APS MATERIALS, INC.

HISTORY AND EVOLUTION OF THERMAL SPRAY COATINGS

The history and evolution of thermal spray coatings show that the thermal spray coating industry is far from sedentary. Numerous thermal spray coating techniques have been developed since thermal spraying was discovered in the 1900s; the development of these new techniques has significantly widened the range of applications of thermal spray coatings.

ORIGINS OF THERMAL SPRAYING

Thermal spraying started in the early 1900s when Dr. Max Ulrick Schoop of Zurich realized it was possible for “a stream of molten particles impinging upon themselves” to create a coating. During that period, engineers were conducting experiments to break up liquids into fine particles or powders using high-pressure gas.

Dr. Schoop’s discovery led to the development of the first thermal spray process. Dr. Schoop and his German engineer collaborators or associates, Felix Meyer and Franz Herkenrath, were able to develop processes and equipment to produce coatings from molten and powder metals. This development, in turn, led to the establishment of the first stationary metal spraying plant in 1910.

It was 1912 when Dr. Schoop and his associates were able to create the first instrument for spraying wire-form solid metal. Metallizing was the technique behind this instrument. The principle of metallizing was that “if a wire rod were fed into an intense, concentrated flame, (the burning of a fuel gas with oxygen), it would melt and, if the flame were surrounded by a stream of compressed gas, the molten metal would become atomized and readily propelled onto a surface to create a coating.”

What was known then as metallizing is now known as oxy-fuel or flame spraying. There is now a wide range of oxy-fuel techniques that involve ceramic powder, ceramic-rod, detonation, high-velocity oxy-fuel (HVOF), metallic powder, molten metal, and wire.

With the advent of World War II in 1939, the American thermal spray industry went into high gear with the members of the International Thermal Spray Association playing a key role in providing the “metallizing” desperately needed for replacement parts for industrial equipment. By the end of the war in 1945, metallizing was recognized worldwide as a major, highly valuable industrial process. Applications during the initial era included large elevated water tanks, tuna fishing boats, chemical industry tanks and tank cars, capacitor castings and pipes.

In response to an increasingly sophisticated market, ITSA produced standard industry specifications for coatings, their applications, and methods of inspection. These specifications were distributed to engineering firms, designers, and educational institutions throughout the world and resulted in increased business opportunities for the entire metallizing industry. The extensive development by up-and-coming businesses included fusible alloys, ceramic coatings, plasma spraying, and further specialized coatings.

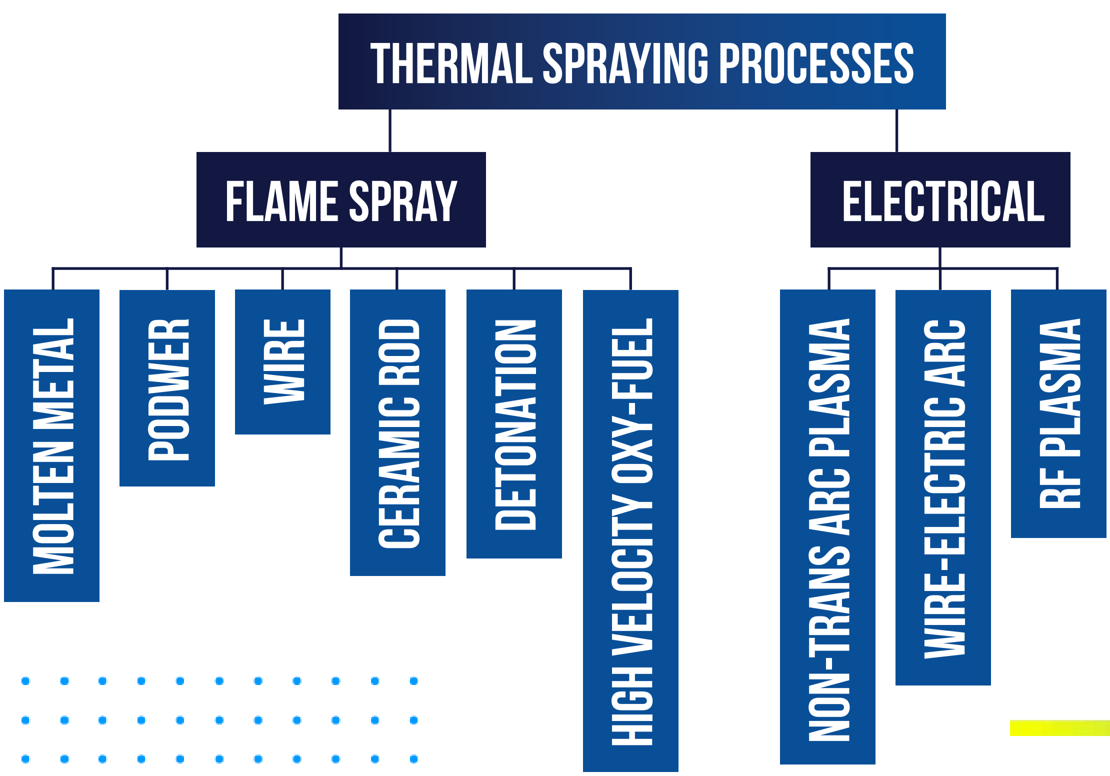
EMERGENCE OF NEW THERMAL SPRAYING PROCESSES

