Towards 3D analysis of aortic heart valve

Javani Joni, H.; Oomens, C.W.J.; Baaijens, F.P.T.

Published: 01/01/2011

Document Version
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):
Soft Tissue Biomechanics & Engineering

Towards 3D analysis of Aortic Heart Valve
H. R. Javani, C. W. J. Oomens and F. P. T. Baaijens

Introduction
A diseased heart valve must be replaced by a prosthetic device in order to continue the function performed by the natural valve - see Figure 1. These prosthetic devices can not perform the function of heart valve with the same efficiency and durability. Therefore, numerical and experimental studies are widely performed to improve the function and avoid their failure.

Objective
On one hand developing a fully three dimensional numerical tools for the interaction between heart valve and blood (fluid-structure interaction) and on the other hand studying the behavior of the heart valve prosthetic device under such a boundary conditions.

Method and results
There is a delicate and complex interaction between the heart valve and the surrounding blood. This interaction (fluid-solid) has to be considered for an accurate mechanical and hemodynamical aspects of the valve behavior.

Here we take the 2D algorithm developed by Bogaerds et al. [2] as the starting point and using Finite Element (instead of spectral element in [2]) the coupling scheme is being transferred to real three dimensional applications. A so called fat boundary layer is connected to the solid and the fluid variables in the interface between the two fluids (boundary layer and background) are connected - see Figure 2.

In the presented approach, the proper coupling of the two fluid domains is the challenging part since the fluid and solid are connected using conforming meshes. The governing equations for the two fluid domains are Navier-Stokes equations:

\[
\frac{\partial \rho v}{\partial t} + \nabla \cdot \rho v v = \nabla \cdot \sigma_f \quad \sigma_f = 2\eta D - p f I \\
\nabla \cdot v = 0
\]  

(1)

and the coupling conditions for their interface:

\[
\begin{align*}
\mathbf{v}_1 &= \mathbf{v}_2 \\
(\sigma_f^1 - \sigma_f^2) \cdot \mathbf{n}_{fsi} &= 0
\end{align*}
\]  

(2)

The Baumann and Oden stabilized technique is used for coupling on fluid-fluid interface. Figure 3 shows how this technique is used to couple two partially overlapping finite element layer.

Conclusion & Further extension
The 2D approach will be extended to three dimensional problems for studying the behavior and loading conditions of the heart valve.

References: