Blood damage prediction on VAD's rough surface by discrete-porosity roughness model

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Ventricular assist devices (VAD) are used for patients with a heart insufficiency. A continuous-flow VAD with rotary pump is promising technical solution but blood damage prediction is required to investigate its hemocompatibility. Roughness features of rotating surface of pump affects viscous shear stress field locally and it may lead to activation of platelets, hemolysis, thrombosis and thromboembolic events (i.e. blood damage) [1]. Therefore, investigations are necessary to describe the influence of roughness features on the blood which will help to decide a manufacturing process of VAD. Thus, a local roughness features of surface must be modelled in numerical roughness model precisely to calculate local viscous shear stress accurately.

Equivalent sand-grain (ESG) roughness height model can calculate global effect of roughness like total pressure loss but not the effect on local shear stress because of roughness features [2]. Simulation considering rough surface feature of the body using body-conforming mesh would provide most accurate results. But it is mostly impossible to create a grid for VAD surfaces having average roughness height of 1µm, in a way with acceptable mesh size and mesh quality.

Discrete porosity model (DPM) is an alternative roughness model to add local roughness features effect in simulations without creating body-conforming mesh. This method is using a viscous loss $\left(\propto (\mu * V)\right)$ and inertial loss $\left(\propto (\rho * V * |V|)\right)$ terms to represent a sink in the momentum equation for each roughness affected cells [3]. Moreover, the sink terms are improved by adding the volume fraction of roughness element in fluid cell volume (α). Cartesian mesh of the fluid domain and CAD data of rough surface are imported together using MATLAB script. An algorithm is written to locate Cartesian fluid cell element interfering with roughness surface. After that α of selected interfering cells are calculated considering real roughness feature for each interfering cell element. This in-house written script, export a file having interfering cell centroid coordinate with α.

A rough channel with blood flow is considered for numerical analysis in OpenFOAM with ESG and DPM roughness models. DPM and ESG models underestimate frictional velocity at rough surface by 25% and 100% respectively to the experimental data. Hemolysis index is predicted by DPM and completely underestimated by ESG model. DPM is a better method for roughness modelling for VADs in order to optimize surface roughness. Pressure gradient, velocity profile, shear stress and hemolysis distribution of the blood flow will be presented in the final paper.

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