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FLOW VISUALIZATION STUDIES IN A CENTRIFUGAL BLOOD PUMP

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Abstract*. At Institute Dante Pazzanese of Cardiology, blood pumps used as temporary circulatory support device (TCSD) are being developed. A new model of centrifugal blood pump, which is under evaluation, can be used as TCSD extracorporeal as bridge to decision or bridge to recovery. Stagnant flow areas and vortex formation inside a TCSD are critical for thrombus formation and hemolysis, respectively. Flow visualization studies were made to investigate hydrodynamic behavior of different TCSD geometries. Specific regions were qualitatively analyzed: the inlet port, outlet port, top and bottom of impellers. Visualization was performed using stroboscopic laser light and polymeric particles to trace the flow inside pump. Particle images were obtained detecting some turbulence in outlet port with TCSD operating under normal working rotational speed. Also was observed sufficient washout inside the housing and weren't detected persistent stagnant areas. Those preliminary results will be very important to improve pump design and impellers geometry.*

Keywords: *flow visualization, temporary circulatory support, laser.*

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Flow Visualization Studies in a Centrifugal Blood Pump

1. **INTRODUCTION**

When patients are affected by Cardiovascular Diseases (CVD), often therapies using Left Ventricular Support Devices (LVAD) are recommended to treatment or while this patients waiting in the cardiac transplant list (Bock, Eduardo *et all,* 2011).

At Institute Dante Pazzanese of Cardiology (IDPC) blood pumps used as LVADs and Temporary Circulatory Support Devices (TCSD) has being developed by Bioengineering Department. Techniques such as Computational Fluid Dynamics (CFD) and Rapid Prototyping can be applied to define impeller characteristics and promote the construction of physical models (TADA, E. *et all*, 2011). *In vitro* tests were realized to validate the hydraulic performance of different pump geometries. The flow visualization study is an interesting tool to investigate the adequacy of TCSDs and LVADs.

2. MATERIALS AND METHODS

A. Temporary Circulatory Support Device

The TCSD in development was dimensioned presenting better hydrodynamic performance to rotational speeds between 1480 rpm and 1500 rpm, at 5L/min and 100 mmHg. The figure 1 shows this TCSD.

Figure 1. Temporary Circulatory Assist Device.

B. Flow Visualization

The flow visualization study allows view the flow pattern in regions of interest, as the inlet port, outlet port or chamber of impeller to detect stagnant flow or vortex formation areas, critical to thrombus formation (TAKAMI, Y. *et all*, 1997).

To perform this test utilizing a tracer method focused on the region of interest are necessary the confection of a physical model of de pump housing with transparent material, a linear laser and a video recorder system. A standard module with magnetic driver coupling the pump was used. A schema of apparatus can be seen on the figure 2.

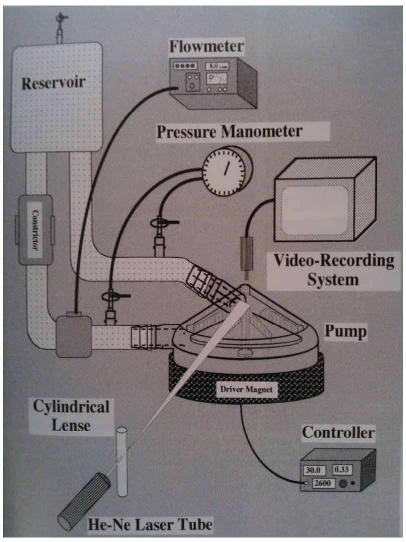

Figure 2. The schematic drawing of the experimental set-up for visualization study (source: Takami, Y. *et all*).

A unit power laser generally is used in the assay of flow visualization, blinking or continuous lighting the region of interest. A unit based in solid state laser diode was used on low cost system presented in this paper. The proposal was to use a commercial laser pen, class III (about 5mW) which complies with the 21 CFR norm and radiating on 405 nm ±10; the choosing this wavelength allows the use of fluorophores responsive to ultraviolet and visible range for electromagnetic spectrum as tracer (Mondal, P.P., 2014). For the tests were used PVC lamellae with a diameter varying in a range between 0.1 and 0.8 mm in diameter as tracer. To create a linear laser was used a cylindrical lens of 4 mm in diameter.

Due to the laser diode sensitivity, was chosen to use the original power driver circuit to prevent damage from thermal effects or due to exceeding the maximum optical power density at one of the end facets of diode. To control the on/off state of light was used a picoreed switch commanded by a PWM out of the myRio controller (National Instruments ™). This controller also was used to acquire pictures of the glittering particles tracing the flow inner device under test (blood pump) by a webcam and stored on a flash drive. The webcam and the flash drive were connected to the controller via a USB hub, because the controller has only one UBS communication port available to the user. The several components of the proposed system can be seen on the figure 3 and the experimental assembly can be seen in the figure 4.

