

## DETERMINATION OF THE INLET PORT'S ANGLE FOR A CENTRIFUGAL BLOOD PUMP BY THE HYDRODYNAMIC CHARACTERISTICS

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**Abstract.** A new blood pump is in final phase of clinical evaluation in Institute Dante Pazzanese of Cardiology (IDPC) to provide the Extracorporeal Circulation (ECC) of blood during the open-heart surgeries. This centrifugal blood pump project is called Spiral Pump (SP) because its spiral impeller. A stainless steel shaft and two bearings separated by a plastic spacer hold the SP's impeller. There is a seal made of silicone rubber to avoid the contact between the blood and the pump's internal parts. This system is very reliable but have some inconveniences like limited durability and blood leakage. To overcome these problems, Takami et al. (1997) adopted a completely sealless pivot bearing in their pump. The pump's inlet port is located on the top of the external cone. Thinking in build new generations of centrifugal blood pumps with higher durability, the present work considers studying an inlet port to substitute the original one. We compared the hydrodynamic performance of three different design configurations and plotted their performance curves 1, 2 and 3. The inlet port that shows better values of flow versus pressure head was the number 1. In future works, we will study the mechanical hemolysis to apply this design on SP project.

**Keywords:** Centrifugal Blood Pump, Extracorporeal Circulation, Spiral Pump, Open-heart Surgery, Hydrodynamic Performance of Blood Pumps.

## 1. Introduction

The Spiral Pump (SP) is a centrifugal blood pump in final phase of clinical evaluation in our institute. This pump could be used in various applications as Extracorporeal Circulation (ECC) and Left Ventricle Assist Device (LVAD). The ECC is a necessary technique during open-heart surgeries. Comparing a centrifugal blood pump with the conventional roller pumps, it is more safety and causes less damage to the blood cells. A stainless steel shaft and two bearings separated by a plastic spacer hold the SP's impeller. There is a seal made of silicone rubber to avoid the contact between the blood and the internal parts, Fig. 1 (Andrade *et al.*, 1996).



Figure 1. The SP Centrifugal Blood Pump with the conventional inlet port. Right on top, assembled. Left on top, the cross section. Below, the separate components.

This system is very reliable but have some inconveniences like limited durability and blood leakage. To overcome these problems, Takami *et al.* (1997a) adopted a completely sealless pivot bearing in their pump. The pump's inlet port is located on the top of the external cone. Thinking in build new generations of centrifugal blood pumps with higher durability, this present work considers study an inlet port to substitute the original one. We manufactured three different design configurations of the inlet port.

The spiral impeller of the SP is a conical shaped structure with threads, called central cone. The rotational motion of the central cone generates the centrifugal pumping principle. The threads is a design singularity between the others conventional centrifugal pumps (Andrade *et al.*, 1996). We started this inlet port modification asking which difference it could occurs in the three possible configurations, Fig 2.

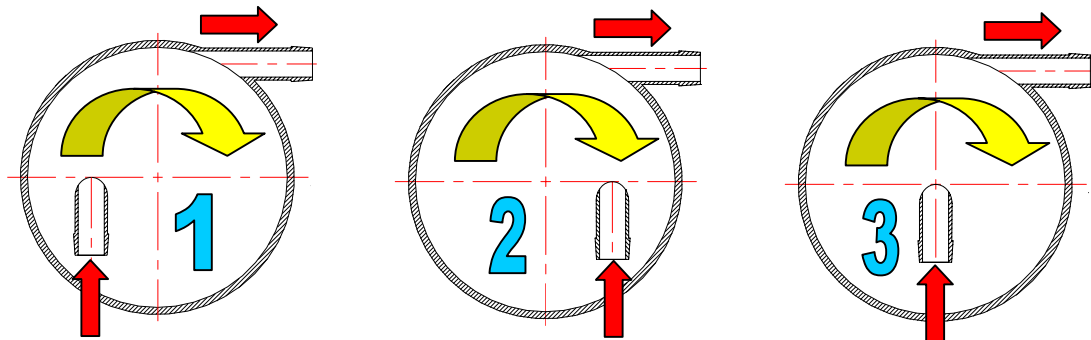


Figure 2. The three inlet ports analyzed. In red, the blood flow. In yellow, impeller rotation.

When the blood flows through the inlet port, in the same direction of the impeller's rotation, we called it inlet port number one. When the blood flows against the impeller's rotation, we called it inlet port number two. And when blood flows perpendicular to the impeller, we called it inlet port number three, as seen on Fig. 2.

In the three cases, we positioned the inlet port at the first thread's height. The interaction between the rotating thread and the inlet flow could aid or prejudice the hydrodynamic performance. Flow visualization studies made by Andrade *et al.* (1997) point the importance of this area.

## 2. Materials and methods

The hydrodynamic performance tests were studied using the yet mentioned three inlet ports. A closed circuit loop, similar to the Andrade *et al.* (1996) was used in these tests with 40% glycerin-water solution at 25 °C simulating the density and viscosity of the blood. The circuit, as seen on the Fig. 3, consists of a polyvinyl chloride reservoir used in ECC. This reservoir has the capacity of 4.0 l. At this reservoir, there are two flexible silicon tubes with 1/2". These tubes are also used in the ECC circuit. An adjustable clamp was used to control the flow of solution in the inlet tubing of the reservoir. Pressure monitors were connected at the pump inlet and outlet. A flow meter was used to measure the flow at the inlet tube of the reservoir, during these tests.

