

A Review - Thermal spraying on Polymers

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Abstract - Polymer coatings are extensively used to enhance the surface performance of engineering components by imparting corrosion resistance, wear protection, hydrophobicity, biocompatibility, and various functional surface properties. Among the available deposition techniques, thermal spray technologies have emerged as versatile and efficient methods for producing polymer and polymer-based composite coatings on metallic, ceramic, and polymeric substrates. These processes enable the fabrication of thick, adherent coatings while minimizing substrate degradation and offering flexibility in material selection. This review presents a comprehensive overview of thermally sprayed polymer coatings, with emphasis on deposition processes, coating microstructure, mechanical and functional properties, and major application areas. It also discusses the characteristics and suitability of commonly employed polymers, including polyethylene (PE), polyamide (PA), polyimide (PI), polyurethane (PU), polyether ether ketone (PEEK), polyethylene terephthalate (PET), and fluoropolymers. Furthermore, the review critically examines the fabrication and performance of polymer and polymer-based composite coatings produced using various thermal spray techniques, such as flame spraying, high-velocity oxy-fuel (HVOF) spraying, plasma spraying (PS), and cold spraying (CS). The advantages, limitations, recent advancements, and future research directions of these techniques are also highlighted to provide a comprehensive understanding of their potential in advanced surface engineering applications.

Keywords - Thermal spray, HVOF, coating

I. INTRODUCTION

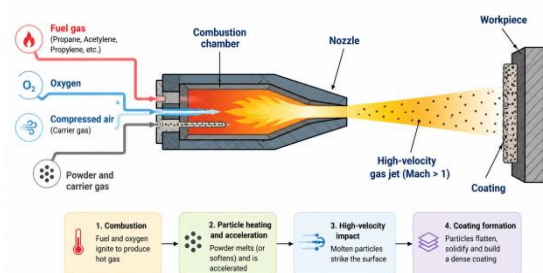
Thermal spray ability to provide coatings of several materials on a wide range of different substrates is a major feature that opens a wide spread application in both manufacturing and maintenance areas [2]. In the past decade, significant progress in the thermal spraying of polymers has been achieved. Thermally sprayed polymer coatings are widely utilized to protect metals from corrosion, solvents, and harsh chemicals, while also offering resistance to weathering, wear, and abrasion. They provide anti-skid properties as well as non-stick, low-friction surfaces. Additionally, these coatings are often applied as bond coats to improve the adhesion of top-layer materials such as Cr_2O_3 and WC-Co on composite substrates. Incorporating reinforcing fillers—whether mineral,

organic, or metallic enhances the mechanical strength of the polymer coatings while retaining their excellent protective and barrier characteristics[3]. The High Velocity Oxy-Fuel (HVOF) process is an advanced spray technique used to produce high-quality, dense, and durable coatings. In this process, a mixture of fuel gas (such as propane, hydrogen, or kerosene) and oxygen is ignited in a combustion chamber, generating a high-pressure, high-temperature gas stream. Coating material, usually in powder form, is injected into this stream, where it becomes heated and accelerated to extremely high velocities (often exceeding the speed of sound). These particles are then propelled onto the substrate surface. Upon impact, they flatten, cool rapidly, and form a tightly bonded coating.

II. HIGH VELOCITY OXY-FUEL (HVOF) PROCESS

A Principle

The High Velocity Oxy-Fuel (HVOF) spraying process develops coatings by combining both thermal and kinetic energy [4]. In this method powder particles are heated to a molten or semi-molten state while simultaneously being accelerated at high velocity. A variety of fuel gases such as propane, acetylene, oxygen, propylene, SPRAL29 kerosene and LPG - can be used. These gases are supplied at high pressure into combustion chamber of the spray torch, where they ignite and produce a high temperature gas stream. This gas jet expands through a nozzle and reaches supersonic velocity (Mach number greater than 1). The coating material, in powder form, is introduced axially into the spray gun, where it is heated by the hot gases and accelerated towards the substrate. This will form a dense and well adhered coating upon impact[5].