Problems associated with the use of liquid metal led to the use of fine metal powder. Cold spraying, which is known today as the process of throwing cold metal powder onto a surface to coat it, was actually attempted more than a century ago. Engineers knew then that this process would create layers of maximum protection. The attempt failed, however, as conditions back then made successful cold spraying impossible. This failure then served as an impetus for the development of the powder flame spraying technique, which is still in use today.

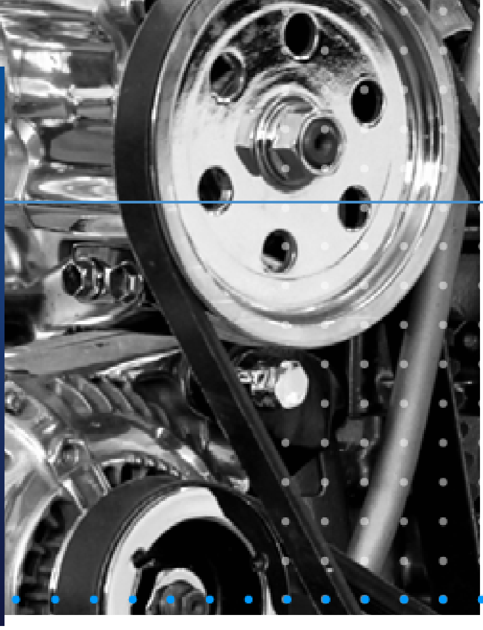
Thermal spraying eventually scaled up to an industrial level where coating plants that converted wires into coating materials were established. It was during this time that the wire flame spraying and arc spraying coating techniques came into existence.

This development was followed by the creation of the laser spraying, plasma spraying, and detonation spraying techniques in the 1950s. These techniques were widely used in the aviation industry. Additional techniques or processes were developed in the 1980s such as the development of the vacuum plasma spraying, low pressure plasma spraying, and HVOF spraying techniques.

The latest major development in the industry is the creation of the cold spraying technique. Although the name cold spraying seems incongruous with thermal spraying, it is considered by the International Thermal Spray Association as one of the leading thermal spraying techniques.

