Chapter 31

Atmospheric Plasma Spray Coating Process (APSC)

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31.1 Introduction

Plasma spray coating is widely used thermal spray technique for protecting various substrates against corrosion, wear and thermal barrier applications [281–284]. The schematic diagram of coating process showing parts of plasma torch is given in Fig. 31.1. In plasma spray coating, an arc is generated between tungsten cathode and constricted anode made of copper. Argon gas, because of its low ionization energy, is used to generate plasma inside a plasma torch. Argon gas, upon passing through an arc, ionizes forms a mixture of ions, electrons and neutral atoms. Although the percentage of ionization is less than 0.1%, the temperature of ionized gas and its surrounding gases reaches well above 10,000 K. The powders are injected into the plasma torch transversely or axially into the plasma jet. The high heat enthalpy of plasma is used to melt various ceramic and metal powders for the coating process. Because of high temperature and short duration of powders inside the plasma jet, powders are heated above its melting temperature. The molten particles are propelled towards the substrates with high velocity. On hitting the substrate, it flattens and forms a splat. The building up splats forms a laminar type of structure, typical of plasma spray coating, forming a coating. The thickness of coatings typically varies from a few microns to few millimeters. The ability to do thicker coatings and faster coating rates makes plasma spray coating a unique technique among various thermal spray processes. Any material which has wide gap between its melting point and boiling point and which doesn't sublime below its melting point can be coated using plasma spray technique. The main disadvantage of plasma spray coating is it is a line-of-sight process, that is any surface that needs to be coated should be in line of sight and blind spots and shadow areas cannot be coated using this technique. Because of laminar type of structure, the porosity in plasma spray coatings varies from 10% to 15%.

31.2 Plasma Spray Coating Process and Optimization

The various stages of coating process and process parameters at each stage are given in flow chart (Fig. 31.2). The process parameters of coating are examined using various techniques to understand and improve the coating quality. The feed stock powders used should have

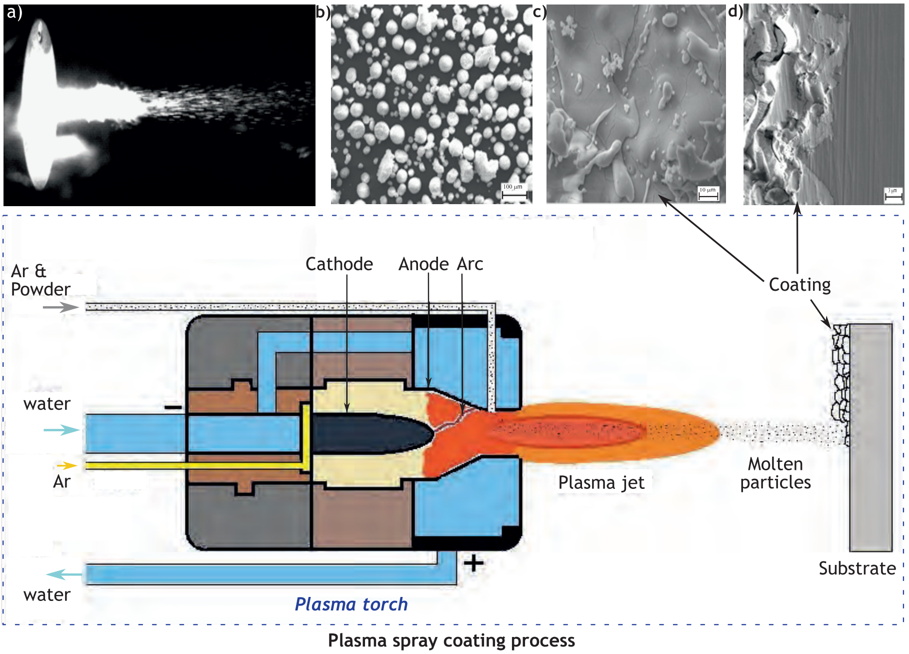

Figure 31.1: Schematic diagram of plasma spray coating process showing parts of plasma torch, plasma jet and coating. Also shown are, (a) high speed camera photo of plasma jet (50000 fps), and SEM images (b) powder, (c) surface morphology after coating, and (d) side view of substrate along with coating.

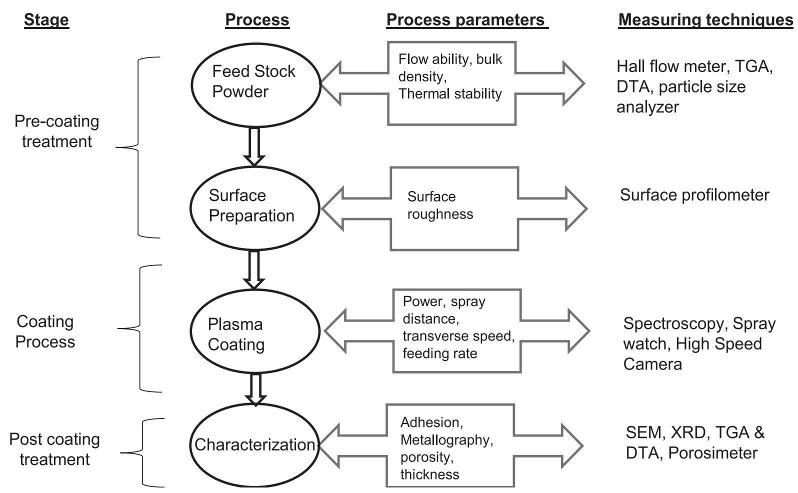

Figure 31.2: Flow chart diagram of coating process.

