

Accepted Manuscript

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PII: S0021-9290(18)30525-6

DOI: <https://doi.org/10.1016/j.jbiomech.2018.07.018>

Reference: BM 8781

To appear in: *Journal of Biomechanics*

Received Date: 12 November 2017

Accepted Date: 9 July 2018

Please cite this article as: D. Sodhani, S. Reese, A. Aksenov, S. Soğancı, S. Jockenhövel, P. Mela, S.E. Stapleton, Fluid-structure interaction simulation of artificial textile reinforced aortic heart valve: validation with an in-vitro test, *Journal of Biomechanics* (2018), doi: <https://doi.org/10.1016/j.jbiomech.2018.07.018>

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Fluid-structure interaction simulation of artificial textile reinforced aortic heart valve: validation with an in-vitro test

Deepanshu Sodhani, Stefanie Reese

Institute of Applied Mechanics, RWTH Aachen University, Mies-van-der-Rohe-Str. 1, 52074 Aachen, Germany

Andrey Aksenov, Sinan Soğancı

Capvidia NV, Research Park Haasrode, Technologielaan 3, B-3001, Leuven, Belgium

Stefan Jockenhövel, Petra Mela

Institute of Applied Medical Engineering, Helmholtz Institute & ITA-Institut for Textiltechnik, RWTH Aachen University, Pauwelsstr. 20, 52074. Aachen, Germany.

Scott E. Stapleton

Dept. of Mechanical Engineering, University of Massachusetts Lowell, 1 University Avenue, Lowell, MA 01854, USA

Abstract

Prosthetic heart valves deployed in the left heart (aortic and mitral) are subjected to harsh hemodynamical conditions. Most of the tissue engineered heart valves have been developed for the low pressure pulmonary position because of the difficulties in fabricating a mechanically strong valve, able to withstand the systemic circulation. This necessitates the use of reinforcing scaffolds, resulting in a tissue-engineered textile reinforced tubular aortic heart valve. Therefore, to better design these implants, material behaviour of the composite, valve kinematics and its hemodynamical response need to be evaluated. Experimental assessment can be immensely time consuming and expensive, paving way for numerical studies. In this work, the material properties obtained using the previously proposed multi-scale numerical method for textile composites was evaluated for its accuracy. An in-silico immersed boundary (IB) fluid structure interaction (FSI) simulation emulating the in-vitro experiment was set-up to evaluate and compare the geometric orifice area and flow rate for one beat cycle. Results from the in-silico FSI simulation were found to be in good coherence with the in-vitro test during the systolic phase, while mean deviation of approximately 9% was observed during the diastolic phase of a beat cycle. Merits and demerits of the in-silico IB-FSI method for the presented case study has been discussed with the advantages outweighing the drawbacks, indicating the potential towards an effective use of this framework in the development and analysis of heart valves.

Keywords: Fluid structure interaction, aortic heart valve, in-vitro test, valve mechanics, multi-scale modelling

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