Euler-Lagrange Approach to Investigate Respiratory Anatomical Shape Effects on Aerosol Particle Transport and Deposition

Model Validation

The present numerical study for aerosol particle TD has been comprehensively validated against various published numerical models [1, 2].

![Graphs showing deposition efficiency comparison](image)

Figure 1: DE comparison for different flow rate with Russo et al. [2] results (a) 15 l/min, (b) 30 l/min, and (c) 60 l/min.
The current model for non-realistic geometry is validated with the published results of Russo et al. [2]. The DE for various size particles is investigated against flow rate and shown in figure 1. The overall DE percentage of the present CFD study shows a discrepancy with the published result of Russo et al. [2]. The published study used ANSYS CFX solver and Java script for particle file injection. Different injection techniques and solver could be the reason for the discrepancy. Despite the discrepancy, the DE of 1, 5 and 10-μm particles of the current model shows good agreement with the trend of the outcomes by Russo et al. [2].

Figure 2 reports the DE in the first generation of the symmetrical human lung airway against the local inlet Stokes number. The dimensionless Stokes number can be defined as:

\[ S_t = \frac{\rho d_p^2 u}{18 \mu D} \]  

(1)

where \( \rho \) is density of the particle, \( d_p \) is diameter of the particle, \( \mu \) is the air viscosity, and \( D \) is the diameter of the pipe. For higher Stokes number \( (S_t > 1) \) particle cannot follow the streamline where the flow decelerates abruptly, while for lower Stokes number \( (S_t < 1) \) particles closely follow the air streamline. Figure 2 also reports the particle deposition density comparison with the published data of Zhang et al. [3]. The findings of this study agree well with the published data for the first bifurcation of the symmetric airway model.
Figure 2: DE comparison in the first bifurcation of the symmetric human lung against local inlet Stokes number Zhang et al. [3].

Figure 3 shows the DE in the first generation of the asymmetric lung model. The present asymmetric model is based on the dimension of the CT-scan model containing smooth surface. The DE for the single bifurcation model is compared with the available computational and experimental measurements [4]. A decent agreement amongst the published results and the present study can be observed for the single bifurcation asymmetric model.
Figure 3: DE comparison in the first bifurcation of the asymmetric human lung as a function of Stokes number [4-6].
Figure 4: The DE comparison with the experimental data in the first bifurcation of the human lung.

Figure 4 represents the DE comparison with the published experimental measurement for the first bifurcation of the human airway. The experimental data of Kim et al. [7] and the numerical results of the present study show a similar trend of DE against the local inlet Stokes number. The numerical result compares well with the experimental measurement for the single bifurcation of the lung, and the DE is within the range of the experimental data.

Figure 5: DHSs for non-realistic geometry (a) first bifurcation model, and (b) triple bifurcation model (G1-G3).
Figure 5(a, b) show the DHS for the non-realistic model of the human lung. Several studies have demonstrated that human lung bifurcation area is the DHS [1, 8, 9]. The current model also shows that in the case of idealized symmetric lung, maximum number of particles are deposited at the carinal region, which aligned with the deposition pattern of published literature. The future study will perform an experimental validation for the central airway.

In summary, the good agreement is achieved between the present numerical model, experimental measurement, and the published numerical data, which adequately indicates the accuracy of the present numerical model.

References

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