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Numerical Simulation on Syphonage Effect of Laval Nozzle for Low Pressure Cold Spray System

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Abstract

Instead of injected by high pressure powder feeder, powders can be drawn into the nozzle by syphonage effect generated by supersonic gas flow in low pressure cold spray. This characteristic makes low pressure cold spray conveniently for on-site operation. However, no data have ever been reported on the relationship between the nozzle structures and the gas flow in the powder feeder pipe. In this paper, a CFD software (STAR CCM+) was used to calculate the gas flow in nozzle of the DYMET413commercial low pressure cold spray system. Variation of structures and process parameters based on the commercial system were also investigated. The syphonage effect is strongly influenced by the powder feeding location, the temperature and pressure in prechamber has little effect on syphonage effect in powder feeder pipe. The syphonaged gas will decelerate the gas velocity and low down the gas temperature in nozzle, so it is best to control the mass flow rate of powder feeding gas by selecting the location. One of the disadvantages is that the particles will collide with the nozzle wall which makes the nozzle a short service life.

Key words: Low pressure cold spray, Syphonage effect, Laval nozzle, Computational Simulation

General symbols

A	Nozzle cross-sectional area	λ	Molecular free path
C_p	Specific heat	D_p	Diameter of particle
C_d	Drag coefficient	F_D	Drag force
H	Convective heat transfer coefficient	C_c	Stokes drag Cunningham correlation
M	Molecular mass	u_g	Velocity of the gas flow
m	Mass flow rate	ρ_p	Particles density
P	Pressure	ρ	Gas density
R	Gas constant	u	Viscosity of gas
Re	Reynolds number	k	k equation coefficient
T	Temperature	ε	Turbulence energy dissipation coefficient
V	Velocity	u_{eff}	Effective viscosity coefficient
X	Axial distance from the nozzle throat	S	Mean-velocity strain-rate tensor coefficient
F_x	Source term	α_k	Reciprocal of effective Prandt1 of k equation
α_T	Reciprocal of effective Prandt1 of energy equation	α_ε	Reciprocal of effective Prandt1 of ε equation
u_p	Velocity of the particles	α	Impacting angle

1. Introduction

Cold spray, also called cold gas dynamic spray, or kinetic spray, was found by **Alkhimov et al. (1994)** occasionally in a wind-tunnel experiment. They found that a metal particle will adhere to substrate when the particle exceeds a certain velocity named critical velocity. **McCune et al. (1995)** found that cold spray is a bulk solid coating deposition process which is totally different from conventional thermal spray methods. Cold spray coating is oxidation free and low porosity due to its relative low temperature and high kinetic energy which arouses numerous interests in industrial application. Especially the high depositing efficiency makes cold spray suitable for rapid prototyping of copper and titanium. After many years of intensive research and development, as well as numerous trials, cold spraying has completed the transition from an emerging process to a commercially viable method for coating various high performance machine components.