6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

Application of Verification Methods on a Complex Flow Field Calculated by Large-Eddy Simulation: Blood Pump Flow

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Key Words: *Verification, Large-Eddy Simulation, Blood Pumps.*

Ventricular Assist Devices (VADs) are the most promising treatment option of end-stage heart failure. These usually continuous-flow pumps are used to bridge the gap between needed and available donor hearts. Unfortunately, most patients with implanted VADs are suffering from adverse events due to flow induced blood damage. These events can be attributed to blood components (red blood cells, platelets, proteins) in contact with crucial shear fields in the pump. Regarding this, it is common to predict blood damage via computational fluid dynamics (CFD) nowadays. Therefore, we calculated the flow within an axial VAD prototype with ANSYS CFX and the Large Eddy Simulation (LES) method on a 100M element mesh with the aim to achieve a more sufficient calculation of transient velocity gradients, i.e. shear stresses, as with high-dissipative turbulence models. The CFD solution needs to be verified, but grid convergence studies of arbitrary flow quantities for solution verification are not useful for LES, due to the direct correlation between turbulence model activity and grid spacing, i.e. filter width. Therefore, we used four alternative verification methods. The first examines the influence of the numerical diffusion and based on these results, an LES index of quality is derived. Secondly, we compare the internal flow losses due to dissipation and turbulence production against hydraulic losses, determined from the pump characteristics to examine, whether the LES is able to capture the turbulent flow losses. Third, we compared resolved vs. modelled turbulent kinetic energy (TKE) and finally, we analyzed TKE spectra in the flow field. Our objective is to present the application of different methods for LES verification of complex flow fields, in which a sufficiently fine temporal and spatial resolution of highly mesh-sensitive quantities is very important. We compared methods in means of consistency among each other and especially regarding the presumable correctness of the numerical blood damage prediction.