i9MASKS

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Numerical simulation: study on the path of expelled and expired water vapor particles

Introduction

Numerical simulation is a tool that provides a prediction of a physical phenomena, reducing the need of physical tests. To predict and visualize the spread of the Covid-19 virus from the nose and mouth, simulations of expelled and expired water particles were performed.

The study was performed in Ansys Fluent® software in a 2D environment. The developed models need physical variables that were previously researched. To have confidence in the results, the convergence of the models is always verified, and only later the optimization of the models can be performed.
Some conditions of the flow are complex and need to be defined by a User Defined Function, such as the velocity of the respiration profile, combined with sneeze or cough.

Through the description of the DPM iteration intervals, which allows control over the frequency at which the particles are tracked, it is possible to have a report of the particles that are injected and how they propagate in space, that is, if they evaporate, stay trapped or escape outside the analysis domain ($1m^2$).

Materials and methods

Initially, a stationary analysis of particles expired by the nose and expelled by the mouth was performed, modeling a simple nose and mouth geometry. At a later stage, some parameters were corrected and a transient analysis was performed. In both analyzes (mouth and nose in transient and static state) the conditions were exposed in table 1:

Table 1 - Variables used for numerical models

Variables	Value	Units
Flow	0,01 [2]	Kg/s
Minimum particle diameter	1e-6	m
Average particle diameter	5e-5	m
Maximum particle diameter	0,001[1]	m
Velocity X	1[2]	m/s
Velocity Y	-0,6755[2]	m/s

In an intermediate phase, the study of the trajectory of the particles when they are exhaled by the nose during breathing was carried out with the implementation of the respiratory cycle. Equation 1 shows the function used for the velocity at entry, v (t), corresponding to a breathing cycle of a healthy adult. [3]

$$v(t) = 0{,}85\sin\left(\frac{\pi t}{1{,}5}\right) \qquad (1)$$

Subsequently, having the respiratory cycle implemented, two UDF's were created:

UDF 1 - occurrence of a sneeze, using equation 2;

$$v(t) = 15exp(-22t) \qquad (2)$$

UDF 2 - occurrence of a cough period, using equation 3.

$$v(t) = 11exp(-32t) + 0.27 \qquad (3)$$

Results

The respiratory cycle simplified as a sinusoidal from equation 1 is presented in Figure 1. The next study addresses the particle dispersion when a sneeze and cough occur. Since the velocity and input angle vary, mouth and nose were studied separately. In the latter study, particles had a greater propagation, as observable in Figures 2 and 3, that refer to the path of the particles exited from the mouth, sneezed and coughed, respectively.

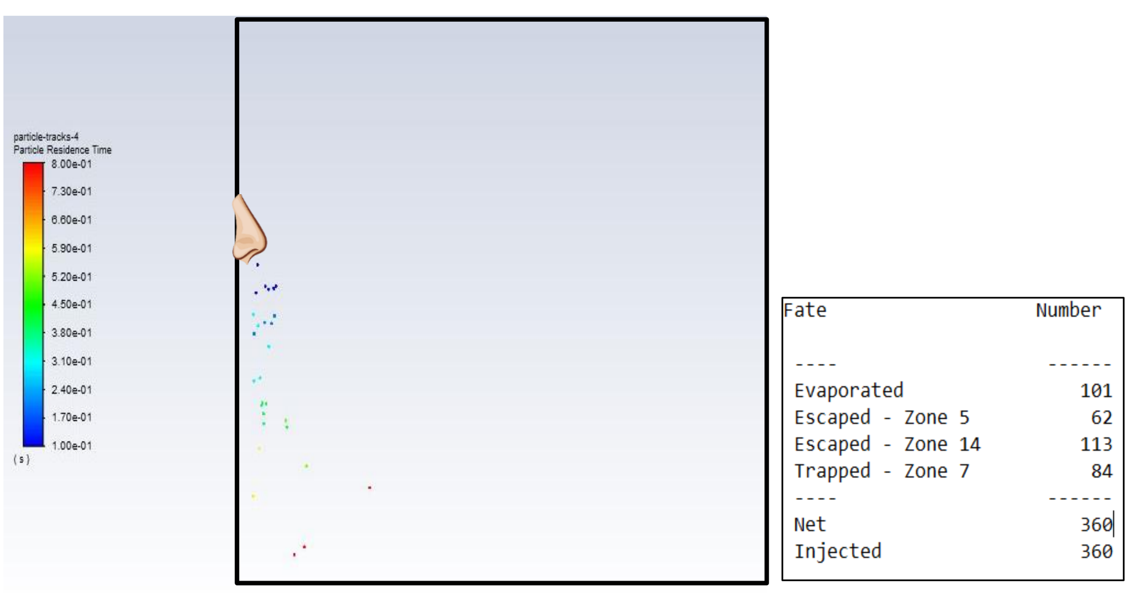

Figure 1 - Study of the path of particles along a respiratory cycle and DPM summary report

