DOI 10.18699/SBB-2022-132

Investigation of various hemodynamic regimes in elastic vessels

Vasyutkin S.A.[1, 2]*, Chupakhin A.P.[1, 2]*

[1] *Novosibirsk State University, Novosibirsk, Russia*

[2] *Lavrentyev Institute of Hydrodynamics, SB RAS, Novosibirsk, Russia*

** s.vasyutkin@g.nsu.ru, * alexander190513@gmail.com*

Key words: one-dimensional model of hemodynamics, traveling waves, blood flow in vessels

The study of fluid flow in an elastic tube is of considerable interest both for fundamental hydrodynamics and for numerous applications: blood flow in vessels, fluid transport in pipelines, etc. An accurate description of this problem includes both finding the velocity and pressure of the fluid, displacements of the pipe walls and stresses in them, and finding the position of the walls. This is a problem with an unknown boundary, the conditions for the coupling of velocity and stresses are set on it. The complexity of this problem initiates the derivation and study of approximate models. One of the most common is the long tube model (one-dimensional model of hemodynamics), in which it is assumed that the length of the tube exceeds its cross-section. The introduction of a small parameter into the problem – the ratio of these quantities – allows us to move to an approximate model in which the velocity is averaged over the pipe section. A lot of works devoted to the one-dimensional model are devoted to both the mathematical side of the issue and physical applications [1, 2]. The characteristic modes of motion in such a system are traveling waves, the study of which was started in [3].

In this case, the system of equations is reduced to a system of ordinary differential equations. The principle is the closure of this system by a kind of equation of state, which sets the dependence of pressure on the radial displacement of the pipe wall. The paper investigates solutions of the traveling wave type for a pipe given by a Coiter shell. In this model, the pressure is represented as a function of the displacement of the wall and the derivatives of this value. The report examines the influence of elastic and viscous factors on the behavior of the solution near the singular point of the corresponding dynamical system. Conditions for different modes of blood flow in the vessels were found. The influence of various physico-chemical characteristics of the vessel walls and blood, which make the greatest contribution to the change of blood flow regimes in the vessels, has been studied. In a numerical experiment, it is shown that solutions of the traveling wave type can describe the deviation of the vessel wall and the characteristics of the blood flow with sufficient accuracy.

References

1. Čanić S., Tambača J., Guidoboni G., Mikelić A., Hartley C.J., Rosenstrauch D. Modeling viscoelastic behavior of arterial walls and their interaction with pulsatile blood flow. *SIAM J Appl Math*. 2006;67(1):164-193.
2. Il'ichev T., Sumskoi S.I., Shargatov V.A. Unsteady Flows in Deformable Pipes: The Energy Conservation Law. In: Proceedings of the Steklov Institute of Mathematics. 2018;300:68-77.
3. Barlukova A.M., Cherevko A.A., Chupakhin A.P. Traveling waves of a one-dimensional model of hemodynamics. *J Appl Mech Tech Phys*. 2014;55(6):917-926.