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Mechanical Analysis in Point of View on Leaflet and Joint Design for Mechanical Trileaflet Heart Valve

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Extended Abstract

A mechanical heart valve is an interesting artificial organ that is invented to treat patients who suffer from valvular heart disease. There are many designs mimicking operation and function of natural heart valves such as caged-ball valve, tilting-disk valve and bileaflet valve as reviewed by Dasi et al. (2009). The dysfunction of mechanical heart valve is the result of cyclic load from blood pressure that exerts on the leaflets. This failure of mechanical heart valve causes a burden and affects the life of patients. Recently, a computational modeling becomes a useful tool and plays a major role in the prefabrication and assessment of many medical devices and artificial organs.

In this study, we designed and performed a computational method for mechanical analysis such as stress, displacement and strain of our three dimensional design of a trileaflet mechanical aortic heart valve. There were two designs of the leaflets; hemispherical shape and conical shape. The position of the hinge joints in this design was located at the center of the leaflet. Thickness of leaflet was also a varied parameter that we considered in the design. Titanium was selected as material of this heart valve. Stress and strain on the mechanical aortic heart valve, during opening and closing, were determined with the computer-aided design and engineering software. Boundary conditions were applied such as fixed base of circular housing of a valve and rotational movement of hinge joints. We implemented the pressure load acting on the leaflets followed to the physiological condition in a cardiac cycle.

Our simulation results showed that the conical trileaflet mechanical aortic heart valve had lower maximum von Mises stress, displacement and strain compared to the hemispherical trileaflet mechanical aortic heart valve. The maximum von Mises stress occurred at the hinge of the heart valves in both designs. Therefore, the hinge joint was the critical point when the heart valve operated. Due to this study, a hinge joint must be a point of concern when a mechanical heart valve is designed. Our study also demonstrated that the geometry of leaflet, thickness of leaflet and hinge joint play an important role on the mechanical properties such as stress and strain distributions. Increasing thickness of leaflet decreased the maximum von Mises stress on the hemispherical heart valve whereas it increased the von Mises stress on the conical heart valve. However, this study performed only a static analysis at the time point of interest during valve opening and closing which is a preliminary idea for a mechanical heart valve design. It is necessary for the future work to further study about fluid flow through this designed artificial heart valve. Moreover, the experimental study is also important to perform in order to verify the operation as well as the function compared to the simulation results.

References

Dasi L.P., Simon H.A., Sucosky P., Yoganathan A.P. (2009). Fluid Mechanics of Artificial Heart Valves. Clin Exp Pharmacol Physiol 36 (2), 225–37.