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Numerical Analysis and Machine Learning Forecasting of Ammonia Spray Atomization in GDI Hollow-cone Injectors

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Ammonia (NH_3) offers a definitive pathway for decarbonizing transport, yet its spray dynamics in hollow-cone injectors remain underexplored. This study combines computational simulations with an artificial neural network (ANN) to evaluate and predict the high-pressure liquid ammonia spray evolution across subcooled, transition, and flash-boiling regimes. ANN model was created using the neural network toolbox and standard backpropagation with the Levenberg-Marquardt training algorithm. The accuracy of the model was validated by comparing the predicted datasets with the experimental data. The results reveal distinct morphological transitions driven by the superheat degree. In the flash-boiling regime, spray width nearly doubles compared to subcooled cases, consistent with explosive thermodynamic fragmentation promoting radial dispersion. Conversely, increasing pressure ratio by 0.47 in the transition regime results in shrinking the spray width by 17% early and 25% at steady state due to aerodynamic confinement significantly restricting radial expansion. In terms of axial development, spray penetration trends in the transition regime align closely with subcooled conditions, governed by distinct aerodynamic suppression. Complementing these findings, a machine learning approach can accurately predict key performance metrics, demonstrating the potential of AI-driven models to support ammonia spray parameter optimization and direction for developing zero-carbon ammonia engines.

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