Design and Simulation of Axial Flow Maglev Blood Pump

Mr. Raghvendra Singh Kashyap, Dept. of Mechanical Engineering

Dr. C.V. Raman University, Bilaspur

ABSTRACT

The axial flow maglev blood pump (AFMBP) has become a global research focus and emphasis for artificial ventricular assist device, which has no mechanical contact, mechanical friction, compact structure and light weight, can effectively solve thrombus and haemolysis. Magnetic suspension and impeller is two of the important parts in the axial flow maglev blood pump, and their structure largely determines the blood pump performance. The research adopts electromagnetic and fluid finite element analysis, and puts forward a method to design the magnetic suspension and impeller of axial flow blood pump, which tacks into account the small volume of axial blood pump. The magnetic bearing's characteristics are evaluated by electromagnetic finite element analysis. The Blades have been designed by calculating aerofoil bone line, and make simulation analysis for different thicken ways of blade by Fluent software, and make a conclusion that the blade thickened with certain rules has better characteristics in the same conditions. The results will provide some guidance for design of axial flow maglev blood pump, and establish theoretical basis for application of the implantable artificial heart pump.

KEYWORDS—Magnetic Levitation, Blood Pump, Impeller, Axial Flow, Fluent, ANSYS

INTRODUCTION

Heart failure is a mainly cause of level heart death, patients with heart failure is expected to reach 4.47 million in China, this is a serious threat to people's health. Through using heart transplantation, ventricular mechanical assistance, stem cell therapy, artificial organs substitution and alternative methods to treat it. Heart transplantation is a relatively mature technology, but there is a serious shortage of donated hearts [1]. In this case, the development of artificial heart pump has become particularly important for treating the heart disease. The study of artificial heart pump in abroad is very early, and has made a great progress. The artificial heart pump has had some commercial product. In contrast, the domestic research about artificial heart pump begins too later and exists some deficiencies on design and experiment [2]. In general, artificial heart pump is often divided into two types of pulsating and non-pulsating pump. Pulsating pump is suit for physiological characteristics, because of valve, stretchy membrane and larger ventricular volume, and with its bulk, non-implantation, and pulsating pump is often used in short-term treatment for patients awaiting heart transplantations in transitional term [3]. the direction of current research is non-pulsating pump, because it has some advantages, such as small structure size, low power, little blood clots and long-term carry. To reduce complications, the development of artificial heart pump is shifting to rotating impeller pump which can produce constant blood stream, and small-sized or micro axial flow pump has become a research hotspot in this field in the world[4]. For the supporting type of axial flow blood pump, there are many choices, which are ball bearing, fluid film bearing and magnetic bearing. Because of existence of friction, they would cause thrombosis, destruction of blood cell and so on. At the same time, it also requires lubrication and sealing. Magnetic bearing offers some advantages of no mechanical contact, non-lubrication, low power and so on. In addition, axial flow blood pump impeller is motivated by motor to provide high-speed rotation, which causes blood flow force.

Therefore, impeller is an important component in axial flow flood pump, and its structure largely determines the heart pump performance. In recent years, the domestic and foreign scholars investigate magnetic suspended and impeller of axial flow blood pump and have got some stage results. Literature [5] has proposed a structure of the axial flow blood pump, which its rotor is suspended by radial permanent magnetic bearing and single axial active magnetic bearing, but the radial stiffness and damping is not enough to resist the disturbance. In 2010, Allaire designed a different structure, consists of two radial magnetic bearings and one thrust permanent magnetic bearing[6]. According to the literature [7], the spiral blade profile was designed according to inlet, outlet velocity triangles and Euler work, and made solid modelling for impeller. Literature [8] mainly discussed the influence of impeller pitch angle for blood flow and the loss of convection. Literature [9] made a conclusion that the impeller with four blades had better performance through the simulation about the number of axial flow heart pump's blades. According to the literature [10], the flow analysis were studied for axial heart pump impeller, and made the pressure distribution. However, magnetic suspended and impeller for axial flow maglev blood pump design still has some lacks of sufficient knowledge, and thus limits the effective application of maglev blood pump greatly. So it is necessary to analyse maglev blood pump impeller and supporting, fix main reasons of maglev blood pump performance, and offer some specific the axial direction with respect to the inlet and outlet cannula, which is, passing through the inducer, the impeller and the diffuser. The inducer and diffuser are enclosed in the rotor without contact, and the impeller is shrunk-fit into the bore of the rotor [11, 12].

