ENGINEERING

McMaster University

Project 2 – Independent Research Summary

Bi-leaflet Mechanical Heart Valves

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Vaisnavi Shanthamoorthy
(shanthav)

Tutorial 07

Team Thurs-23

Submitted: December 09, 2020

Executive Summary

Bi-leaflet mechanical heart valves mainly function as replacement valves, expected to perform the function of any of the other natural heart valves [1]. Some of these functions include controlling bi-directional blood flow between the ventricles and the atria. Bi-leaflet valves are generally constructed by attaching two semi-lunar disks to a rigid ring by small hinges where the open valve consists of three orifices: a small slit-like central orifice between the two open leaflets and two larger semicircle orifices laterally [1]. Typical materials used in this device include graphite, nitinol, polyethylene terephthalate, polytetrafluoroethylene, pyrolytic carbon (LTI) coating, and titanium alloys [1].

References

[1] Ansys GRANTA EduPack software, GRANTA Design Limited, Cambridge, UK, 2020 (www.grantadesign.com)

Annotated Bibliography

[1] G. Zhu, M. B. Ismail, M. Nakao, Q. Yuan, and J. H. Yeo, "Numerical and in-vitro experimental assessment of the performance of a novel designed expanded-polytetrafluoroethylene stentless bi-leaflet valve for aortic valve replacement," *PLOS ONE*, vol. 14, no. 1, p. e0210780, Jan. 2019, doi: 10.1371/journal.pone.0210780.

This article focuses on materials development as it examines the dynamic behaviour of the newly expanded polytetrafluoroethylene (ePTFE) bi-leaflet valve design for aortic valve replacement. The performance of the proposed valve was numerically and experimentally examined using commercial finite element code and numerous in-vitro tests to assess the hemodynamic performance of its modified design. Compared with a tri-leaflet valve, tested under the same conditions for reference, the proposed design performed better in terms of hemodynamics and its' structure, which improved the overall valve competency. Based on the results, the bi-leaflet valve design is not only capable of functioning as an aortic valve substitute under certain aortic physiological loadings, but also shows encouraging outcomes in certain critical hemodynamic parameters. All in all, the authors concluded that this novel design, although it may have implications for further studies, poses as a viable option for future clinical applications of this device.

[2] S. G. D. Tan, S. Kim, and H. L. Leo, "A biomimetic bi-leaflet mitral prosthesis with enhanced physiological left ventricular swirl restorative capability," *Experiments in Fluids*, vol. 57, no. 6, Jun. 2016, doi: 10.1007/s00348-016-2195-8.

This article focuses on materials development as it examines a newly proposed bi-leaflet mechanical heart valve design that mimics the geometry of a human mitral valve. Authors hypothesized that using biomimicry will replicate physiological flow fields normally seen in a healthy heart, ultimately leading to lower left ventricle turbulence levels. In the left heart in-vitro simulator, the silicon atrium was positioned upstream of the mitral valve and the associated flow probe, which aided in the generation of the physiological transmitral flow waveform with two peak flow rates. Based on the results, the subtle changes made using biomimicry significantly restored the altered flow field to a more physiological left ventricular flow field, potentially lowering blood damage. The authors concluded that with the use of biomimicry and materials such as silicon, the performance of mechanical valves in terms of hemodynamics can be improved, specifically focusing on minimizing anti-coagulation complications for the future.

[3] M. C. Arokiaraj, A. Centeno, A. Pesquera, and A. Zurutuza, "Novel graphene-coated mechanical bi-leaflet valves after accelerated wear test of 40M test cycles in saline," *Acta Cardiologica*, vol. 71, no. 3, pp. 331–347, Jun. 2016, doi: 10.1080/ac.71.3.3152094.

This article focuses on the materials development of bi-leaflet mechanical heart valves, as it examines the application of the material graphene onto mechanical heart valves and the morphology of graphene through numerous accelerated wear tests in saline. To do so, monolayer graphene was transferred to four bi-leaflet mechanical mitral valves, three of which were tested under the accelerated wear test in saline. After completing this test, all valves were evaluated through a scanning electron microscopy analysis where one of the bi-leaflet valves was coated with graphene and the other remained uncoated, so that it could serve as a control variable in this study. The authors concluded that graphene could be applied to bi-leaflet mechanical heart valves as its presence was seen in two out of the three valves through SEM analysis and after accelerated wear tests in 40M test cycles in saline.

Additional References

[1] S. G. D. Tan, S. Kim, and H. L. Leo, “The application of biomimicry to a mechanical valve design for the abatement of flow instabilities,” *European Journal of Mechanics, B/Fluids*, vol. 74, pp. 19–33, Mar. 2019, doi: 10.1016/j.euromechflu.2018.10.007.

[2] S. G. Tan, J. K. F. Hon, Y. N. Nguyen, S. Kim, and H. L. Leo, “An in vitro investigation into the hemodynamic effects of orifice geometry and position on left ventricular vortex formation and turbulence intensity,” *Artificial Organs*, p. aor.13781, Aug. 2020, doi: 10.1111/aor.13781.

[3] P. Lancellotti, C. éCile Oury, C. Jerome, and L. A. Pierard, “Graphene coating onto mechanical heart valve prosthesis and resistance to flow dynamics,” *Acta Cardiologica*, vol. 71, no. 3, pp. 235–255, Jun. 2016, doi: 10.1080/ac.71.3.3152084.