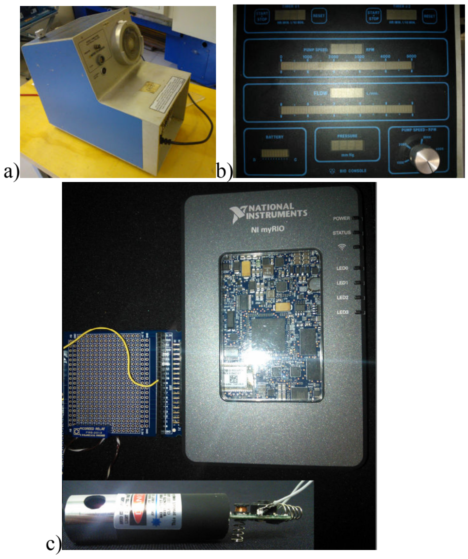

Figure 3. Module with magnetic driver to coupling the pump (a); control panel module (b); myRio controller connected to the expansion card with the

Figure 4. Experimental assembly to visualization test.

The program code, written in LabView ™, was embedded in to the FPGA on myRio controller; this allowed the system to work independently of a laptop, which could be used optionally for viewing online the images acquired via a USB connection between the computer and the controller. The program code is shown on the figure 5 and the front end, on the figure 6. The front panel allows setting the frequency and duty cycle PWM parameters to adjust the blink rate and time ratio on/off to the laser light.

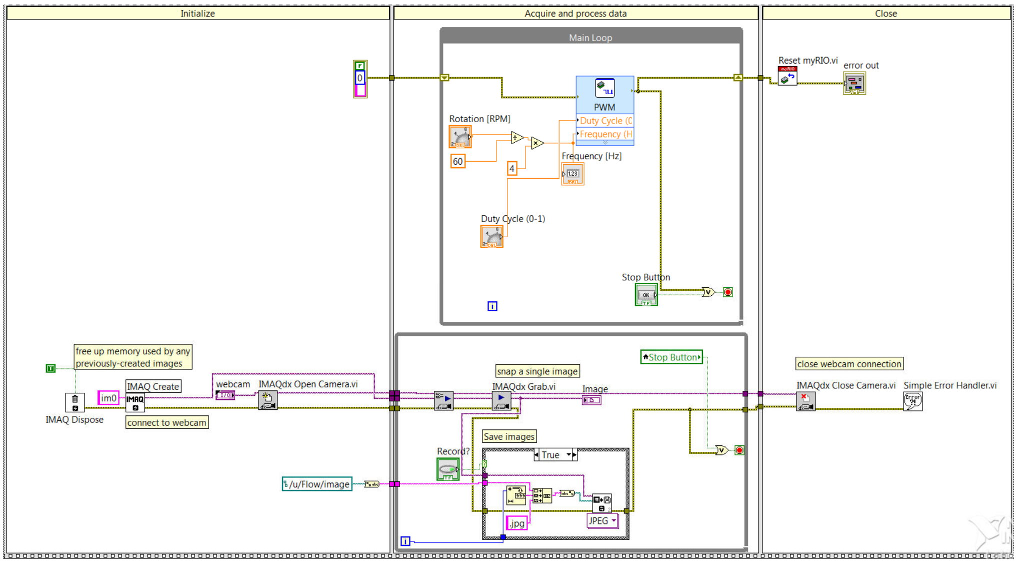

Figure 5. Program diagram block embedded in FPGA.

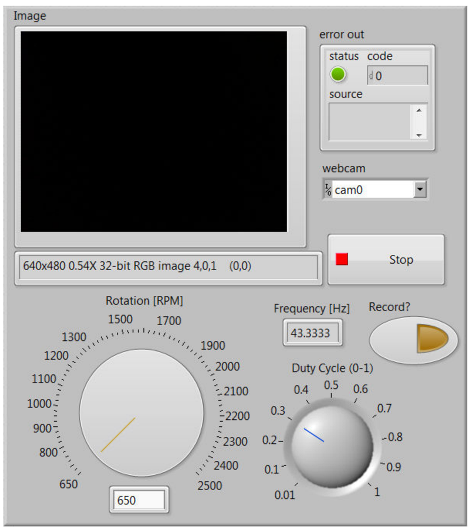

Figure 6. Control panel to set blink laser parameters.

The scale dial, which adjust the frequency of PWM on the front panel, was calibrated to show rotation in RPM to a blood pump propeller with four blades. This allow to setting the blink rate to freeze a propeller image, as a stroboscope.

3. RESULTS

Due the low quality image provide to webcam, we choose capture images by smart phone, whose resources have proved suitable for this purpose. The satisfactory results, as a first step for qualitative analysis of flow, are shown in figure 7. Maybe, on a second analysis step, the captured images could be subjected to a post-processing for the Particle Image Velocimetry (PIV) analysis.