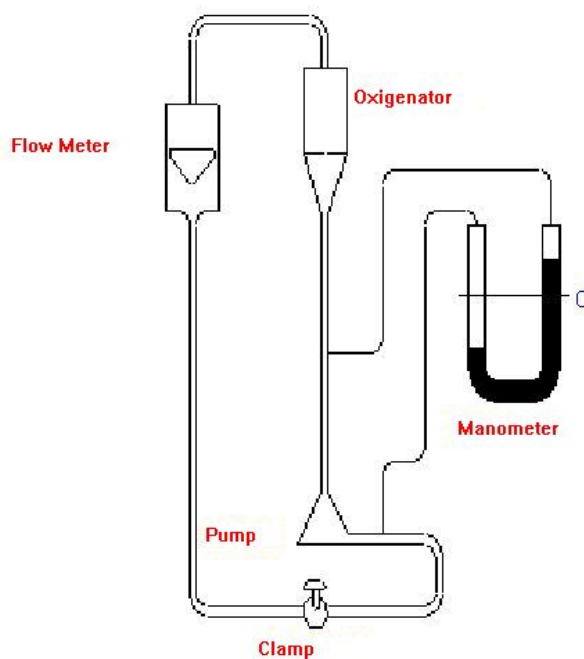


Figure 3. The Closed Mock Loop Test used to study the hydrodynamic characteristics of the pumps.

Clamping the reservoir's inlet tube we fixed the flow between 0,5 l/min and 9,0 l/min with constant steps of 0,5 l/min. With the motor controller, the pumping rotations were fixed at 1000 rpm, 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm, 3500 rpm and 4000 rpm. Each pressure value was measured changing the flow parameters in a fixed rotation.

## 3. Results

With the data collected from the hydrodynamic performance test of each inlet port we built separated tables. For each rotation of each inlet port we plotted a curve. To simplify we made a graphic with the two mean curves of the three cases. We decided that the rotations used would be 3000 rpm and 4000 rpm because the great values of pressure and flow measured in high rotations, as seen on the Fig. 4.

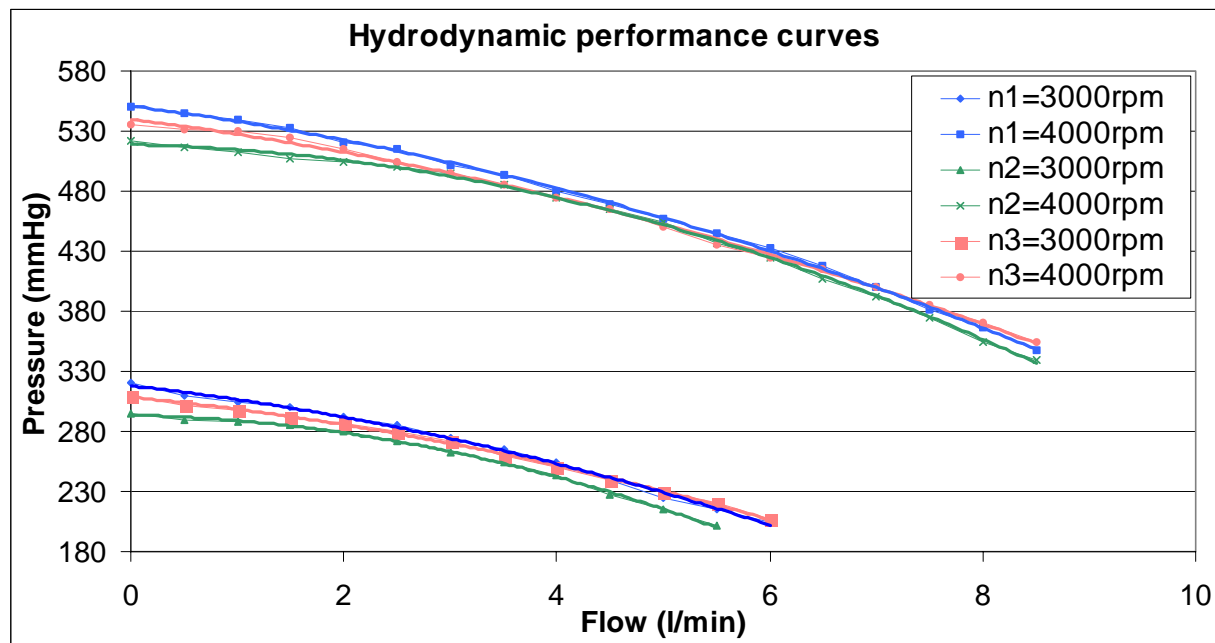


Figure 4. Selected curves from the hydrodynamic performance tests.

The inlet port that shows better values of flow versus pressure ahead was the number 1. The case number 2 shows very similar pressure values for high flow.

#### 4. Conclusion

There are some problems at the seal of conventional centrifugal pump. The blood leakage turns the ECC usually pumps not allowed to LVAD. With pivot bearings the durability of a pump could increase and also its reliability (Takami, 1997b). With this work, we can decide about a new position of the SP's inlet port. It turns possible a sealess system of bearings, the Pivot Bearings, and the usage of SP as a LVAD in bridge to transplant that will be another option to the patients who are waiting for a heart donor. Many cardiac patients who need a heart transplant die before the organ became available.

In future works, we will study the flow visualization to see visible flow patterns and study the velocity field on the first thread with the inlet port number 1. Also, it will be necessary to study the normalized index of hemolysis before apply the sealess concept design on SP project.

#### 5. Acknowledgements

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#### 6. References

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