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Localized Collocation Meshless Method (LCMM) Shape Optimization of Vascular Grafts Part I: LCMM Hemodynamics Modeling

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Summary

In the first part of this paper, we present the developments of a Localized Collocation Meshless Method (LCMM) to simulate blood flow under laminar conditions. The meshless notion indicates that the current method is not cell-based; rather it relies on a point distribution in the computational domain. Each of those points is referred to as a data center. The pre-processing for this meshless method is independent from the geometry shape as it always yields a Cartesian point distribution in the interior and non-uniformly distributed points near the boundaries. The formulation of LCMM depends on radial basis function collocations and moving least square polynomial expansions. This particular formulation leads to the so-called "derivative vectors" at each data center. A derivative of a given field variable is obtained at the data center by multiplying the corresponding derivative vector by a "scalar vector". The scalar vector has the same size of the derivative vector and it comprises of the given field variable values at points neighboring the data center. As the current meshless method deals with a fluid flow problem, a high order upwinding scheme is incorporated to dampen the numerical oscillations arising due to dominating convection forces. The blood flow is treated as incompressible and pulsatile with a non-Newtonian viscosity. The Carreau model is used to evaluate the viscosity. The meshless results were analytically and numerically validated. The analytical validation was performed using the decaying vortex problem and an error analysis was conducted to identify the spatial accuracy order of the current meshless technique. The numerical validation was carried out with the finite volume commercial solver Fluent 6.2. The flow geometry for the numerical validation consists of an end-to-side distal anastomosis, which is the inter-connection between a bypass graft and an artery. A very good agreement was found between the LCMM and the finite volume method.

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