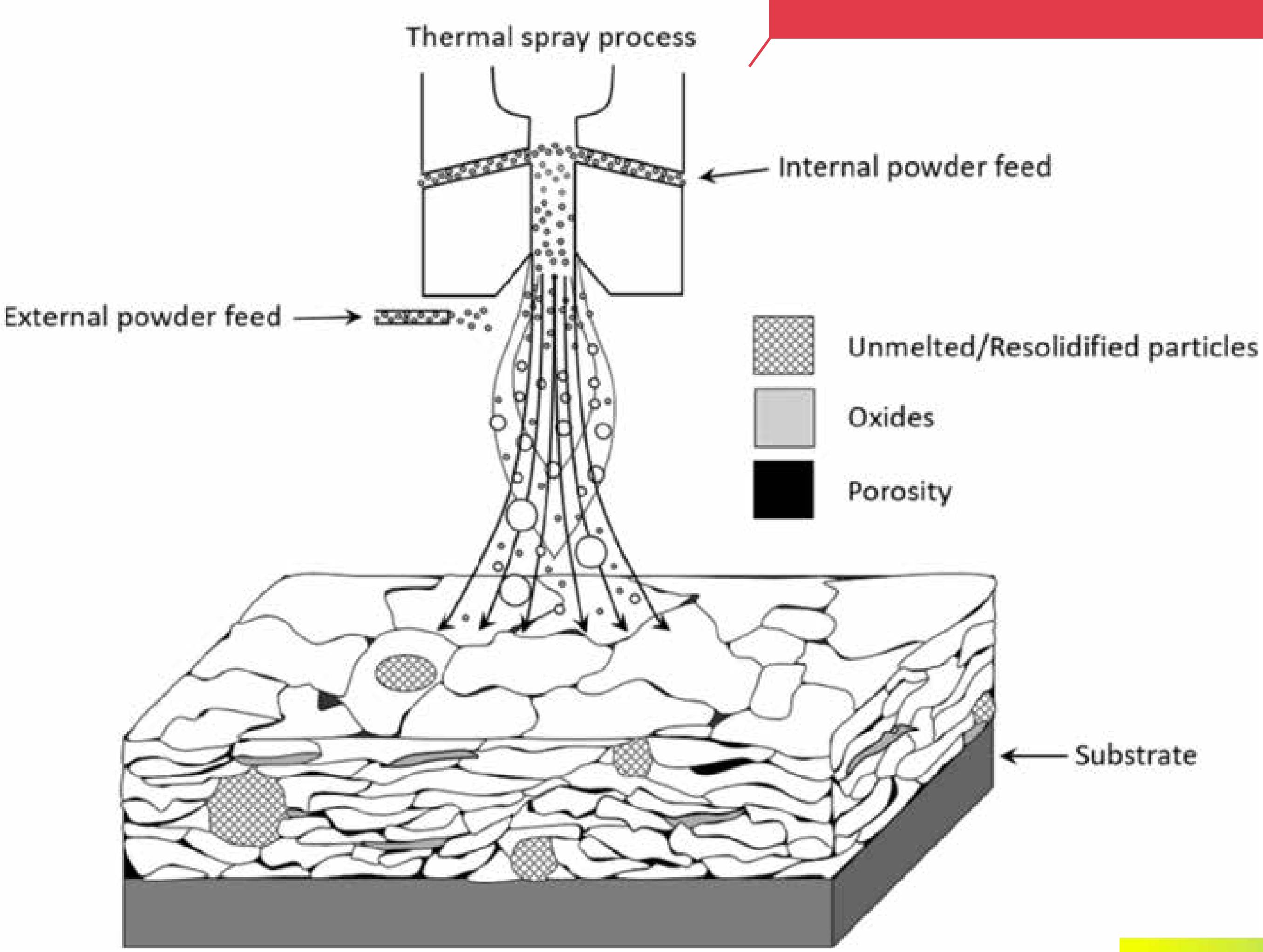


CURRENT THERMAL SPRAYING PROCESSES AND APPLICATIONS



Molten metal flame spraying, powder flame spraying, wire flame spraying, ceramic rod flame spraying, detonation flame spraying, and HVOF spraying techniques are considered flame spraying techniques, while non-transferred plasma arc spraying, electric arc spraying, and radio-frequency (RF) plasma spraying are considered electrical techniques. Cold spraying is in a category of its own.

KEY THERMAL SPRAY COATING PROCESSES AT PRESENT ARE CATEGORIZED BY THEIR HEAT SOURCE SCHEMATIC.



CURRENT THERMAL SPRAYING PROCESSES AND APPLICATIONS

THERMAL SPRAY COATINGS HAVE APPLICATIONS IN THE FOLLOWING INDUSTRIES:

INDUSTRY	WEAR						TBC	Clearance Control		Restoration	Corross/Oxidat	Electrical	
	Abrasive	Adhesive	Fretting	Erosion	Cavitation	Impact		Abradable	Abrasive			Resistance	Conduct
Aero gas turbine	✓	✓	✓	✓			✓	✓	✓	✓	✓		
Stationary gas turbine	✓	✓	✓	✓			✓	✓	✓	✓	✓		
Hydro-steam turbine	✓	✓	✓	✓	✓					✓	✓		
Automotive engines	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	
Diesel engines	✓	✓		✓		✓	✓			✓	✓		
Transportation non-engine	✓	✓					✓			✓	✓	✓	
Agriculture implementations	✓			✓		✓				✓			
Railroad	✓	✓				✓				✓	✓		✓
Iron and steel manufacture	✓			✓		✓				✓	✓		
Steeling rollings mills	✓	✓				✓				✓	✓		
Iron and steel casting	✓			✓						✓	✓		
Forging	✓	✓				✓				✓	✓		
Copper and brass mills	✓									✓	✓		
Ship and boat manufacture/repair	✓			✓						✓	✓		
Oil and gas exploration	✓	✓		✓		✓				✓	✓		
Mining, constructive and dredging	✓			✓	✓	✓				✓	✓		
Rock products	✓					✓				✓	✓		
Screening	✓					✓				✓	✓		
Cement and structural clay	✓					✓				✓	✓		
Chemical processing	✓			✓						✓	✓		
Rubber and plastic manufacture	✓			✓		✓				✓	✓		
Textile	✓									✓			
Food processing	✓									✓			
Electrical utilities		✓		✓	✓	✓					✓		
Pulp and paper	✓				✓	✓				✓	✓		
Printing equipment	✓	✓								✓			
Defense and aerospace	✓	✓	✓	✓	✓	✓	✓			✓			
Nuclear											✓		
Medical	✓		✓								✓		
Business Equipment	✓	✓	✓										
Electrical and electronic										✓	✓		
Architectural	✓					✓							
Glass Manufacture	✓	✓								✓	✓		