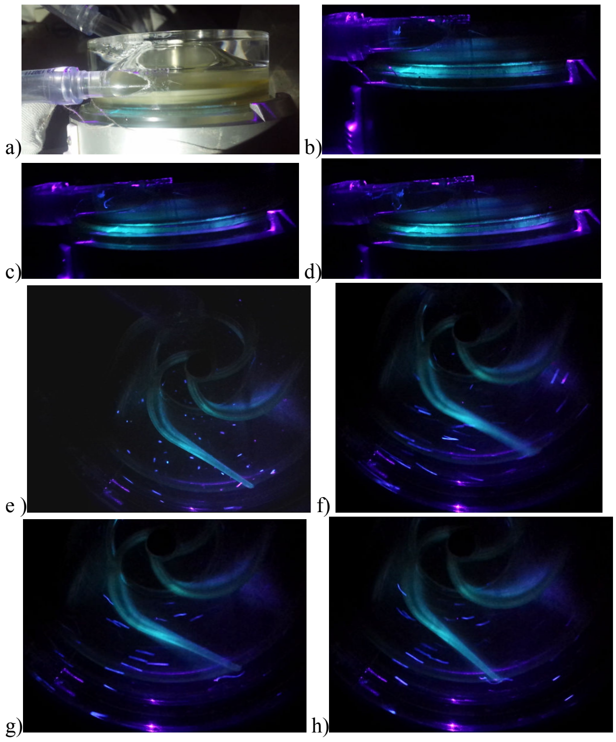

Figura 7. Device under test: side view (a); detail in the flow sequence on the device output (b), (c) and (d); top view sequence of flow visualization in the impeller housing (e), (f), (g) and (h).

One can notice the tracer revolution in the pictures of device outlet port, with TCSD operating under normal working rotational speed, (c) and (d) of Figure 7. It is also possible to follow the path described by a particle in the pictures (f), (g) and (h) round a of the impeller blades, presenting sufficient washout inside the housing.

4. CONCLUSION

The flow visualization system mounted showed great versatility in its configuration, compared to systems using traditional and more expensive light bulb units He-Ne laser, because the small size of the diode laser head allows easy attachment to any position for easy determination plans to be viewed.

The times on/off the laser unit were precisely controlled due to real-time operation of the FPGA; and relatively low working frequencies range between 40 to 200 Hz approximately allowed the use of an electro-mechanical switch for on/off action of the light.

Visualization was performed using stroboscopic laser light and polymeric particles to trace the flow inside pump. Particle images were obtained detecting some turbulence in outlet port with TCSD operating under normal working rotational speed, however this did not occur in its normal operate range. Also was observed sufficient washout inside the housing and weren't detected persistent stagnant areas. Those preliminary results will be very important to improve pump design and impellers geometry.

5. REFERENCES

Bock, Eduardo; Antunes, Pedro; Uebelhart, Beatriz; CAMPOS, P. ; Leao, Tarcisio ; DRIGO, E. ; Fonseca, Jeison; Dinkhuysen, Jarbas; Biscegli, José SILVA, C.; SILVA, B. U. ; Cardoso, Jose R.; Andrade, Aron. Implantable Centrifugal Blood Pump designed for long term left ventricular supportance. In: 2º OBI - Taller de Órganos Artificiales, Biomateriales e Ingeniería de Tejidos, 2011, Mar del Plata. 2º OBI - Taller de Órganos Artificiales, Biomateriales e Ingeniería de Tejidos, 2011.

TADA, E. ; Antunes, Pedro; Uebelhart, Beatriz; CAMPOS, P.; Tarcisio Leão; DRIGO, E. ; Andrade, Aron; Bock, Eduardo. A mathematical model for flow analysis of an implantable centrifugal blood pump. In: 2º OBI - Taller de Órganos Artificiales, Biomateriales e Ingeniería de Tejidos, 2011, Mar del Plata. 2º OBI - Taller de Órganos Artificiales, Biomateriales e Ingeniería de Tejidos, 2011.

TAKAMI, Y. ; ANDRADE, A. J. P. ; NAKAZAWA, T. ; MAKINOUCHI, K. ; GLUECK, J. ; BENKOWSKI, R. J. ; NOSÉ, Y. . Eccentric Inlet Port of the Pivot Bearing Supported Gyro Centrifugal Pump. Artificial Organs, v. 21, n.4, p. 312-317, 1997.

Mondal, P.P. "Fundamentals of Fluorescence Microscopy - Exploring Life with Light ", ISBN 978-94-7544-2, DOI 1.1007/978-94-007-7545-9, Springer Dordrecht Heidelberg, New York, London, 2014.

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