B Technical details

In HVOF process different HVOF spray systems have been manufactured by several companies in various designs and process-capabilities. HVOF spraying systems are available in a wide range of gun configurations and performance capacities. While their designs may vary from one system to another, they all operate based on the same core principles.

1. Combustion characteristics

The generation of supersonic gas velocities is achieved through the use of high pressures (generally exceeding 3 bar) along with gas flow rates of several hundred liters per minute [6]. The HVOF systems are roughly divided into the first, second, and third generation systems. In the first two generations guns, the pressurized burning of gaseous fuel with oxygen is used to generate an exhaust jet traveling at a speed of about 2000 m/s[6]. Depends on combustion chamber and nozzle design first generation and second generation system is classified. In third generation system chamber is designed for high pressure range from 8 bar to 25 bar. The process operates at flame temperatures of approximately 2500°C to 3200°C.

2. Particle Velocity & Temperature

In the HVOF process, particles are accelerated to very high velocities in the range of 500–1000 m/s while reaching temperatures between 1500°C and 3000°C. This results in the formation of a supersonic jet. The extremely high particle velocity during impact plays a crucial role in producing coatings that are dense, exhibit very low porosity (less than 1–2%), and possess high bond strength with the substrate.

3. Powder Feedstock Properties

The quality and performance of coatings produced by **High-Velocity Oxy-Fuel (HVOF) spraying** are strongly influenced by the characteristics of the powder feedstock. The powder serves as the primary coating material and undergoes heating, acceleration, deformation, and solidification during deposition. Therefore, selecting appropriate feedstock properties is essential for achieving coatings with high density, strong adhesion, low porosity, and excellent mechanical and functional performance.

1. Particle Size and Size Distribution
2. Particle Morphology and Shape
3. Particle Density and Flowability
4. Thermal Properties
5. Chemical Composition and Purity
6. Powder Preparation Techniques

C Properties of Coatings

1. Wear Resistance Properties

HVOF is among the versatile techniques of deposition of coating material. This method increases wear resistance. This is a process with no material constraint and has the ability to deposit coatings ranging from few micrometres to tens of

millimetres. Wide variety of shapes and sizes are possible with HVOF. The carbide ceramic coatings HVOF are commonly used against tribo-corrosion in the petroleum industries[8].

2. Erosion and Corrosion Behaviour of Coatings

High-performance polymers show a great potential to replace machined metal components in a wide variety of applications owing to their promising mechanical, thermal and tribological properties[10]. **Erosion–corrosion** is a synergistic degradation process in which the corrosion rate is significantly accelerated by the relative motion between a corrosive fluid and the metal surface. This mechanical action continuously removes the protective oxide film, exposing fresh metal to the corrosive environment and resulting in enhanced material loss compared to corrosion or erosion acting independently.

III CONCLUSION

Thermal spray technologies (HVOF) have emerged as promising techniques for the deposition of metals, polymer and polymer composite coatings, offering an effective means of enhancing the surface properties of engineering components. Compared with conventional coating methods, HVOF spraying enables the fabrication of thick, durable, and multifunctional coatings with improved

corrosion resistance, wear resistance, thermal insulation, chemical stability, hydrophobicity, and biocompatibility. The performance of thermally sprayed polymer coatings is strongly influenced by feedstock characteristics, spray parameters, substrate preparation, and post-treatment processes. Optimizing these factors is essential for achieving desirable coating microstructures, strong interfacial adhesion, low porosity, and enhanced mechanical and functional properties. The performance of thermally sprayed polymer coatings is strongly influenced by feedstock characteristics, spray parameters, substrate preparation, and post-treatment processes. Optimizing these factors is essential for achieving desirable coating microstructures, strong interfacial adhesion, low porosity, and enhanced mechanical and functional properties.

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