FOCUS ON IMAGING

In Application

Fluid-Structure Interaction Studies of Bioscience Subjects

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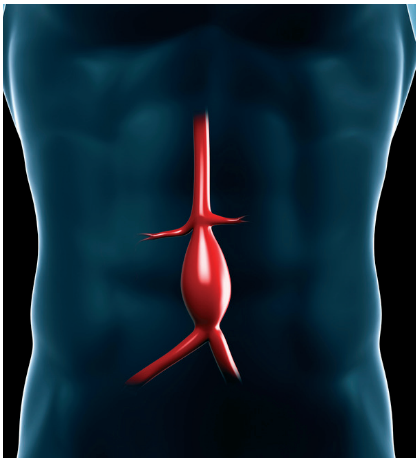
Introduction

Presently the fluid-structure interaction (FSI) of a flexible body and a surrounding fluid (i.e. fish fin, insect or bird wing, arterial wall) is acutely challenging to measure because separate techniques are required to measure the fluid flow and surface deformation.
LaVision is able to provide exactly the measurement systems required to carry out such an investigation, and in this study the techniques of Tomographic PIV (Tomo-PIV) and Digital Image Correlation (DIC) were used simultaneously to develop FSI measurement methodologies for the biosciences.

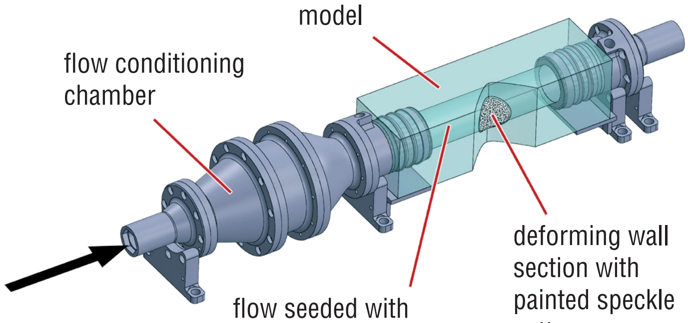


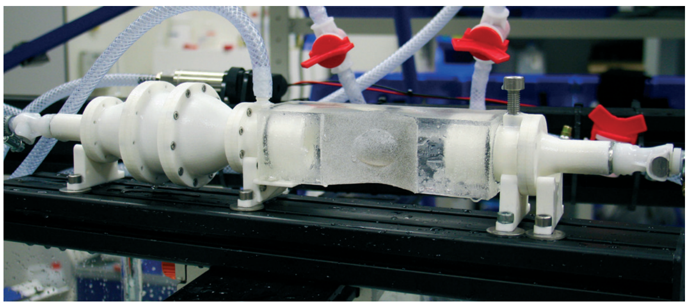
The subject of the study is a model of an abdominal aortic aneurysm. An abdominal aortic aneurysm is when the main blood vessel (aorta) that leads away from the heart swells. The abdominal aorta is the largest blood vessel in the body. Normally this aorta is 2 cm wide however it can swell to almost 6 cm. Although rare, if a large aneurysm bursts, it causes huge internal bleeding and is usually fatal.

This bulging occurs when the wall of the aorta weakens, and this is simulated by the experimental setup. In reality the biological material properties are complex, but this type of approach allows us to experiment with known material properties and therefore potentially validate a simulation.

Principle

The first test utilized a simplified model of an abdominal aortic aneurysm. A pulsating flow was driven through a flexible silicone model to simulate the blood flow, and the model incorporates a thin walled section that protruded with each pulse. A mixture of glycerine and water was used to index match the fluid to the walls and avoid strong distortions due to refractive index effects. The seeding medium in the fluid was fluorescent coated particles and the wall was speckled with ink to provide the pattern for the image correlation. Four high-speed cameras operated at 28 Hz to image the seeded fluid which was illuminated by a high-speed Nd:YLF laser. Two standard frame rate E-Lite cameras viewed the speckled deformable membrane in a stereo arrangement to observe the wall deformation.





