRIFUGAL SLURRY PUMP THROUGH THE SPLITTER BLADES POSITION] of EHSAN ABDOLAHNEJAD proves that we can optimize other parameters such as the number of splitters, the position and the length of the splitters. Here is their turbine model (1 single splitter between two blades) :



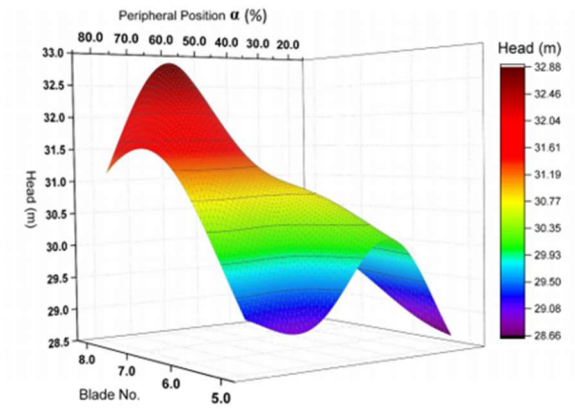


Fig. 10. Effect of splitter blade number and peripheral position on the head

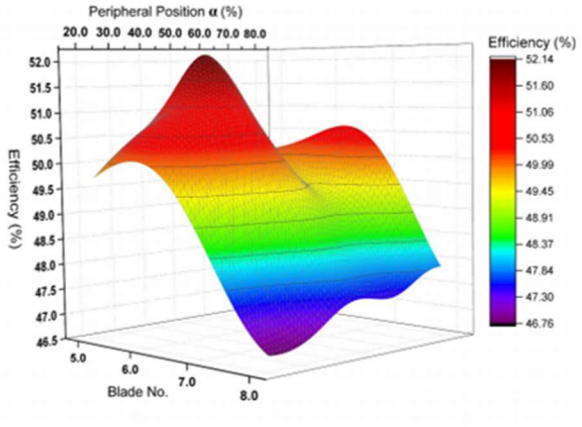


Fig. 11. Effect of splitter blade number and peripheral position on efficiency

INFLUENCE DE LA POSITION, DE LA LONGUEUR ET DU NOMBRE DE SPLITTERS SUR LE RENDEMENT ET LA HAUTEUR MANOMETRIQUE

Observation :

- An increase in the number of total splitters increases the manometric head but decreases the efficiency.
- - The offset of the splitter α with respect to the blades considerably varies the performance.

Source :

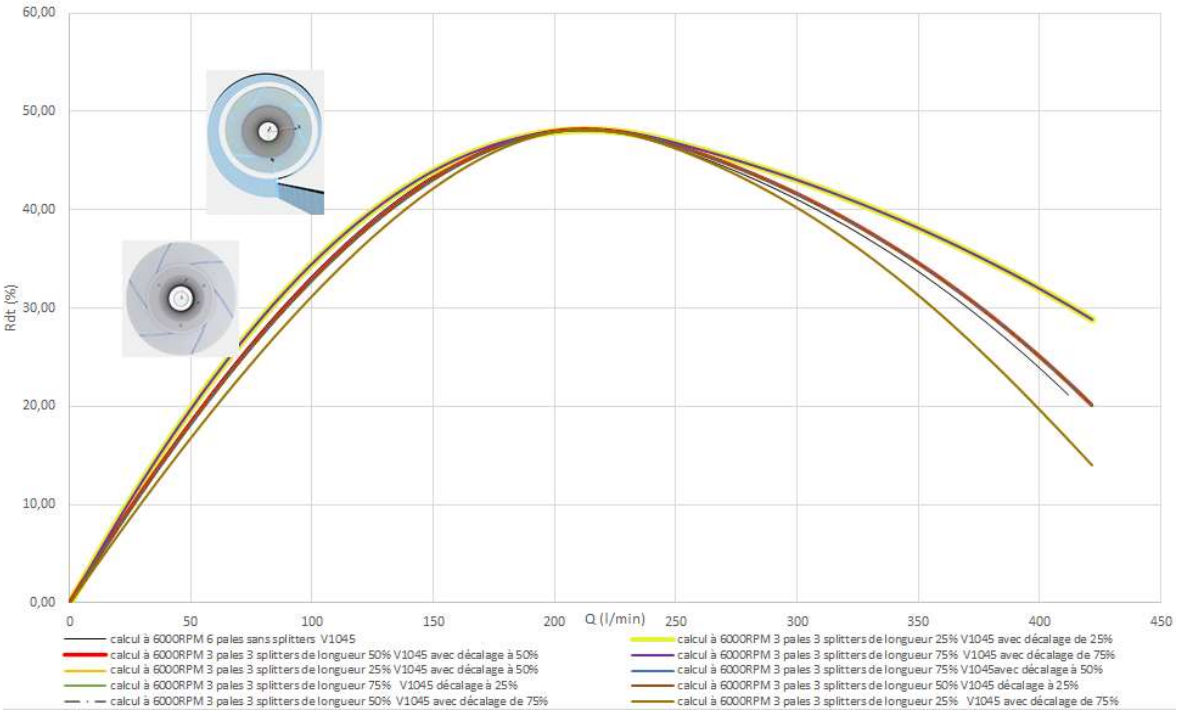
https://www.sid.ir/FileServer/JE/112520200104.pdf - OPTIMIZATION OF THE SPLITTER BLADE CONFIGURATION AND GEOMETRY OF A CENTRIFUGAL PUMP IMPELLER USING DESIGN OF EXPERIMENT – Page 7