good flowability and narrow size distribution for a better coating properties. Flowability of powders is measured using a hall flow meter by the time it required to pass 50 gram of powder through a standard funnel. Lesser the time more the flowability. Powders with flowability less than 100 sec is considered good for plasma spray coating. The primary bonding between

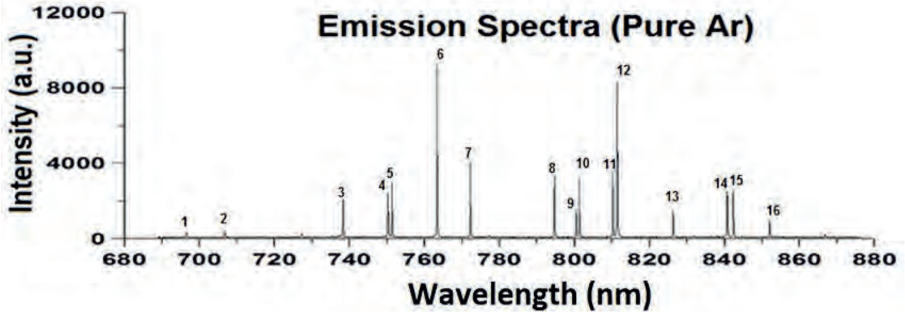

Figure 31.3: Emission spectra of Plasma gas. Lines 1-16 are standard emission lines of pure argon.

substrate and coating is mechanical interlocking at the coating interface. The substrates are therefore sand blasted before coating to improve the surface roughness and for cleaning purposes. Typical surface roughness after sand blasting is around 10 μm to 20 μm. More the surface roughness, more will be adhesion strength between coating and substrate, which is measured using a tensometer (ASTM C 633 standard). Since the powders are heated well above its melting temperature in plasma jet, any compositional and phase changes are measured using TGA and DTA before the coating process. Temperature of a plasma gas in

Figure 31.4: Spray watch experiment showing in-flight particle temperature and velocity.

plasma jet is measured using optical emission spectroscopy. A typical spectrograph of argon plasma is given in Fig. 31.3. The temperature is found to be around 8000 K and increases with increase in power from 16 kW to 30 kW. Although plasma temperatures are very high, the residence time of powder in the plasma jet is very low (few milliseconds). Therefore, the particles are allowed to heat just above its melting point without any evaporation. The in-flight particle temperature and velocity are experimentally measured using a spray watch instrument. A typical spray watch experiment with particle temperature and velocity is given in Fig. 31.4. The particle trajectory and velocity are also observed using a high-speed camera. Coating parameters such as plasma power, spray distance, powder feed rate,

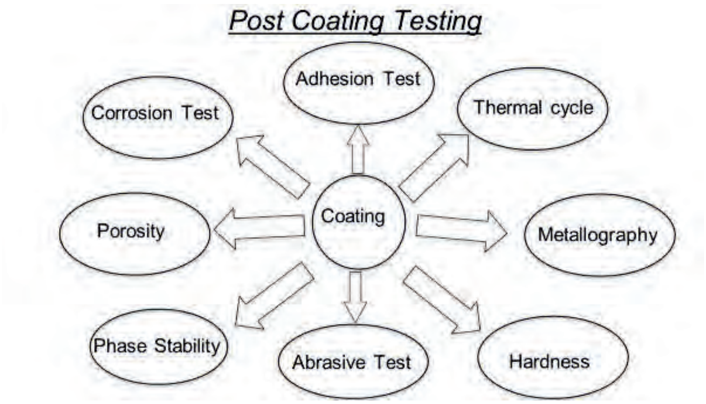

Figure 31.5: Schematic diagram of various tests conducted after coating.

transverse speed etc. are optimized for a given powder to get desired properties and thickness. After optimizing coating parameters, sample specimens are prepared and various test are conducted to evaluate coating performance (Fig. 31.5) for its intended use. Characterization will be done by using various techniques such as SEM, XRD, TGA/DTA, Porosimeter etc.

A typical automated atmospheric plasma spray system consists of Acoustic chamber, Industrial Robot, Dust Collector, Mass flow-controlled powder feeder, Power supply, Chiller unit and various plasma torches (Fig. 31.6). The coating will be carried out inside an acoustic chamber and plasma torch is remotely handled by a robot. The temperature of substrate will remain at room temperature during coating process. The inputs for each subsystem are given through a touch paneled control console located outside acoustic chamber.

Figure 31.6: Plasma spray coating facility at TPTS, L&PTD.

31.3 Plasma Spray Coating Applications

Ceramics are the most commonly used powders in plasma spray coating due to its high melting points and phase stability. The most commonly used powders in plasma spray coating industry are YSZ, Al_2O_3, Y_2O_3, WC, Cr_2O_3, NiCrAlY, TiO_2 etc. Each powder is used for a specific application like YSZ, Y_2O_3, Al_2O_3 is used for thermal barrier applications, Al_2O_3, Cr_2O_3, WC is used for wear applications, Y_2O_3, Al_2O_3 is used for corrosion barrier applications and NiCrAlY is used as a bond coat between substrates and top coat. Coating parameters of each powder are different depending on exposed environment, time of exposure, temperature, substrate to be coated. Figure 31.7 shows various coatings carried out using plasma spray technique.

Figure 31.7: Various coatings carried out at TPTS, L&PTD.