ELEMENTARY EXPERIMENTAL SETUP FOR FLOW VISUALIZATION IN UPPER HUMAN RESPIRATORY TRACT

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Introduction

The increasing demand of treatment methods like drug application in nasopharynx, caused by its open and pain free access to mucosa, in comparison to intestinal or conjunctival mucosa brings an enormous interest in exact understanding of flow conditions in nasopharynx. Additionally, surgical corrections for diseases in human respiratory tract e.g. atrophic rhinitis [1] and empty nose syndrome [2] are necessary. Several studies developed on the one hand experimental setups and on the other hand numerical models based on based on patient-specific CT-scans [3]. These measurements bring the requirement of an open source numerical model, based on and validated by an experimental setup with exactly the same geometries.

Methods

Figure 1 shows a sketch of the developed mold and parts of the produced mold twice as large as original for exact measurements also in smaller regions. Therefore a clinical CT-scan of a male patients head was captured. Because of complex structures in human nasal region the front part of the mold was produced by rapid prototyping. The rest of the mold was constructed out of aluminum. The mold was filled with silicone (Sylgard 184) and removed after curing.

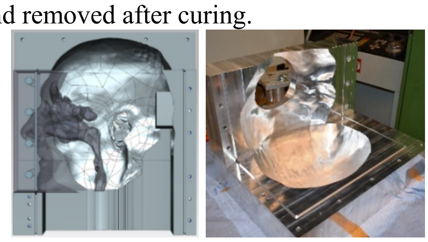

Figure 1: Sketch of mold with inner respiratory tract (left). Parts of manufactured mold (right).

Different materials refract light waves in different angles on their surfaces, so refractive index adaptation of the silicone head and the surrounding medium is necessary to eliminate optical distortion in following PIV measurements. For Sylgard 184 ($n \approx 1.418$) [4] water glycerol mixture in ratio 65:35 at 20°C is needed. To fill in the water-glycerol a vessel with minimum diameter of traverse travel range to cover up the full head geometry is required. Therefore a PVC bag was constructed with three portholes (BK7 glass). Angles between each porthole were adjusted to 60°. Radially the bag was reinforced by 5 wooden frames as shown in figure 2. The tomo-PIV system (LaVision) with three cameras and macro objectives (ZEISS Milvus 2/100) was used.

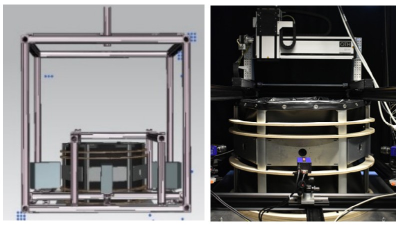

Figure 2: Experimental setup.

Results

To provide an overview, a CFD calculation with laminar flow of the inner respiratory tract, captured by a clinical CT, was conducted. Streamlines and velocities are shown in figure 3 and no signal in the sinuses can be found. But to confirm this assumption experimental studies are required.

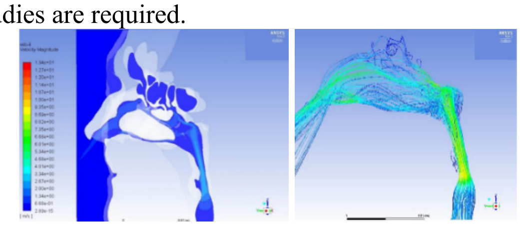

Figure 3: Velocities (left) and streamlines (right) within the respiratory tract calculated by ANSYS.

Therefore an experimental setup for tomographic PIV measurement of human nasopharynx was developed. The experimental setup consists of two parts, a container to fill in a water glycerol solution a silicon head with geometries of the human nasopharynx.

Discussion

Subsequent to the completion of the experimental setup, velocity measurements are planned. Simultaneously geometries of the silicone head will be captured and an open source CFD-model will be developed. For an exact validation of a numerical model an exact measurement in each region of the nasopharynx has to be fulfilled.

References

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