The oxy-fuel spraying techniques, especially HVOF, and the air plasma spraying technique appear to be the most widely used thermal spraying techniques. These techniques are used by the majority of the aforementioned industries.

Iron and steel, self-fluxing materials, nickel alloys, cobalt alloys, and non-ferrous alloys appear to be the most widely used coating materials. Chrome carbide is used by the aero gas turbine, stationary gas turbine, hydro-steam turbine, automotive engine, diesel engine, defense and aerospace, architectural, and glass manufacture industries.

Thermal spray coatings are applied to surfaces to give them properties such as wear resistance, abrasion resistance, erosion resistance, corrosion resistance, temperature resistance, and low friction.

Emerging thermal spray techniques include the high-velocity air-fuel (HVAF) spraying technique and the liquid feedstock thermal spraying technique.

TRENDS IN THE THERMAL SPRAY COATING INDUSTRY

The development of new or proprietary thermal spray coatings, the use of robotics, and the exploration of anti-virus, anti-bacteria, and anti-fungus applications are three trends in the United States thermal spray coating industry.

DEVELOPMENT OF NEW OR PROPRIETARY THERMAL SPRAY COATINGS

The development of proprietary thermal spray coatings seems to be an ongoing trend in the United States thermal spray coating industry. Players in the industry appear to be in a continuous search for high-performing and cost-effective thermal spray coatings.

These new or proprietary thermal spray coatings appear to be designed with specific industries or desired properties in mind. With APS Materials, research and development is a high priority for the industry-leading business. Specialized engineers draw from over forty years of experience in materials coating services to develop proprietary coating solutions for parts that require custom applications, unique coating materials, or an accommodation of size. Solving the unique problems of their diverse clientele is held in the highest regard and is the driving force behind each coating. Their experienced R&D technicians can isolate materials and develop a spraying process for nearly any project.

GENERAL ELECTRIC'S AIRCRAFT ENGINE GROUP (AEG) TRUSTS OUR TEAM TO COAT THEIR AEROSPACE MATERIALS. OUR THERMAL COATING PROCESS IS A CRUCIAL PART OF MEDICAL IMPLANTS FOR 7 OF THE TOP 10 INTERNATIONAL BIOMEDICAL MANUFACTURERS. AS WELL AS PLAYING A CRUCIAL ROLE IN THE CREATION OF SEMICONDUCTOR WAFERS. COMPANIES TRUST APS FOR THERMAL COATINGS.

USE OF ROBOTICS

Thermal spray coating providers in the United States appear to be increasing its usage of robotics to improve the accuracy, efficiency, consistency, and flexibility of their operations. They recognize that robots allow for the accurate and precise setup of process parameters.

APS Materials, an Ohio-based key market player, has acquired multiple additions to its expansive robot family. It has bought a new thermal spray robot manipulator for added accuracy, efficiency, consistency, and flexibility in the types of process fixtures it could use. What makes this robot manipulator special is its small footprint and its ability to adapt to various kinds of spray guns.

Thermal spray guns are controlled by industrial robots so that coating properties and process parameters such as stand-off distance, traverse r ate, number of coating passes, and coating angle can be accurately controlled, and the process can be repeated in a precise manner.

EXPLORATION OF ANTI-VIRUS, ANTI-BACTERIA, AND ANTI-FUNGUS APPLICATIONS

Players in the thermal spray coating space seem to be exploring the anti-virus, anti bacteria, and anti-fungus applications of thermal spray coatings. Anti-virus, anti-bacteria, and anti-fungus applications are a prevalent topic of the ITSC (International Thermal Spray Conference and Exposition) 2021 Preview organized by the Ohio-based Thermal Spray Society.

Industry experts are exploring how thermal spray techniques can be utilized in depositing antimicrobial compounds on various high-touch surfaces. In the preview, industry experts will discuss how biocidal thermal spray coatings can be implemented and utilized in a large scale to lower the risk of virus or bacteria transmission in high-touch places such as hospitals and public transportation.

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