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NUMERICAL MODELLING OF HEART VALVES USING OPEN-SOURCE SOFTWARE WITH PRECICE

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Artificial heart valves are currently far from ideal, with calcification, blood damage and structural fatigue being significant factors in their sub-standard performance. Not only must the valve be strong enough to resist fatigue damage, but it must allow for blood to flow easily through. It is therefore imperative to look at the combined effects of the fluid and solid structure together when modelling a heart valve to be able to determine if either any damage will occur to the material itself or to the blood. Due to the highly complex nature of designing medical devices, numerical simulations are becoming standard use in designing heart valves.

In this study, preCICE was used, coupled with Foam-Extend and Calculix to perform numerical simulations of a polyurethane based trileaflet heart valve. The geometry consisted of a simple tube and a simplified valve geometry with a physiologically correct inlet velocity waveform. The fluid domain mesh motion was performed using the radial basis function. Remeshing of the fluid domain was performed after the mesh quality was diminished due to extreme mesh deformation. The quasi-Newton coupling method was used in preCICE which reduced the simulation time when compared to Aitken relaxation. The nearest-neighbour mapping scheme showed to be suitable for the application.The parallel-implicit coupling feature improved stability when performing simulation restarts due to the large forces on the valve.

The pressure drop across the valve was shown to vary minimally for varying mesh densities. However, the wall shear stress is more sensitive to the mesh refinement and suitable boundary layers. However, sizing of the boundary layers is complex when a transient inlet velocity and a moving domain is used. The results from Calculix indicate that the highest stress occurs at the leaflet attachment at the top of the frame pillars, where damage occurred during experimental studies. The results show that numerical simulations have the potential to assist in further research and development of heart valves. Future work will involve simulating blood flow in a physiologically representative sinus regions, and coupling preCICE with immersed boundary solvers for large deformation simulations.

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