https://www.ijert.org/research/an-overview-of-effect-of-splitter-blades-on-centrifugal-pump-performance-IJERTV2IS110882.pdf - AN OVERVIEW OF EFFECT OF SPLITTER BLADES ON CENTRIFUGAL PUMP PERFORMANCE – Page 3

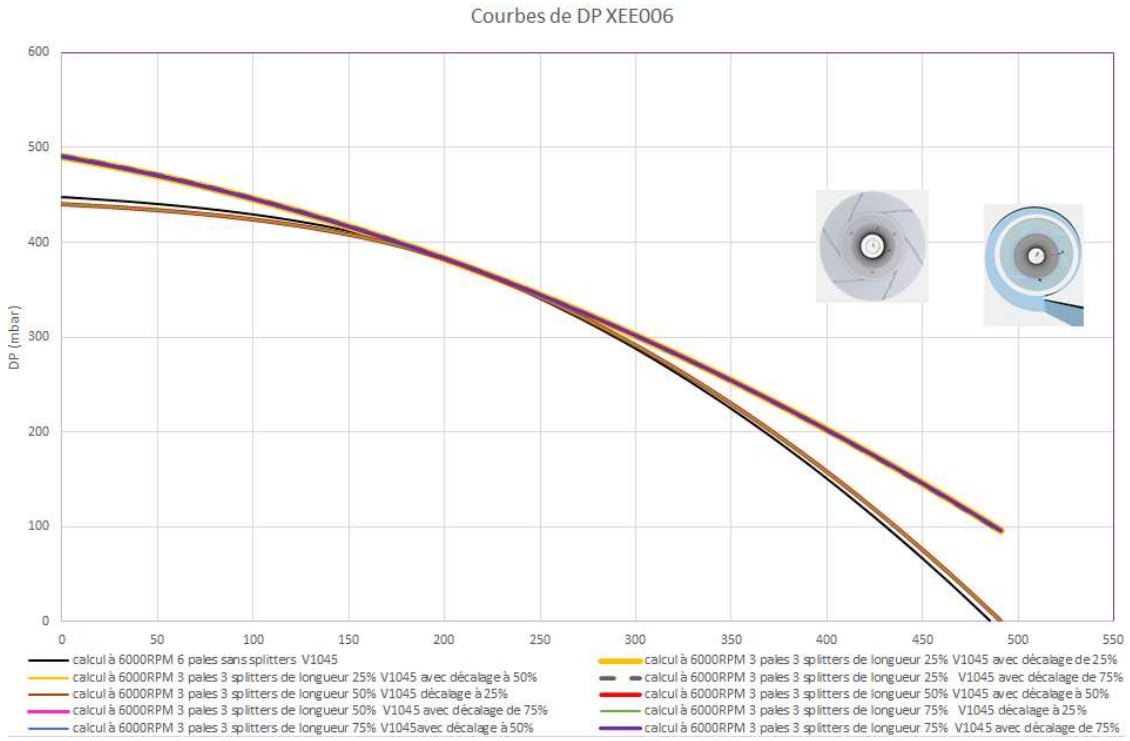
http://docsdrive.com/pdfs/medwelljournals/jeasci/2017/1612-1618.pdf - EFFECTS OF SPLITTER BLADE LENGTH ON DISC PUMP PERFORMANCE – Page 5

https://www.researchsquare.com/article/rs-155416/v1.pdf - OPTIMIZATION OF CENTRIFUGAL SLURRY PUMP THROUGH THE SPLITTER BLADES POSITION – Page 19-20

