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Numerical Simulation and Prediction of Particle Distribution Based on Aeroacoustic Signals Emitted by the HVAF Process

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Abstract

Thermal spray processes, such as High Velocity Air Fuel (HVAF) and High Velocity Oxy-Fuel (HVOF), generate considerable noise levels due to the turbulent combustion and high-velocity particle streams involved. This noise can be highly informative, as it is closely tied to flow dynamics, particle trajectories, and ultimately the quality of the deposited coating. However, extracting meaningful insights from aero-acoustic signals poses a significant challenge, given that multiple noise sources—ranging from combustion instabilities to turbulent eddies—overlap in both time and frequency domains. By successfully correlating these acoustic signatures to particle behavior, one can potentially develop powerful predictive tools for real-time monitoring and control of thermal spray processes.

In this work, we employ a numerical approach to investigate how particle distribution in HVAF is related to the aero-acoustic signals generated under various operating conditions. Different torch inlet pressures and temperatures are considered to capture a wide range of operating conditions that influence both the flow structure and the resulting noise production. The acoustic field is computed using the Ffowcs-Williams and Hawkings (FW-H) formulation, which facilitates the prediction of sound generation. Additionally, Lagrangian-based particle tracking is incorporated to model the trajectories of the particles as they are accelerated and heated by the high-velocity jet.

Acoustic probes are placed at various distances downstream of the nozzle exit to record pressure fluctuations and associated noise metrics. This acoustic dataset is then merged with the corresponding particle distribution data—collected at multiple axial distances—to create a comprehensive database spanning a range of process conditions. Leveraging machine learning and deep learning algorithms, a predictive model is trained to correlate the recorded acoustic signals with the observed particle distributions. Such a model enables the prediction of critical spray parameters, such as particle velocity, temperature, and concentration, based solely on real-time acoustic measurements. By illustrating how noise data can be mapped to particle behavior, this research opens new avenues for non-intrusive process monitoring in thermal spray operations. Ultimately, the ability to infer coating properties from acoustic emissions can lead to more efficient, cost-effective, and robust control strategies for HVAF and HVOF processes.

Keywords-component

Thermal Spray Processes, Aero-acoustics Signals, Computational Fluid Dynamics, Machine Learning, High Velocity Air Fuel