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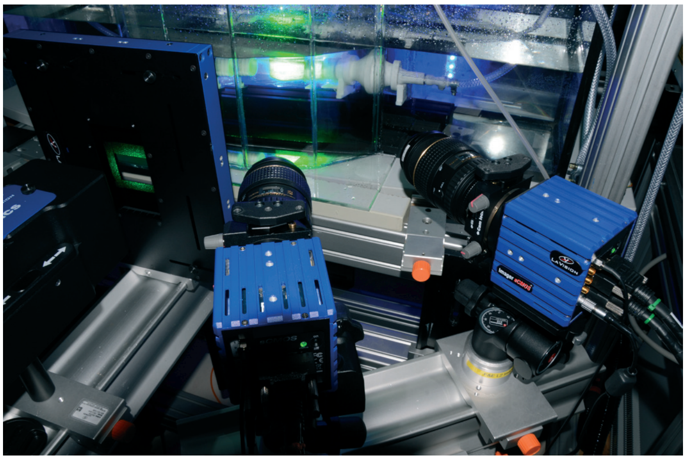
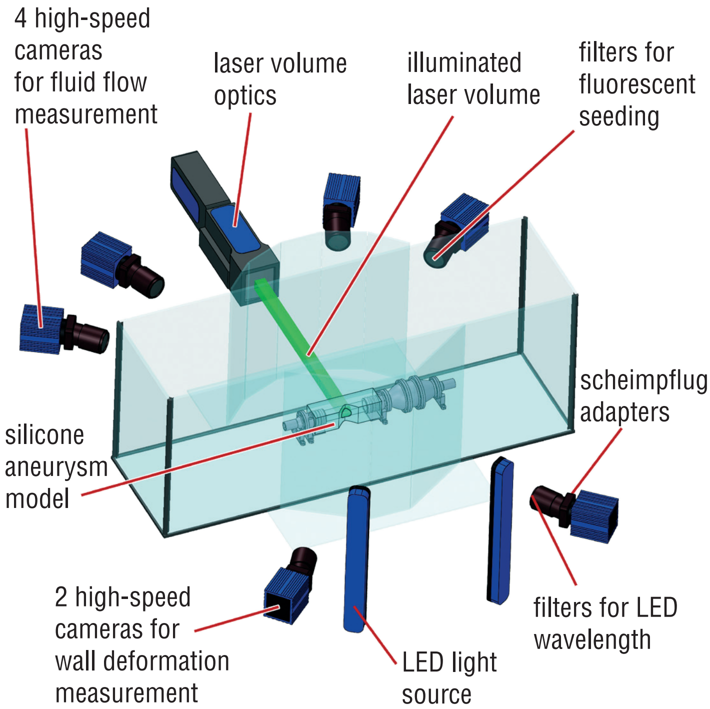
Experimental Setup

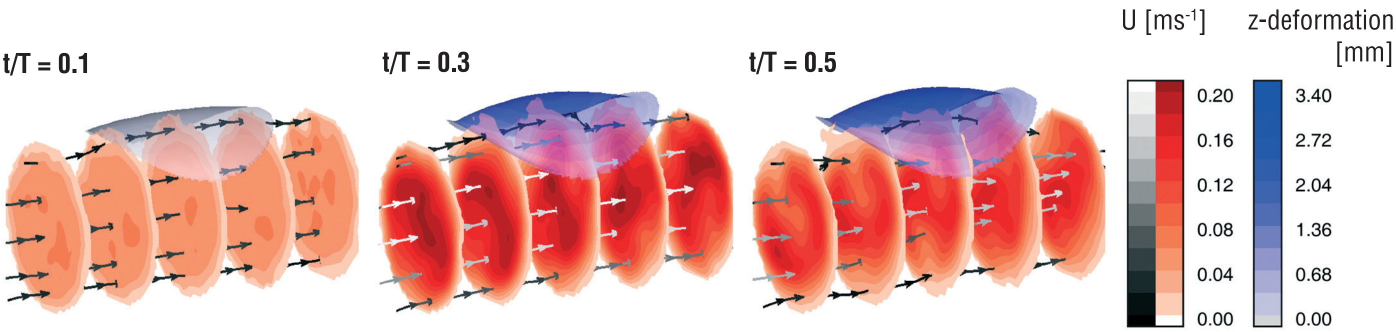
FlowMaster Tomo-PIV systems can provide time resolved full volume data regarding fluid flow behaviour, allowing the user to calculate and visualize the three dimensional structures within the flow field. StrainMaster Digital Image Correlation systems are able to capture deformation of materials subjected to some kind of load, and in this case the response of the membrane to the flow was calculated.





Results

Flow development and membrane deformation at three instances throughout the pulse cycle are shown in the image below. The wall is maximally deformed at the mid point of the cycle. Streamlines and contours overlaid on slices through the flow reveal the instantaneous flow structure in the fluid volume, in conjunction with the degree of wall deformation.



This study has shown a novel approach for studying Fluid-Structure Interactions utilizing FlowMaster Tomo-PIV and StrainMaster DIC systems from LaVision, providing valuable insight and validation data for future simulations of this complex problem.

For further details please refer to the corresponding authors N. Phillips, H. Safi, D. Michaelis, H. Nagel, R. J. Bomphrey

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