Chapter 6
A Review of the Cold Gas Dynamic Spraying Process

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ABSTRACT

In this modern era, use of coatings on engineering materials has become highly inevitable. One such emerging coating method is the cold gas dynamic spraying. It is a solid-state process where deposition on to the surface of the material is done at high pressure and velocity. Adhesion of the powder to the substrate is possible because of the high amount of plastic deformation. This chapter introduces the CGDS system and discusses the types of set-ups and its modifications that are generally used. Further, the chapter delves into the process parameters in the spraying process and the correlation of these parameters with the coating properties. It also provides a comprehensive review of the current theories of bonding mechanism in cold spray. It aims to provide an overview of the material systems that have been investigated so far for cold spraying with an outline of the experimental and numerical simulation that have been researched.

1. INTRODUCTION

A deposition process is used to deposit a material (referred to as coating) on to a bulk material (referred to as substrate). Depending on the desired coating properties different methods may be used for the application of the coating such as physical vapor deposition (PVD), chemical vapor deposition (CVD), sputtering, laser cladding, electroplating, thermal spraying and cold gas dynamic spraying (Steyer2001), (Kalita2014), (Anisur2018) and (Zhou2019). The process may deposit the coating material atom by atom, as in the vapor deposition process or as molecule and ions as in the laser cladding and electroplating or

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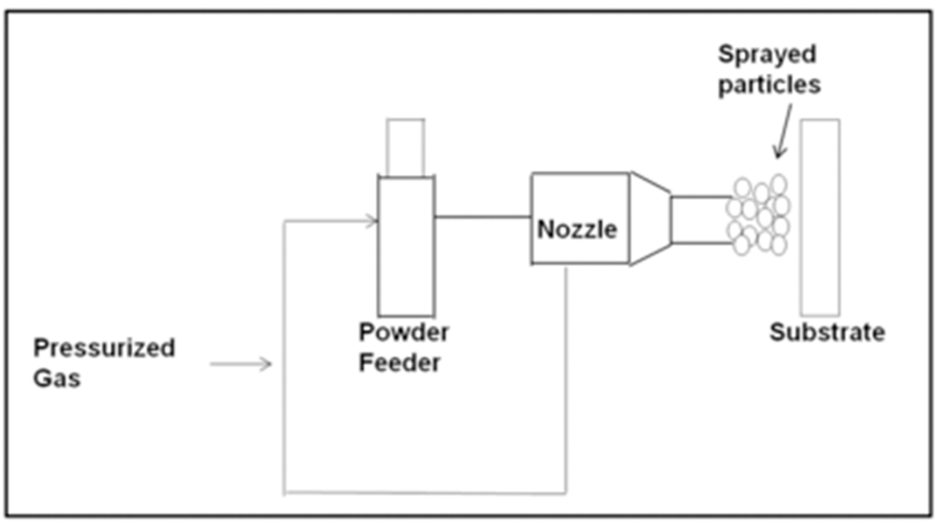
as aggregate powders as in thermal and cold gas dynamic spraying. It is the aim of this chapter to focus on the cold gas dynamic spraying method. Cold gas dynamic spraying (CGDS) or simply known as cold spraying, is an emerging technology where powders or particles are carried with a gas and impacted on the substrate at high velocities. CGDS was invented in 1980's at the Institute of Theoretical and Applied Mechanics of Siberian Branch Russian Academy of Science (Papyrin2007) and (Dykhuzein1998). CGDS has many advantages as to other deposition methods that include high deposition efficiency, low residual stress, less heat input, elimination/minimization of porosity, control of phase transformation and compositional stability (Papyrin2007) and (Koivluoto2010). Since the deposition temperatures are at room temperatures and much below the melting point, the particles cannot be melted in the gas flow. Being a solid state process, oxide inclusion and void formation can be avoided in cold spraying (Sobolov, 2004) and (Stoltenhoff,2001). Further it has also been reported that wide range of coating materials, e.g. pure metals like Al, Cu, Ti, Fe, Ag, Zn and Ni; metal alloys like Cu-Al, Cu-Zn, Ni-Cu, Ni-Al, CoNiCrAIY and stainless steel and composites like Cu+Al2O3, Ni+TiC, Al- Al_2O_3 have also been used in the cold spray system (Champagne,2007), (Maev, 2006) and (Dykhuzein,1998).

Figure 1. Schematic diagram of cold gas dynamic spraying



1.1 Principle of Cold Spraying

Cold spray being a solid state process is used to form a deposit by the means of ballistic impingement (Koivluoto2001). In this process powder particle strikes the substrate with a high velocity and leads to formation of plastic deformation or erosion of the substrate. A gas (nitrogen, helium or air) is accelerated to supersonic velocity by a converging diverging de Laval type nozzle. On impinging to the substrate the particles either adhere on to the substrate or bounce back (rebound). This phenomena of the particles is due to the drag effect of the gas as the particles flow in it (Maev2006). There is no sign of adhesion of the particles until a critical particle velocity is exceeded. The temperature of the powder particle (also same as the gas temperature) plays an important role during the impact. The particle size