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Simulation of the FDA Centrifugal Blood Pump Using High Performance Computing

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Abstract : Computational Fluid Dynamics blood-flow simulations are increasingly used to develop and validate blood-contacting medical devices. This study shows that numerical simulations can provide additional and accurate estimates of relevant hemodynamic indicators (e.g., recirculation zones or wall shear stresses), which may be difficult and expensive to obtain from in-vivo or in-vitro experiments. The most recent FDA (Food and Drug Administration) benchmark consisted of a simplified centrifugal blood pump model that contains fluid flow features as they are commonly found in these devices with a clear focus on highly turbulent phenomena. The FDA centrifugal blood pump study is composed of six test cases with different volumetric flow rates ranging from 2.5 to 7.0 liters per minute, pump speeds, and Reynolds numbers ranging from 210,000 to 293,000. Within the frame of this study different turbulence models were tested including RANS models, e.g. k-omega, k-epsilon and a Reynolds Stress Model (RSM) and, LES. The partitioners Hilbert, METIS, ParMETIS and SCOTCH were used to create an unstructured mesh of 76 million elements and compared in their efficiency. Computations were performed on the JUQUEEN BG/Q architecture applying the highly parallel flow solver Code SATURNE and typically using 32768 or more processors in parallel. Visualisations were performed by means of PARAVIEW. Different turbulence models including all six flow situations could be successfully analysed and validated against analytical considerations and from comparison to other data-bases. It showed that an RSM represents an appropriate choice with respect to modeling high-Reynolds number flow cases. Especially, the Rij-SSG (Speziale, Sarkar, Gatzki) variant turned out to be a good approach. Visualisation of complex flow features could be obtained and the flow situation inside the pump could be characterized.

Keywords : blood flow, centrifugal blood pump, high performance computing, scalability, turbulence
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