Aerospace Engineering Master's Defense

Theoretical Predictions of Sauter Mean Diameter and Droplet Velocities for Pressure-Swirl Atomizers through Energy Conservation Methods

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abstract

A new theoretical model was developed utilizing energy conservation methods in order to determine the fully-atomized cross-sectional Sauter mean diameters of pressure-swirl atomizers. A detailed boundary-layer assessment led to the development of a new viscous dissipation model for droplets in the spray. Integral momentum methods were also used to determine the complete velocity history of the droplets and entrained gas in the spray. The model was extensively validated through comparison with experiment and it was found that the model could predict the correct droplet size with high accuracy for a wide range of operating conditions. Based on detailed analysis, it was found that the energy model has a tendency to overestimate the droplet diameters for very low injection velocities, Weber numbers, and cone angles. A full parametric study was also performed in order to unveil some underlying behavior of pressure-swirl atomizers. It was found that at high injection velocities, the kinetic energy in the spray is significantly larger than the surface tension energy, therefore efforts into improving atomization quality by changing the liquid's surface tension is not productive. From the parametric studies, it was also shown how the Sauter mean diameter and entrained velocities vary with increasing ambient gas density. Overall, the present energy model has the potential to provide quick and reasonably accurate solutions for a wide range of operating conditions enabling the user to determine how different injection parameters affect the overall spray quality.

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