Simulation of Air-Guiding in a Respiration Therapy Device

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Respiratory therapy devices are used for patients suffering from lung disease with breathlessness. A state-of-the-art system has the disadvantage that it can only be used in a horizontal position during the therapy. Furthermore, it is only possible to train at rest. The optimization includes on the one hand the improvement of the gas mixture control and on the other hand an included variable breathing resistance. This will allow a more flexible respiratory therapy. 1

Materials and Methods

This master's thesis supports the optimization of the device in the area of breathing resistance. The final goal is simulation and analysis of the air-guiding in the optimized therapy system (Fig. 1a). The analysis covers both the interaction of the different components and the mixing ratio of the gas-mixing module. Also the ratio of pressure, volume flow and cross section is analyzed. The simulation of the air-guiding through the device is done with the software Comsol Multiphysics Version 4.3a. To become acquainted with CFD simulations, the diaphragm according to the standard EN ISO 5167-1 was simulated first. Furthermore, the diaphragm is a possible breathing resistance. The gained knowledge and experience was the basics for the subsequent simulation, analysis and optimization of the therapy system.

Results

The oval shape of the inlet pipe to the diaphragm influences the mass flow distribution through the openings of the diaphragm. Therefore, also the streamwise orientation of the openings plays an important role: The orientation influence the dissipated power over the system. The influence can be even around 20%. The examination in the field of static pressure measurements shows that the difference in the measured pressure between the measuring tube (Fig. 2a) and the measuring ring (Fig. 2b) simulated at a positive volume flow is in the range of 0.2%. The advantage of the measuring ring is the homogenous pressure distribution in the ring. The complicated cleaning of the ring supply channels is a disadvantage. Problems occurred with the gas-mixing module: it was not possible to simulate the mixing ratio. With this model, the limitation of the k-epsilon turbulence model of Comsol was reached. Also the turbulence model k-omega seemed not very suitable for solving these problems.

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Discussion

The analysis of the air-guiding in the optimized therapy device model gave important information about the interaction of the various components and the influence of diaphragm shape. This supported the project in the design optimization. The graphical comparison of results between simulations and initial experiments shows a good match. But deviations occur since the simulation does not take certain real effects into account (such as leakage, different inlet velocity profile etc.).

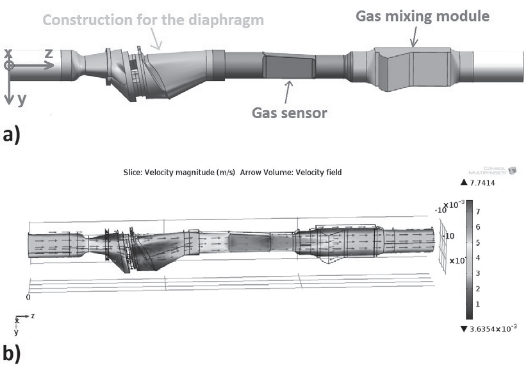

Fig. 1
a) CAD air-guiding model, b) Velocity magnitude and the vector plot of the velocity field done with Comsol

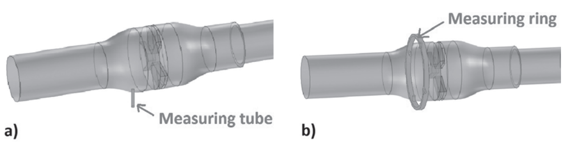

Fig. 2
Pressure measurement with a) measuring tube, b) measuring ring