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Asymptotic and numerical analysis of non-Newtonian flows in networks of blood vessels

Abstract

Partial differential equations in thin domains combining thin plates and thin rods or pipes (so-called multi-structures) are extensively studied in mathematical solid and fluid mechanics (see e.g. [1-3]). In particular, in [3-6] the so called thin tube structures were introduced as geometrical models for networks of thin blood vessels, tubes in catalytic converters, pipelines etc. The asymptotic analysis of the viscous Newtonian flows in these structures allowed to introduce the hybrid dimension models. They combine one-dimensional and multidimensional description of the flow with asymptotically exact coupling conditions between 3D and 1D parts of the model (see [4,5] and a recent monograph [6]). Another approach for junction of models of different dimensions for blood flow in arteries was proposed in [7, 8]. Thus, hybrid dimension models provide the one-dimensional description in the main part of the domain and make small full-dimensional zooms. These zooms give detailed description of the flow in the zones of interest such as the bifurcations of vessels, zones of blood clot formation, stents and so on. The hybrid dimension models allow substantially accelerate computations without loss of accuracy. In [3-6] the so called Newtonian rheology was considered : the Navier-Stokes equations with constant viscosity. However, it is well-known



that the blood as well as melted polymers exhibit non-Newtonian rheology, when the viscosity depends on the gradient of velocity (shear rate). In particular, the numerical simulations for the blood show the difference about 10-15

References:

1. P.G. Ciarlet, *Plates and Junctions in Elastic Multi-structures. An Asymptotic Analysis*, Masson, Paris, 1990.
2. V. Kozlov, V. Maz'ya, A. Movchan, *Asymptotic Analysis of Fields in Multi-Structures*, Oxford Mathematical Monographs., Oxford Science Publications, The Clarendon Press, Oxford University Press, New York, 1999.
3. G. Panasenko, *Multi-scale Modeling for Structures and Composites*, Springer, Dordrecht, 2005.
4. G. Panasenko, Asymptotic expansion of the solution of Navier-Stokes equation in a tube structure, *C.R. Acad. Sci. Paris*, 326, IIb, 1998, 867—872.
5. G. Panasenko, Partial asymptotic decomposition of domain: Navier-Stokes equation in tube structure, *C.R. Acad. Sci. Paris*, 326, IIb, 1998, 893—898.
6. G. Panasenko, K. Pileckas, *Multiscale Analysis of Viscoous Flows in Thin Tube Structures*, Birkhauser, Springer Nature Switzerland AG, 2024.
7. L. Formaggia, A. Veneziani, *Reduced and Multiscale Models for the Human Cardiovascular System. Lecture Notes*, VKI, Brussels, 2003.
8. L. Formaggia, A. Moura, F. Nobile, On the stability of the coupling of 3D and 1D fluid-structure interaction models for blood flow simulations, *M2AN*, 2007, 743-769.
9. G. Panasenko, K. Pileckas, Partial asymptotic dimension reduction for steady state non-Newtonian flow with strain rate dependent viscosity in thin tube structure, *J.Math. Fluid. Mech.*, 25:11, 2023.