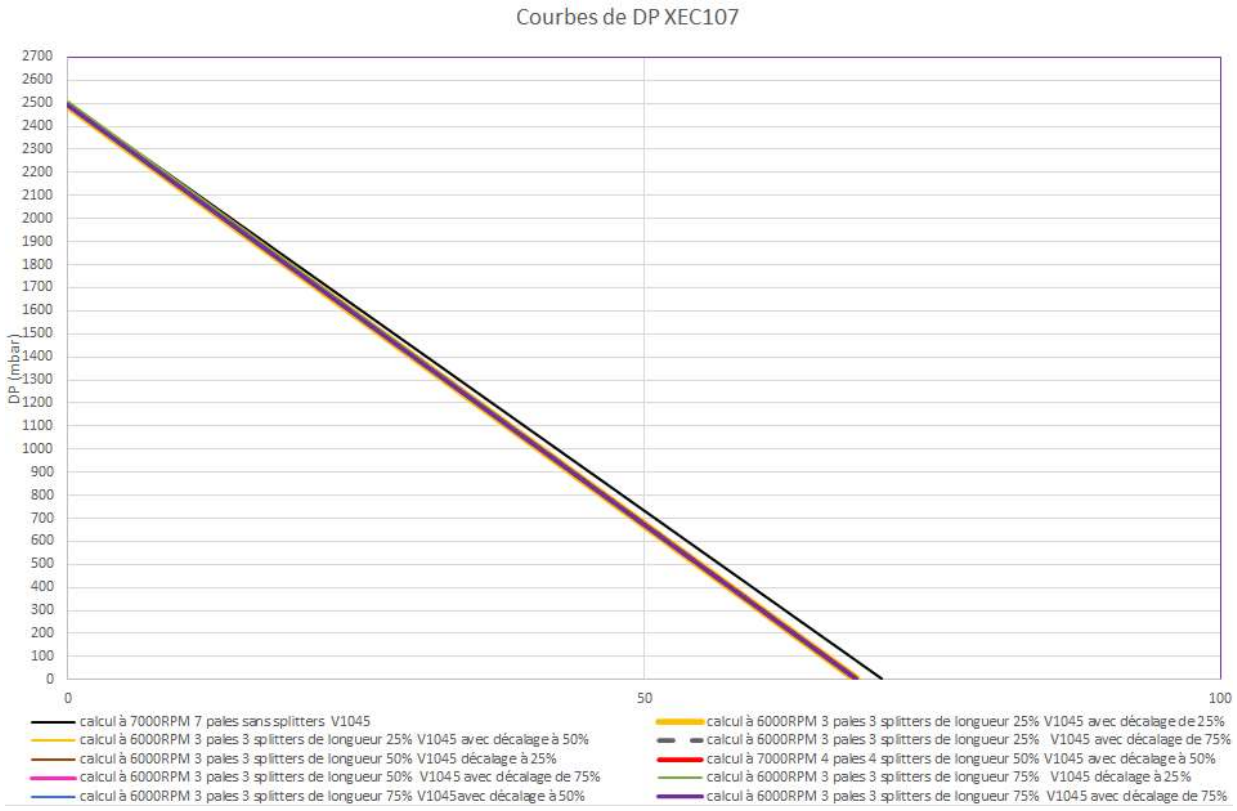
Splitters study with CF Turbo



GRAPHE 1 : COURBES DES RENDEMENTS DE LA POMPE A (AVEC/SANS SPLITTER)



GRAPHE 2 : COURBES DES DELTAS DE PRESSION DE LA POMPE A (AVEC/SANS SPLITTER)



GRAPHE 3 : COURBES DES DELTAS DE PRESSION DE LA POMPE B (AVEC/SANS SPLITTER)