A fractional model for blood flow in small arterial vessels

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Abstract

It is widely known that the rheological behaviour of blood is quite complex because of its multiphase nature. For large arterial vessel, the Hagen-Poiseuille model, which main assumption is that the blood behaves as a Newtonian fluid, is suitable for reproducing experimental measuring; for small arterial vessels, instead, the Hagen-Poiseuille model is not adequate. Among all existing rheological models, the Casson law is considered the most suitable for the blood behaviour in small capillary vessels. However this model is not constructed on a mechanical basis and, since it is a nonlinear mechanical model, mathematical manipulations are not straightforward. In this work an alternative approach is proposed. The model is builded up on a mechanical basis by taking into account the presence of Red Blood Cells and other smaller cells that are dispersed in the plasma. The blood is modeled as an homogeneous fluid and the presence of solid parts in it are modeled by inserting long-range (or non-local) viscous interactions in the constitutive equation. The non-local forces are thought as forces mutually exerted by non-adjacent fluid elements; they are constructed as linearly dependent on the product of the two volume considered, on their relative velocity and on an attenuation function that decreases the entity of long-range interactions as the distance between two volume elements increases. If the attenuation function is chosen as a power law with real order of the distance between two volume elements, fractional derivatives appears in the linear governing equation. It is shown that the model is capable of reproducing experimentally measured profile of velocity across small capillary vessels, moreover for large arterial vessels non-local interactions become negligible and the model reverts to the Hagen-Poisueille model.

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