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# DEVELOPMENT OF A NEW HUBLESS VENTRICULAR ASSIST DEVICE

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## ABSTRACT

Heart failure is a serious cardiovascular disease associated with an important death rate. The gold standard of treatment of end stage heart failure is transplantation. Given the severe shortage of potential organ donors, mechanical pumps have been developed for long term support. A novel hubless ventricular assist device is presented in order to reduce the potential of blood damage caused by shear stress levels. The concept is assessed using numerical simulations and its potential is shown in terms of decreasing the speed needed to achieve a given flow requirement.

***Keywords:*** ventricular assist device, blood damage, numerical simulations.

## INTRODUCTION

In its 2014 update, the American Heart Association (AHA) reported that there are about 280000 deaths annually related to heart failure [1]. The gold standard for the treatment of end-stage heart failure is transplantation. However, there is an important shortage of suitable organ donors to treat end stage heart failure patients. In fact, in the US, only about 6 % of the estimated 35000 annual patients that would benefit from transplantation actually receives a heart in time [2]. For these reasons, mechanical pumps have been designed to assist the heart in its pumping function.

In the last 40 years, the design of heart mechanical support has evolved from bulky pulsatile pumps with multiple cavities and valves to implantable rotary dynamic pumps. These devices have progressed from temporary support (for acute perfusion), to short term support (bridge to bridge), to mid-term support (bridge to transplant, bridge to recovery) to long term support (destination therapy). Important requirements for destination therapy are device longevity, long term hemocompatibility (2) while addressing the standard short term issues of blood trauma, thrombosis, and infections.

The most recent implantable devices have shown to improve quality of life and survival rate but do not yet integrate all the requirements and specifically the long term hemocompatibility. Because pump efficiency is closely related to hydraulic losses, less efficiency is associated with more blood trauma hemolysis due blood flow disturbances (shear stress, turbulence). Therefore, our main design objective was to decrease the potential of blood damage with a design that would reduce the needed speed in order to reduce the shear stress linked to blood damage.

## RESULTS AND CONCLUSIONS

The concept that we put forward is a hubless design [3]. Such a configuration is a departure from convention turbine design where vanes are usually connected on a hub in an inducer-impeller-diffuser configuration (Figure 1).

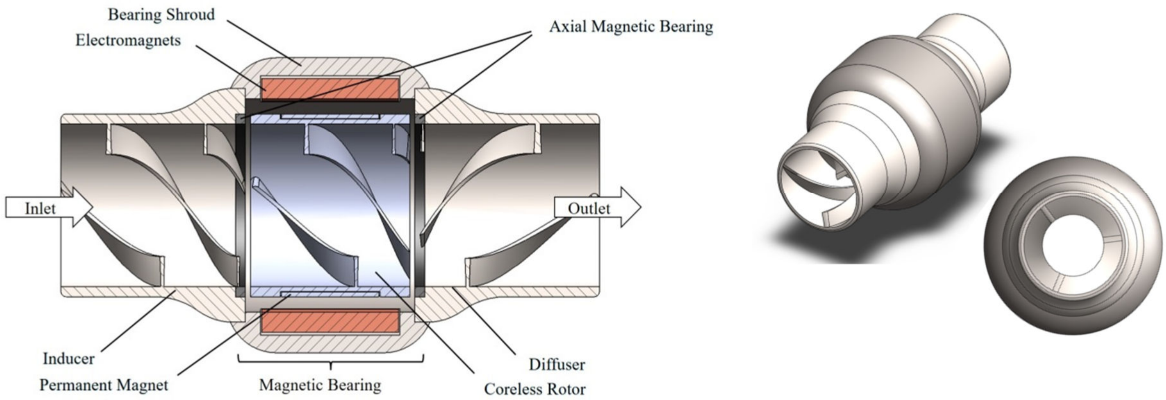
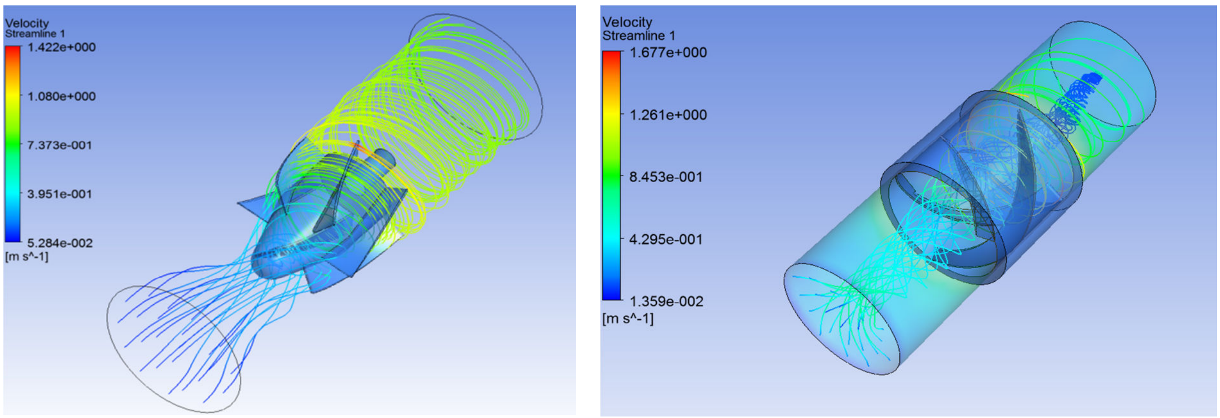



