-ABSTRACT-

In medical applications it is important that aerosols reach the alveolar zone of the respiratory tract, to be effective. Before this region is reached, the aerosols have to pass the upper airway (UA), starting with the mouth and a 90-degree bend leading into the trachea. The UA geometry's irregularity and constrictions (such as the vocal cords) potentially affect the deposition of inhaled aerosols.

The goal of this dissertation was to develop from the available CT-scans, a simplified yet realistic human UA geometry. From this computer generated UA geometry, a suitable physical model was created for Particle Image Velocimetry (PIV) measurements. Via Reynolds similitude, a seeded water-glycerine mixture, matching the refraction index of the transparent model was measured in a central sagittal plane of the model at four flow rates (corresponding to 10, 15, 30 and 45 l/min air breathing flow rate). These PIV measurements were compared with Computational Fluid Dynamics (CFD) simulations of the fluid phase. Of the various available turbulence models that were combined with the Reynolds Averaged Navier-Stokes (RANS) equations to compute the fluid phase in this UA model, the k-ω Shear-Stress Transport (SST) turbulence model best reproduced the experimental results.

For the simulation of the particle phase, particles with diameter ranging from 1 to 20 micrometer were tracked in a Lagrangian frame of reference through the obtained converged flow field. Simulations of total deposition compared well with experimental deposition data, for particles with a value for the non-dimensional parameter $Stk.Re^{0.37}$ (Stokes number .Reynolds number$^{0.37}$) higher than 0.1. Total deposition of particles with a smaller value was overpredicted, probably due to exaggerated turbulence simulated at low flow rates. Simulations of local particle deposition patterns in the UA model were much more realistic than local deposition patters previously reported in simplified geometries. In particular, simulated mouth deposition more closely resembled that obtained experimentally in realistic upper airway geometries. The influences of gravity, of carrier gas, of degree of turbulence at the model entrance, and of considering non-steady flow at particle injection were discussed.

Finally a clinical problem of tracheal stenosis was tackled by introducing various degrees of constriction in the upper third of the trachea in the UA model. CFD simulations of pressure drops across the stenosis allowed us to propose a rule of thumb from which pressure drops over the stenosis can be estimated, simply on the basis of breathing flow and stenosis cross section. In addition, the best-fit exponent in the power law that relates pressure drop to breathing flow was proposed as a diagnostic tool in the non-invasive monitoring of tracheal stenosis patients.