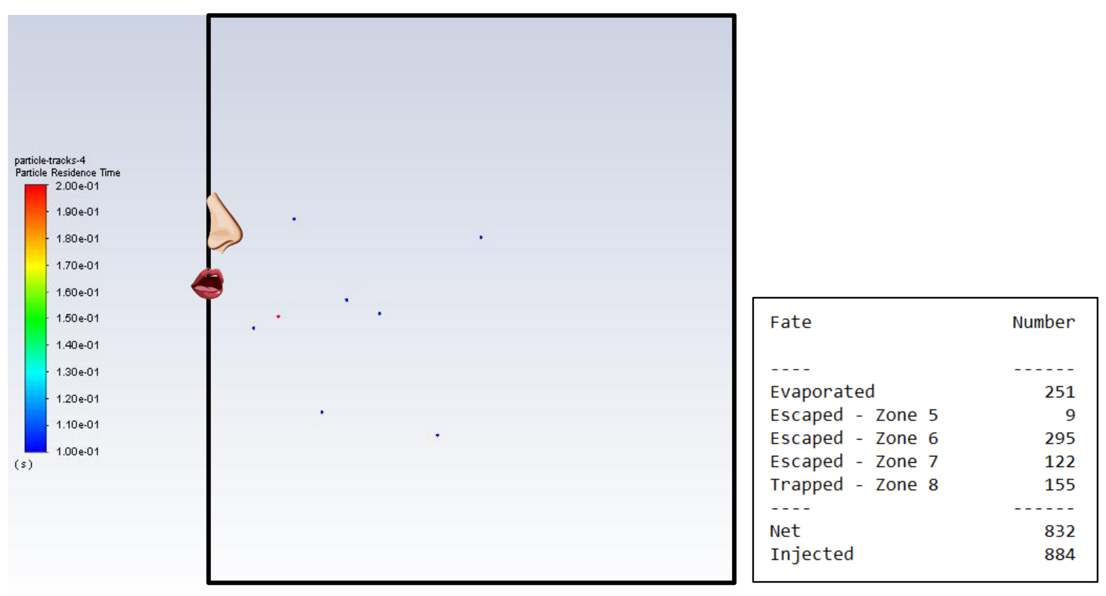

Figure 2 - Study of particle path during a sneeze and DPM summary report

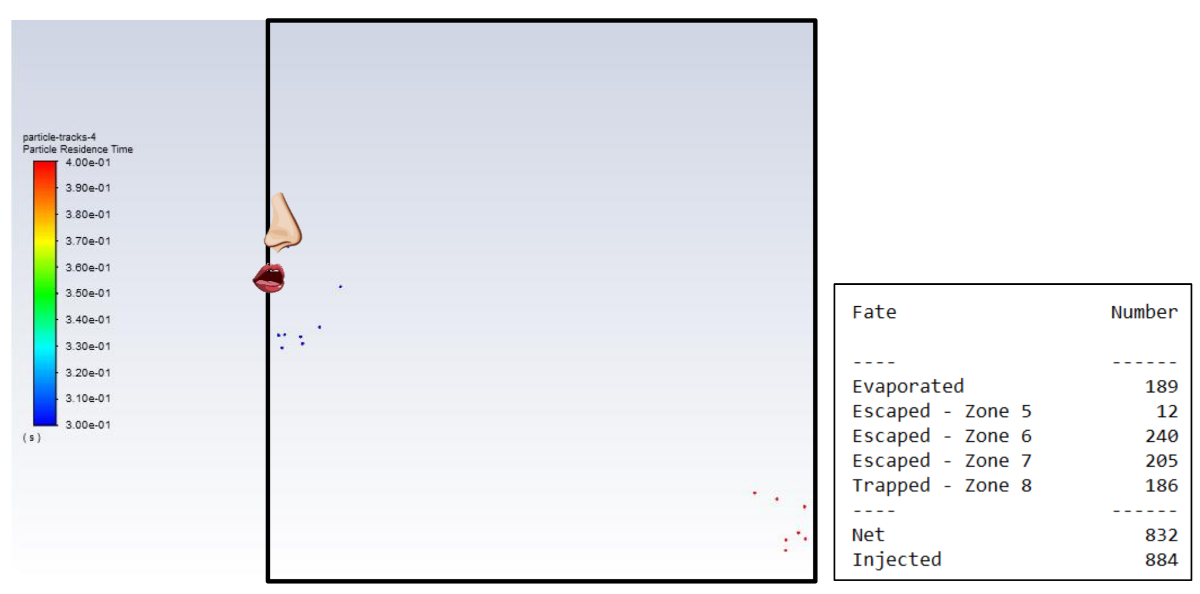

Figure 3 - Study of particle path during a cough and DPM summary report

References

[1] M. A. dos A. Corvo, C. A. Eckley, L. V. Rizzo, L. R. Sardinha, T. N. Rodriguez, and I. Bussoloti Filho, "Salivary transforming growth factor alpha in patients with Sjögren's syndrome and reflux laryngitis," *Braz. J. Otorhinolaryngol.*, vol. 80, no. 6, pp. 462–469, 2014, doi: 10.1016/j.bjorl.2014.08.006.

[2] J. W. Tang *et al.*, "Airflow Dynamics of Human Jets: Sneezing and Breathing - Potential Sources of Infectious Aerosols," *PLoS One*, vol. 8, no. 4, pp. 1–7, 2013, doi: 10.1371/journal.pone.0059970.

[3] C. N. Ngonghala, E. Iboi, and A. B. Gumel, "Could masks curtail the post-lockdown resurgence of COVID-19 in the US?," *Math. Biosci.*, 2020, doi: 10.1016/j.mbs.2020.108452.