# Abstract

## Development of numerical model for modeling artificial heart valves for performing virtual therapies

**Keywords:** aortic valve, hemodynamics, moving deforming mesh, fluid-structure interaction, CFD, coronary artery, blood flow, calcification, virtual therapy, test rig, computer vision

Aortic valve disease is one of the most common cardiovascular disease; they can be divided into congenital defects, such as biscupid aortic valve, or they appear as a disease with aging. The most common valvular disease is calcified aortic valve disease, reaching 13% in the general population over 65 years. For patients with advanced calcification stage, artificial aortic valve implantation is the only option, however this can lead to medical complications. There is a large potential in the development of a hybrid approach that combines fast echocardiography with an advanced numerical model.

In the Thesis different approaches for the modeling the movable, rigid and deformable structures, as human and artificial valves were used. Different moving mesh approaches were used and their results and validity were compared. The numerical results were compared with those obtained via measurements, performed using the inhouse test rig, also physiological data were used for such purpose. Laboratory test rig included the pulsatile blood pump, fast camera, mass flow meter, pressure transducers and valve holder designed for the measurements.

The mathematical model comprise the solving of the physics present on the fluid and the solid side, also the interaction between those two participants. The fluid equations included the partial-differential Navier-Stokes equations, turbulence model and Windkessel model for outflows, created based on the electrical analogy. Also, the non-Newtonian viscosity model had to be implemented into solution procedure. On the solid side, the structural governing equations were applied, which allowed to calculate the transient deformation fields. For the rigid bodies, the inhouse model was implemented into the fluid solver to determine their motion.

The synthetic valve operation was analyzed after its virtual implantation in the real patient vasculature geometry. The inhouse model for determining the transient angular leaflet motion was implemented. The inhouse algorithm was developed, to automatically determine the angular positions of the rigid-leaflet valves and valve opening of the elastic-leaflet valve, from the large set of the images. The two-way partitioned fluid-structure interaction model was applied for modeling of the elastic human valve. The novel, advanced moving mesh model was used. The impact of calcification process onto natural and artificial aortic valves was assessed and compared.