Thermal and Evaporative Spray Plume Characteristics Using Computational Fluid Dynamics

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Abstract

Spray plume shape can be visualized with Computational Fluid Dynamics (CFD) when substantially low isosurface of a spray concentration value is applied. In FLUENT's CFD package, spray concentration is automatically calculated while applying the discrete phase model (DPM). This method has been previously used in gas cooling and spray-drying applications, where the spray plume was loosely defined with a low concentration value. Visualization of spray plume shape and wall attachment (wall wetting) aids in the assessment and optimization of spray nozzle placement with respect to targeted gas cooling temperature reduction and wall wetting minimization. To omit the loosely defined Spray Plume Boundary (SPB) value, a stricter requirement for the SPB was imposed through experimentally obtained data. The spray was injected in a co-flow configuration within the wind tunnel with square cross-sectional size of 0.6x0.6 m^2 with nominally uniform air speed of 15.4 m/s. To correlate the experimental SPB with CFD based results, the numerical results were compared by the Sauter-Mean Diameter and volume flux distribution data. The experimental results were acquired with an Artium Phase Doppler Interferometer.

Based on validated criterion for SPB evaluated at 20°C, this system was evaluated computationally with increased air inlet temperatures at 100, 400, 700 and 1000°C. To evaluate the effect of temperature on evaporation, the spray plume shape was analyzed with DPM concentration (DPMC) values, air temperature reduction between inlet and an outlet, and percentage of water evaporation inside of spray plume. As the air stream temperature and evaporation rate of water droplets were increased, the SPB which was represented by DPMC isosurfaces, became more sensitive to the evaporation process. The percentage of evaporation rate measured inside spray plume's SPB with DPMC value validated at 20°C (DPMC=0.0004 kg/m^3) decreased from 96.6% at 20°C to 73.7% at 1000°C. The percentage evaporation rate inside the spray plume increased with a decrease in the DPMC value for the SPB.

Key words: Computation Fluid Dynamics, Evaporation, Spray Plume Boundary

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