COMPUTATIONAL FLUID DYNAMICS SIMULATION OF 3RD GENERATION ROTODYNAMIC BLOOD PUMPS UNDER REALISTIC DYNAMIC OPERATING CONDITIONS

Bente Thamsen (1), Rosmarie Schöfbeck (1), Simon Klocker (1,2), Marko Grujic (1), Theodor Abart (1), Adrian Wisniewski (3), Bernhard Semlitsch (2), Daniel Zimpfer (1), Marcus Granegger (1)

1. Christian Doppler Laboratory for Mechanical Circulatory Support, Department of Cardiac Surgery, Medical University of Vienna, Austria; 2. Department of Fluid Flow Machinery, Technical University of Vienna, Austria; 3. Berlin Heart GmbH, Berlin, Germany.

Introduction

Rotodynamic blood pumps (RBPs) provide support that directly depends on the pulsatile hemodynamic conditions set by the cardiovascular interface. Although designed for a single static operating point, these pumps are operated in a highly transient manner. Computational Fluid Dynamics (CFD) simulations are successfully used to investigate RBPs in static conditions, but for dynamic operation there is no standard methodology with a broad range of setups used so far [1-3]. Aim of this study was to establish a CFD framework to adequately and efficiently capture the realistic fluid dynamics within an RBP working in tandem with the native heart through thorough experimental validation using a hybrid mock loop [4].

Methods

Using two different RBPs, the Heartmate 3 (HM3) for adult patients and a functional model of a next generation RBP (NGP) in pediatric use, three different clinical cases (high/low pulsatility adult, typical pulsatility pediatric) were investigated. Measured data from the hybrid mock loop were translated into numerical models of the pumps and their periphe-ries [4, 5]. In the simulations, fluid density and viscosity as well as a pulsatile inlet mass flow were specified based on the experiments (fluid: 1120kg/m³ density and 3.5mPas dynamic viscosity). To identify an appropriate setup, the effects of different CFD settings (time step size, simulation of rotation, turbulence model) on the results were analyzed for the HM3. The computed dynamic pressure-flow behavior for both pumps was validated on the basis of the experimental results. In addition, the influences of surface roughness and inflow conditions were investigated experimentally.

Time step	Rotation	Turbulence
2°, 4°, 8°, 16°	Sliding Mesh, Mixing Plane, Frozen Rotor	k-omega SST, laminar

Table 1: Investigated setup parameters.

Results

As shown in Figure 1, dynamic pressure-flow loops could be qualitatively replicated with CFD for both pumps in typical conditions (NGP: RMSE=5.19mmHg; HM3: RMSE=8.34mmHg). For the HM3, the pressures were widely overpredicted. The Frozen Rotor scheme showed a substantial dependence on impeller position, but the Mixing Plane model allowed a similarly good prediction (RMSE=8.15mmHg) of global hydraulic performance as the Sliding Mesh model. Consideration of turbulence did not influence the global results. Surface roughness in the volute casing had no impact on the measured pressures.

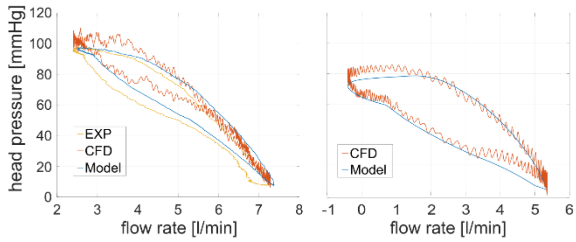

Figure 1: Dynamic pressure-flow loops. Left: HM3: data from experiment, CFD and numerical model; Right: NGP numerical model vs. CFD.

Discussion & Conclusion

We developed a framework to capture the realistic fluid dynamics within two different RBPs at three different clinically relevant, pulsatile operating conditions. In conducting such dynamic simulations, it is crucial to meticulously validate the accuracy of the results. While using Sliding Mesh enables the analysis of local flow features within a cardiac cycle, Mixing Plane can be used to describe global performance. The deviations for the HM3, especially in the high flow regime, may stem from the magnetic levitation system, which involves a non-fixed rotor position, that is not reflected in CFD.

References

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