18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 370–371
Paper **#38**

NON-NEWTONIAN EFFECTS OF PULSATILE BLOOD FLOW IN A REALISTIC BYPASS GRAFT GEOMETRY

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Abstract: *The study is focused on mathematical modelling of pulsatile blood flow in a patient-specific aorto-coronary bypass model with individual graft. Blood is considered to be an incompressible non-Newtonian fluid, whose behaviour is described by the macroscopic Carreau-Yasuda model. The numerical solution of the non-linear system of incompressible Navier-Stokes equations is based on the three-stage fractional step method and the cell-centred finite volume method formulated for hybrid unstructured tetrahedral grids. Since patency and long-term performance of all implanted bypass grafts is closely related to hemodynamics, all obtained results are analysed and discussed with the help of several significant hemodynamical wall parameters such as cycle-averaged wall shear stress and oscillatory shear index.*

Keywords: ***aorto-coronary bypass, non-Newtonian fluid, fractional step method, finite volume method.***

Nowadays it is generally accepted that the performance and patency of implanted bypass grafts is significantly affected by local hemodynamics, Loth et al. (2008). The majority of recorded bypass failures is often caused by intimal hyperplasia, Haruguchi and Teraoka (2003), a form of intimal thickening observed at the distal anastomosis of the implanted graft. The changes are hypothesised to be triggered by disturbed blood flow and low and oscillating shear stress, Bassiouny et al. (1992). The main objective of the present study lies in the investigation of blood's non-Newtonian behaviour in a patient-specific bypass graft. This way, we hope to extend our conclusions previously drawn in Vimmr and Jonášová (2010) for the modelling of non-Newtonian blood flow in coronary bypasses.

The aorto-coronary bypass model considered in the study is reconstructed from CT data provided by the courtesy of the University Hospital in Pilsen, Czech Republic, Fig. 1. The model reconstruction and mesh generation is carried out in the software packages Amira and Altair Hypermesh, respectively. For the numerical simulation of pulsatile blood flow several assumptions are made. First of them is related to vessel compliance, which is neglected here, even for the in reality elastic aorta. We hope to rectify this considerable limitation of the present study in one of our future projects by solving the fluid-structure interaction problem. Further, the beating of the heart is not considered, i.e., we assume a static aorto-coronary bypass model in accordance with conclusions drawn in Zeng et al. (2003). For the description of blood's complex rheological properties, we introduce the macroscopic Carreau-Yasuda model with parameters taken from Cho and Kensey (1991). The numerical solution of the time-dependent non-linear system of generalized incompressible Navier-Stokes equations is based on the three-stage fractional step method and cell-centred finite volume method formulated for hybrid unstructured tetrahedral grids. The overall computational efficiency of the developed CFD code is improved by introducing the principle of the well-known local time-stepping method. The analysis and discussion of obtained numerical results is carried out with the help of two hemodynamically significant wall parameters – cycle-averaged wall shear stress (WSS) and oscillatory shear index (OSI). Fig. 2 shows the distribution of the cycle-averaged WSS at the proximal and distal anastomosis. On the basis of the computed numerical results, we can conclude, similarly to our previous work Vimmr and Jonášová (2010), that blood's non-Newtonian behaviour does not have any significant impact on the hemodynamics in coronary bypasses, even when considering pulsatile flow conditions and a realistic bypass geometry.

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Acknowledgments

This study was supported by the European Regional Development Fund (ERDF), project NTIS - New Technologies for Information Society, European Centre of Excellence, CZ.1.05/1.1.00/02.0090 and by the internal student grant project SGS-2010-046 of the University of West Bohemia.

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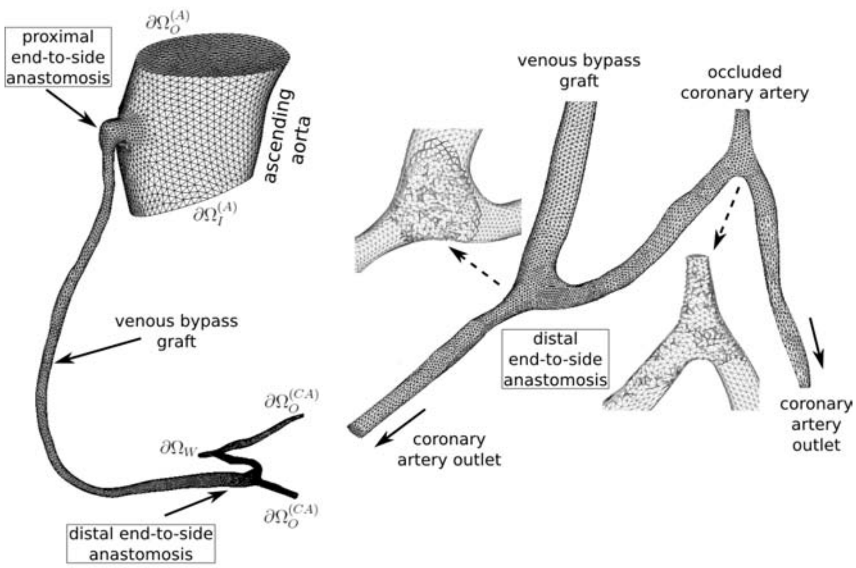

Fig. 1: Individual graft – unstructured computational mesh and relevant terminology

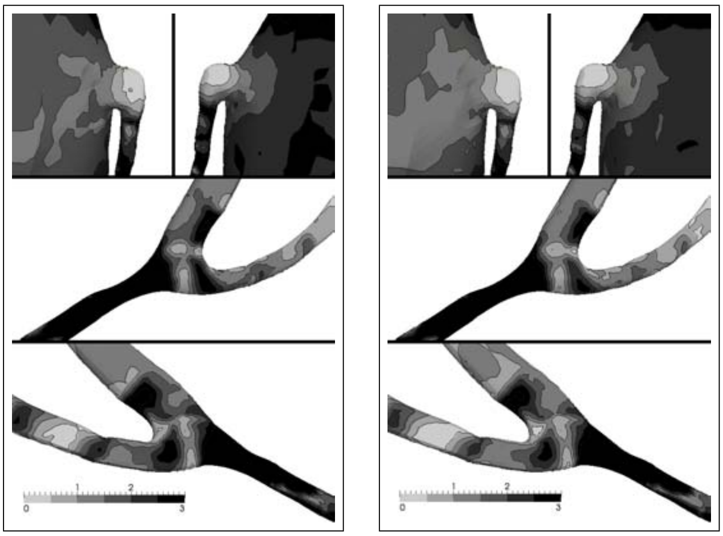

Fig. 2: Distribution of cycle-averaged WSS for the Newtonian (left) and non-Newtonian flow (right)