Investigation Of Environmental Variations On The Performance Of A Cascade Impactor

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Abstract

The goal of this study was to simulate the collection efficiency curves of a Dekati-ELPI® cascade impactor. Seven of the twelve stages of the device in the lower range of deposition, D50 of 10 nm to 600nm, were simulated.
"High Mach number flow; laminar & turbulent" and "particle tracing for fluid flow" modules were used. The effect of particle flow on the fluid is negligible and thus omitted from the simulations. Mach values in these seven platforms range from subsonic to transonic, and Reynold's numbers vary from laminar up to close to the transient flow region. The collection efficiency curves were obtained for the platforms and compared with literature. Results show higher precision of COMSOL results at smaller particle diameters compared to the literature, while the results diverge more from experimental values for higher particle diameters. The results of 2D-Axisymmetric and 3D models were compared for simulation of 1 nozzle. Small differences were observed comparing 3D and 2D-Axisymmetric simulations. Thus, all nozzles were simulated using 2D-Axisymmetrey to accelerate the simulations.
Density, pressure, and temperature were varied in the numerical model. They were used as factors in a Design Of Experiment (DOE) approach to quantify their effects. The agglomeration of particles on the impact-platforms was selected as the response. Agglomeration was evaluated based on the variation of the deposition area under a nozzle. The extremum values used for density, pressure, and temperature were 1-20 g/cm^3, 100-300 mbar in the lowest ELPI platform, and 25-60 °C, respectively. The deposition diameters of the particles on the seven simulated platforms were extracted from the collection efficiency curves. The relative half effect from the DOE analysis on these diameters showed no clear trend except for the pressure factor, which reached more than 20% influence on the agglomeration for platform 7, and 15% for platform 6. Temperature played a more significant role in platforms 5 and 6. The interaction between pressure and temperature showed an impact on the agglomeration of more than 5% for platforms 1, 4, and 7.
In order to confirm the simulation results, PSL (ρ=1 gr/cm^3) and gold (ρ=20 gr/cm^3) nanoparticles were deposited in the impactor. The spot-areas from the tests were compared with that of the simulations. The results show that the average value of the deposition spot area is 0.18 mm^2 for the simulations and 0.077 mm^2 for the tests. The difference could be explained in part by the elliptical shape of the deposition spots obtained from the tests, which is due to the presence of other nozzles nearby.
According to the analyzed data from the performed experiments and the simulations, we can conclude that the results for the simulated deposition-spots and the obtained collection efficiency curves are in good agreement with the values obtained from the tests and reported in the literature.

Figures used in the abstract

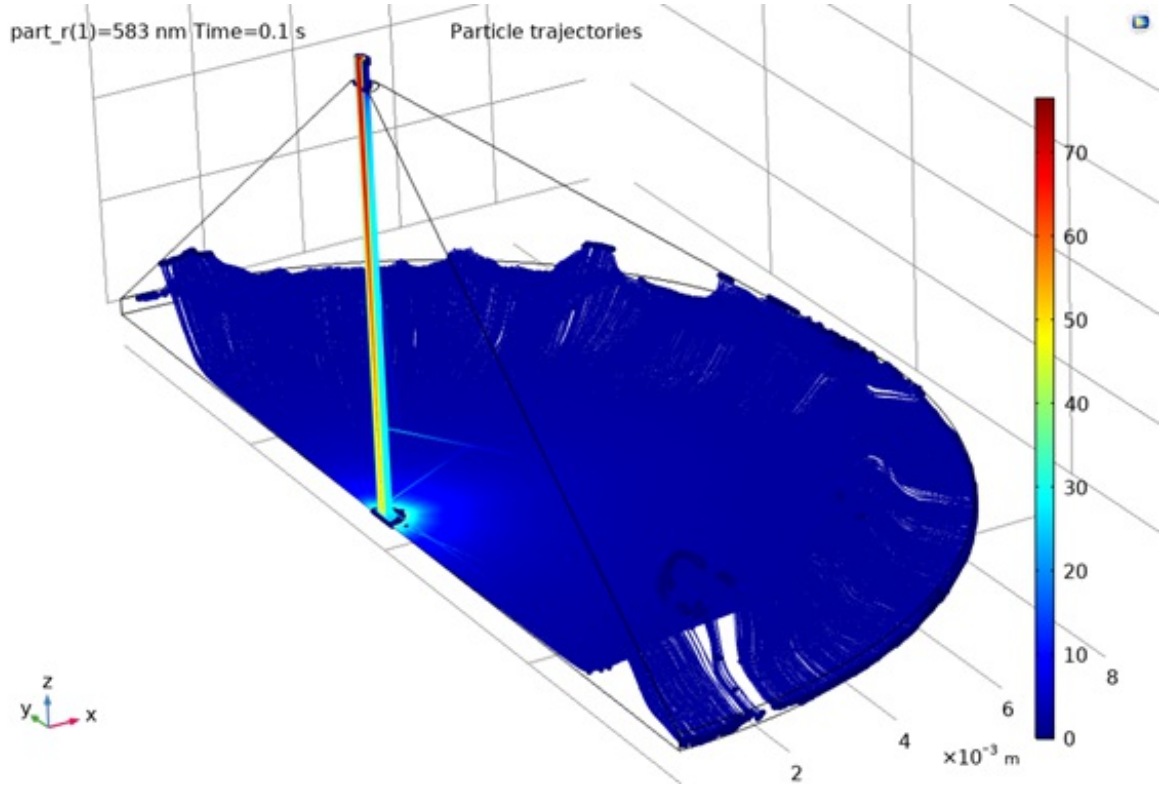

Figure 1 : Figure 1: Simulated particle trajectories from one nozzle of the 6th platform of the cascade impactor.