CONCLUSIONS

This paper designed magnetic suspension and elaborated the design process of impeller for axial maglev heart pump, made the simulation analysis of structure with Ansys and Fluent software, and compared the uniform thickness blade impeller with the blade impeller which thickened according to certain rules, then obtained the following conclusions:

(1) The magnetic suspended structure was designed. The maglev blood pump consists of an impeller, two radial active magnetic bearings, one axial permanent magnetic bearing, and four hall sensors and so on.

(2) The uniform thickness blade impeller was compared with the blade impeller which thickened according to certain rules. Both the two methods can guarantee the static pressure which is 100mmHg, but the variable thickness blade impeller meets the requirements better because the pressure distribution is better distributed, from entrance to export with progressive increase, and the most tremendous pressure appears in the back of leaf blade. Meanwhile, in scheme II, the maximum shear stress is much smaller than scheme I, and in the blood withstanding range.

(3) In both two methods, the export ends have a small amount of reflux, easy to form thrombus, and the structure of the export end needs to be improved. The speed of export has a large circumference component; a guide wheel is needed to be added to eliminate the circumferential velocity component.

(4) Both the pressure and shear stress on the front end of blades are relatively large, that should be reduced by changing the impeller hub structure.

(5) Overall, in the same conditions, the impeller that the blade thickened according to certain rules is better than the impeller with uniform thickness blade in the pressure distribution, the shear stress and the speed of flow lines, so the design and modification of the structure should first consider the variable thickness blade.

ACKNOWLEDGMENT

The authors wish to thank National Nature Science Foundation of China, WUT. This work was supported in part by a grant from National Nature Science Foundation of China (50675163) and self-determined and innovative research funds of WUT.

REFERENCES

[1] China Medical Tribune. 2008,4,10.C5 Edition

[2] Qu Zheng. Mechanical Circulatory Support of Modern Treatment of Heart Failure [M].Beijing, Science and Technology Literature Publishing House.2008

[3] Portner P M, Oyer P E, Pennington D G, et al. Implantable Electrical Left Ventricular Assist System: Bridge to Transplantation and the Future [J]. Ann Thorac Surg, 1989,47:142～150

[4] Pennington D G, McBride L R, Kanter K R, et al. Bridging to Heart Transplantation with Circulatory Support Devices [J]. J Heart Transplant, 1989,8:116～123

[5] Yong Guan, Shuqin Liu, Hongwei Li, et al. Study on Magnetic Bearings System in Axial-Flow Blood Pump[C].//2010 International Conference on Mechanic Automation and Control Engineering, June 26-28, 2010, Wuhan, China, 2010:3903～3907

[6] Paul Allaire. Design and Analysis of Magnetic Suspension for New Artificial Heart [C].//The 12th International Symposium on Magnetic Bearings, August 22-25, 2010, Wuhan University of Technology Press, Wuhan, 2010:XII.

[7] Yun Zhong, Tan Jianping, Yang Jianping. Design of an Embedded Micro Spiral Blood Pump Impeller [J]. Mechanical Engineering＆Automation, 2006,138(5):4～9

[8] Matthew D. SINNOTT, Paul W. CLEARY. Effect of Rotor Blade Angle and Clearance on Blood Flow [C]//The 7th International Conference on CFD in the Minerals and Process Industries, December 9-11, 2009, Melbourne, Australia, 2009:1～6

[9] Wang Yingpeng, Song Xinwei, Ying Chtmtong. Decision for the Blade Number of an Axial Blood Pump [J]. Beijing Biomedical Engineering, 2007,26(6):589～592

[10] W. K. Chan, Y. W. Wong, S. Y. KOH, et al. Performance Characterization and CFD Analysis of an Axial Blood Pump [J]. Journal of Mechanics in Medicine and Biology, 2005,5:151～163

[11] Shenyang Institute of Pumps, Vane pump design manual [M]. Beijing, Machinery Industry Press,1983

[12] A.T. Teroscerlansky, S.Razagievetes. Vane pump calculation and structure [M].beijing: mechanical industry press, 1981