Chapter 6

Cold Spray Method for Wear-Resistant Surface Coating:
Supersonic Jet Structure and Its Impact on the Particle Deposition Process

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ABSTRACT

This chapter is focused on cold spray deposition of particles for surface modification. The method, which has been recently proven to have wide applicability in the domain of tribology and wear-resistant coatings, relies on supersonic gaseous jets to deposit the particle without phase change. The chapter aims at examining the influence of the unique gas dynamic characteristics of the high-speed jets on the deposition process. The general structure of the supersonic jets, including the velocity field, pressure gradients, and the impingement behaviour, is discussed with specific attention to the requirements of the sprays for tribological coatings. Results of detailed numerical simulation of the impingement process are made use of to demonstrate the parametric influence of the supersonic jet structure on critical spray characteristics, like the particle velocity. The study also examines various aspects of the energy conversion as applied to the basic nature of the supersonic jet as well as its interaction with the microparticles.

INTRODUCTION

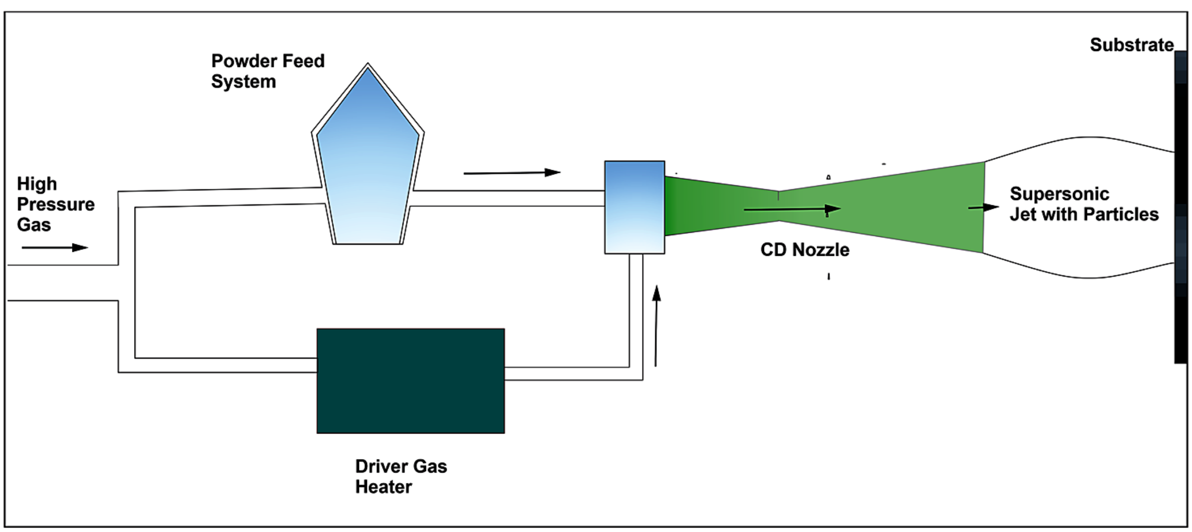
Cold spray deposition of micro-particles is a relatively new technique of surface coating, which has recently found extensive applicability in improving the wear resistance of surfaces that are subjected to mechanical contact and friction (He & Hassani, 2020). In this method, the micro-particles (typically in the diameter range of 5 to 50 microns) are carried by a driver gas which is pressurized and accelerated to supersonic velocity by an appropriately contoured nozzle and this high velocity stream is made to

DOI: 10.4018/978-1-7998-9683-8.ch006

impinge on the substrate, the surface to be modified. The high kinetic energy imparted to the particles by the supersonic stream of the driver gas leads to plastic deformation during the impact and thereby results in their deposition on the surface. The cold spray approach differs from the conventional thermal spray deposition process in two critical aspects: (i) As the name indicates, the method is characterized by a relatively "cold" system: neither the particles nor the substrate are heated to their melting temperature – Hence it is a completely solid-state process (ii) The driver gas is accelerated (by way of an appropriately designed nozzle) to a high velocity, exceeding the velocity of sound in the gas ('supersonic' velocity).

Figure 1 provides a schematic representation of the cold-flow setup. Since both the particle material and the substrate material are maintained at temperatures significantly lower than their melting temperatures, the microstructure of the coating will be superior to what would result in a conventional thermal spray process where the temperatures are high. In conventional thermal spray deposition the particles are melted and accelerated through either a flame or thermal-plasma arc. The molten or semi-molten materials solidify on impingement and get deposited as a thin film (Herman, Sampath & McCune, 2000). In cold spray method, since there is no phase change involved the process, the deposition does not entail tensile residual stresses and the concomitant distortion (Wang & Zhang, 2012), which are some of the disadvantages of thermal spray deposition. Also, the lower temperature levels ensure that surface deposition of materials like Aluminium, Copper and Titanium can be carried out without the risk of them getting oxidized (Ghelichi & Guagliano, 2009). From a metallurgical perspective, grain growth phase transformation is mostly avoided or reduced in comparison to the traditional thermal spray processes (Chenxi et al, 2019 and Karthikeyan, 2007). Substrates which are sensitive to temperature can also be deposited on by this process (Karthikeyan, 2007).

Figure 1. A Schematic representation of Cold Spray particle deposition system



Specific to the applications in tribology, the capability of cold spray process in providing wear resistant coatings has attracted research interest in the recent years. While the initial applications were constrained to ductile materials, more recent investigations have shown that with adequate pressurization of the

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