Fig. 1 - Hubless pump front view (with inducer, impeller/rotor and diffuser) and an isometric and front view

The hubless design provides a larger pumping volume within the impeller/rotor thus allowing to reduce the needed rotational speed to achieve a given pumping rate. This in turns decreases the resulting velocity gradients and thus the resulting shear stress levels that are directly linked to blood damage [4]. We used ANSYS CFD to simulate the flow in the pump (tetrahedron volume meshes were generated for the fluid domain and steady flow was used at the inlet). The assigned blood viscosity is 3.5 cP and the density is 1.05 g/cm3 corresponding to Newtonian flow regime.

From the ANSYS post-function calculator of the preliminary results, we find that a RPM around 1000 provides for 5L/min and a RPM around 2000 provides for 6L/min. We note in the preliminary results, that the maximum velocities are lower with the hubless design.




| | Conventional rotor | | Hubless rotor | |
|---|---|---|---|---|
| RPM | 1000 | 2000 | 1000 | 2000 |
| Outlet max velocity (m/s) | 0.117 | 0.128 | 0.105 | 0.126 |

Fig. 2 - Flow simulation for the hubless design and comparison of the maximum velocity with a conventional design

The next step is the experimental verification and assessment of the hydraulic efficiency. A 3D printed version of the concept was generated (Figure 3). This rapid prototype will be inserted in a test rig (under construction) for assessing the efficiency.

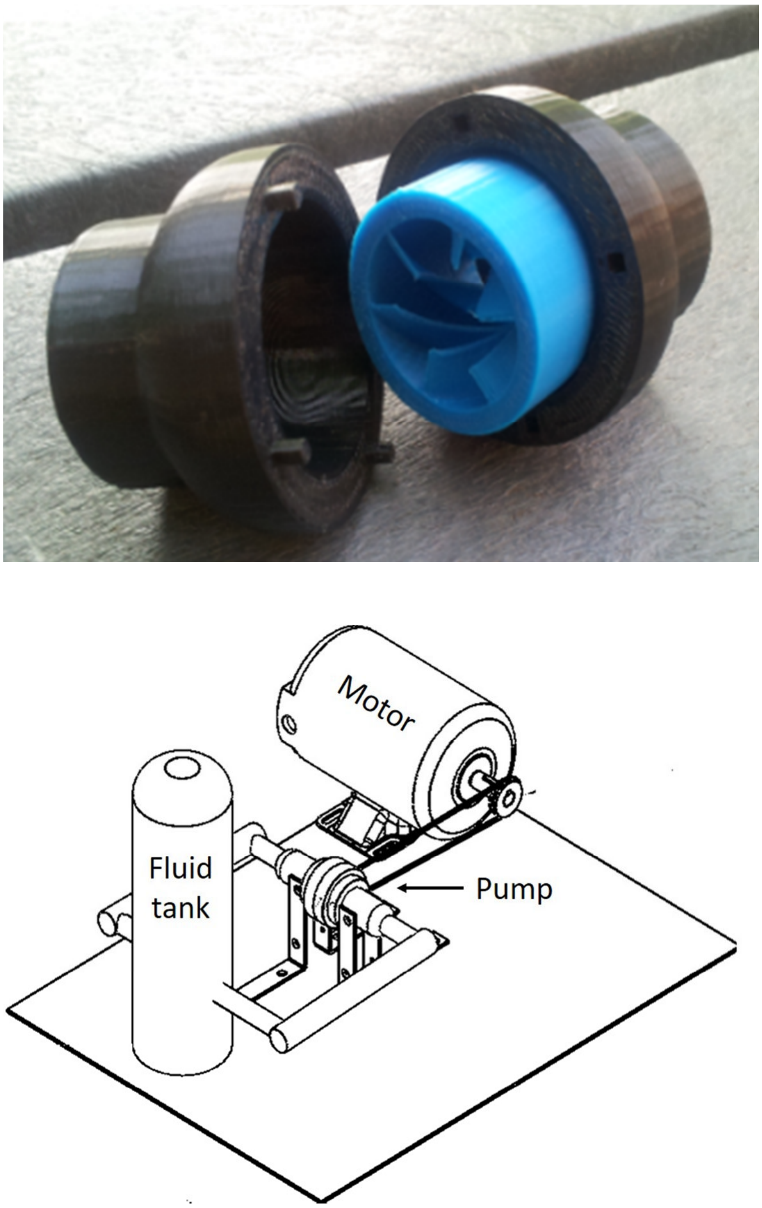



Fig. 3 - Rapid prototype of the hubless concept and the hydraulic setup for testing the hydraulic efficiency

In conclusion, we developed a hubless pump design that has a larger pumping volume within the impeller and allows to decrease the maximum velocities for a given flow regime requirements based on the numerical preliminary numerical simulations. This design is currently under experimental assessment to confirm the numerical results.

## ACKNOWLEDGMENTS

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