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Future Development of Thermal Spray Coatings

Types, Designs, Manufacture and Applications

Edited by Nuria Espallargas

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Introduction to thermal spray coatings

1

N. Espallargas

1.1 Introduction and historical overview of thermal spray

Thermal spray is a technology that involves a group of techniques and coating processes that improve the performance of a component by adding functionality to surfaces. Thermal spray techniques aim at increasing the lifetime of materials compared to their structural mechanisms of breakdown or to provide them with a specific property (e.g. optical and electrical). Thermal spray is a very versatile technology that can be used in many types of applications and virtually almost on any component. This is why it has grown to become a large worldwide market of several billion dollars since the first produced coatings in the early years of the twentieth century. Its versatility makes this technology suitable for use against wear, corrosion and aggressive and high-temperature environments and for repair and restoration of components.

In the late-nineteenth century and early-twentieth century, Dr. Max Ulrich Schoop (Zurich, Switzerland) and collaborators worked on the development of a series of equipment able to melt and propel metals in the form of powder towards surfaces to produce a coating. In the beginning of this invention, only metals with low melting point were used (i.e. tin and lead) and the process was called *metallizing* (Hermanek, 2014; Davis and Davis & Associates, 2005). Some years and patents later, Dr. Schoop and collaborators produced the first thermal spray device for spraying metal wires. This system was based on the melting of a metal wire in a flame generated by the combustion of fuel with oxygen. The melted metal was afterwards atomized by a compressed gas that propelled the metal droplets onto a substrate to build up a coating. This technique is known nowadays as *flame spray*, and it has been the basis for the development of more advanced techniques such as the high-velocity oxygen fuel (HVOF) in the late 1970s and establishes the big family of the combustion thermal spray techniques (Figure 1.1). In view of the need for new types of metals for corrosion protection, Dr. Schoop's group introduced the *electric arc* as an improvement in the metallizing technique. The electric arc allowed spraying metals with higher melting points (i.e. steel, zinc and stainless steel), being the basis for the development of the second big family of thermal spray techniques based on the use of electrical energy (Figure 1.1). The third and latest family of thermal spray techniques started in the 1980s, and it is based on solid-state spraying; this is propelling the feedstock material onto the substrate for producing coatings in the absence of combustion or electrical energy. This latest family is known as cold spraying and the mechanisms of coating

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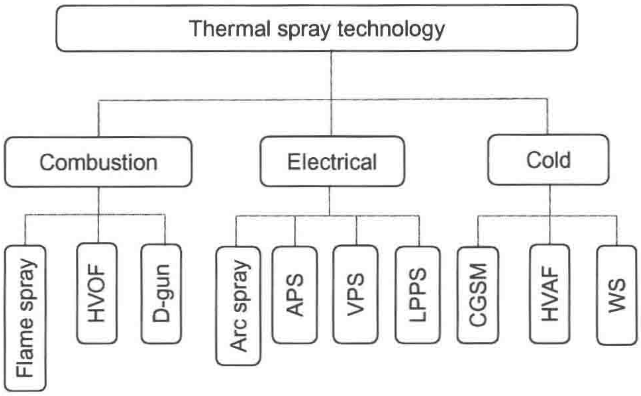

Figure 1.1 Family tree of the thermal spray technology, where the acronyms stand for HVOF (high-velocity oxygen fuel), D-gun (detonation gun), APS (atmospheric plasma spray), VPS (vacuum plasma spray), LPPS (low-pressure plasma spray), CGSM (cold gas spraying method), HVAF (high-velocity air fuel) and WS (warm spray).

build-up are still not fully understood. The more classical combustion techniques have been adapted around the concept of cold spraying, and low-temperature combustion techniques (e.g. warm spray and high-velocity air fuel) have appeared in recent years. However, only the cold gas spraying method can be considered a solid-state spraying technique (i.e. not melting the feedstock material) since the others involve the use of a combusted gas. The goal of the cold spraying techniques is mainly to produce metal coatings without altering the microstructure of the feedstock material and thus keeping a low degree of oxidation and the original structure and properties of the feedstock material. Figure 1.1 summarizes the thermal spray techniques in a family tree.

After the initial periods of thermal spray in the first half of the twentieth century with the development of many patents around the metallizing method by either combustion or electric (arc) techniques, the greatest advance in thermal spray happened after the Second World War with the needs and advances of the space and aircraft age. In this period, techniques able to generate flames with higher temperatures for producing coatings of high melting point materials (ceramics and refractory metals) were necessary. It is in this period when thermal spray technology found its largest development in terms of both equipment and materials (feedstock/consumables). Thermal spray techniques such as the ceramic rod flame spray, the *detonation gun* (D-gun), and the *plasma spray* emerged after the 1940s–1950s with the need for producing robust and durable coatings to protect components used at high temperatures in engines. These developments were possible in a great extent due to the progress in the feedstock materials, which were available in the form of both powder and wire.

The equipment and materials sales and industrial sectors where thermal spraying is used have increased exponentially after the 1950s in parallel with the development of the techniques, processes and research around thermal spray. In addition, diagnostic tools (e.g. observation of individual particles in-flight), optimization of spraying