Assessing Conical and Method Of Characteristics-Contoured Convergent-Divergent Nozzles for Cold Spray Applications

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Cold Spray performance depends on the nozzle shape to accelerate particles beyond their critical impact velocity while ensuring a uniform deposition profile. Conventional conical convergent–divergent (CD) nozzles produce internal shocks and a non-parallel exit flow, which can reduce particle acceleration and lead to an uneven radial particle distribution.

This study examines whether a bell-shaped nozzle, designed using the Method Of Characteristics (MOC), can improve cold spray performance by enhancing the particle velocity and the spatial uniformity of the particle deposition. Three-dimensional numerical simulations were carried out in ANSYS Fluent to compare a standard CD nozzle with an MOC-contoured nozzle under identical operating conditions. The contoured geometry was developed to achieve parallel flow at the nozzle exit, thereby minimizing expansion losses.

The gas phase (nitrogen) was modelled using Reynolds-Averaged Navier–Stokes equations with the SST k–ω turbulence model. Copper particles with a representative size distribution were tracked using a Discrete Phase Model with two-way coupling, allowing for momentum and heat exchange between the gas and particle phases.

Results indicate that the MOC-designed nozzle produces higher average particle velocities than the conventional CD design while maintaining more stable particle temperatures. The contoured nozzle gives a more uniform radial distribution of particle velocity and concentration. In contrast, the CD nozzle shows particle clustering along the nozzle centerline and greater velocity variation toward the periphery.

Overall, MOC-designed nozzles offer improved control over particle kinetics and thermal conditions, presenting a promising approach for enhancing coating quality and process efficiency in cold spray applications.