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Industrial Guide—Markets, Materials, and Applications for Thermal-Sprayed Coatings

F.N. Longo

This article is presented in two parts. First, some select industrial sectors are analyzed, and the activities most likely to sustain or promote growth are highlighted. The second part profiles current activity by showing, for each of these industrial sectors, which equipment and processes are operating, which coating functions are required, and which types of material are currently consumed.

1. Introduction

THE main elements of the existing thermal spray coatings market comprise: consumables such as powder, wire and rod, thermal spray guns and accessories, systems (including vacuum plasma systems), ancillary supplies, and contract coating services. The current estimated market for these elements is between 600 and 675 million dollars/year in North America. The Gorham* study shows that the most lucrative sector is coating contract services, accounting for more than 50% of the total market, followed by consumable supplies, systems, and guns in that order. The total market is projected to reach 1.8 to 2.0 billion dollars in 1990 dollars by the end of the decade on the strength of a growing and expanding powder business, a strong demand for standard equipment systems and vacuum plasma systems, and a growing demand for contract coating services.

2. Thermal Spray Coatings End Use Analysis

Applications for thermal spray and other coatings have been identified in 34 industrial sectors. Twelve of the 34 industries have been isolated and studied for this shortened guide. These are shown in Table 1, which highlights each industry according to current activity and growth potential. One of the 12, aircraft gas turbine applications, accounts for 30 to 40% of the total North American market. Some of the current activities for each industry are as follows.

The aircraft turbine industry remains the most lucrative market for thermal spraying because of widespread use of coatings from the fan to the turbine section. Some new engines (*e.g.*, PWA 4000, GE/Snecma CFM-56, and RR class RB211) have close to 5500 parts manufactured with thermal spray coatings. Growth is projected on the strength of expanding applications, particularly for ceramic coatings used for thermal barrier coatings and clearance control and for composite powders used as compressor abradable seals. There is also a continuing strong demand for new engines into the next decade.

Industrial/stationary gas turbine builders are expected to use current aircraft gas turbine experience and adapt thermal spray coatings for repair and original engine manufacture (OEM) applications, thus providing additional growth for current materials.

The steam turbine industry, required to improve component life, is poised for major use of thermal spray coatings. It also is expected to utilize the coatings experience used for aircraft engines.

The automotive gasoline engine sector is currently characterized by several OEM applications for thermal spray coatings, namely piston rings, synchro rings, shifter forks, and oxygen sensors. The future is very bright, as development activity with dielectric coatings using plasma-sprayed alumina is under development. High resistivity and cost-effective deposition are cited as reasons for development.

The application of thermal spray zirconia coatings to diesel engine combustion zone components is expected to produce a

Table 1 Thermal Spray Coating Activity by Industry

Industry	Current activity	Growth potential to year 2000
Gas turbine, aircraft	1	1
Gas turbine, industrial	4	2
Turbine, steam	4	3
Engines, automotive	5	1
Engines, diesel	3	2
Transportation	4	2
Oil and gas exploration	3	3
Chemical processing	4	2
Paper and pulp	3	3
Defense and aerospace	4	3
Medical and dental	4	3
Electric and electronic	4	2

Note: Scale based on 1 equals the highest growth and 5 equals modest growth.

Keywords: commercial study, thermal spray materials, process guide, commercial markets, industrial applications

F.N. Longo, Consultant, East Northport, New York.

*Material presented in this article was taken in part from the 1990 multiclient study prepared by Gorham Advanced Materials Institute, entitled "The Expanding Business Opportunities and Challenges in Thermal Sprayed Coatings." Frank Longo is a thermal spray industry consultant and is a principal author of this study.

Table 2 Thermal Spray Processes Used by Industry

	Processes													
Industries	O_2/fuel powder low velocity	Spray and fuse torch	HVOF	Air plasma	Vacuum plasma	Inert gas shroud plasma	Plasma transfered arc	Laser-assisted plasma	D-gun	Gator gard	O_2/fuel wire spray	Electric arc	Electric arc with inert cover or vacuum	Rokide
Gas turbine, aircraft	X	...	X	X	X	X	X	X	X	X	X	X	...	...
Gas turbine, industrial	...	...	...	X	...	X	X	...	...	...	X	...	...	...
Turbine, steam	...	X	...	X	...	X	X	...	...	...	...	...	...	...
Engines, automotive	X	...	...	X	...	...	X	...	...	...	X	X	...	X
Engines, diesel	X	...	...	X	...	...	X	...	...	...	X	X	...	X
Transportation	X	...	...	X	...	...	X	...	X	...	...	X	...	...
Oil and gas exploration	X	X	X	X	...	...	X	...	X	...	X	X	...	X
Chemical processing	X	...	...	X	X	...	...	...	X	...	...	X	X	...
Paper and pulp	X	...	X	X	...	...	X	...	...	...	X	X	...	X
Defense and aerospace	X	...	X	X	X	...	X	...	X	...	X	X	...	...
Medical and dental	...	...	...	X	X	...	...	...	X	...	...	...	...	...
Electric and electronic	...	...	...	X	X	...	...	...	X	...	...	...	...	...

Table 3 Thermal Spray Coating Function by Industry

	Coating function														
Industries	Abrasive wear resistance	Adhesive wear resistance tribology	Anti-fretting	Erosion resistance	Cavitation resistance	Thermal barriers	Clearance control abrad-ability	Restoration of dimen-sion and repair	Corrosion resistance	Corrosion resistance, iron and steel	Near-net shape forming	Electric resis-tance	Electric conduc-tivity	Impact	Oxi-dation
Gas turbine, aircraft	X	X	X	X	...	X	X	X	X	X	X	...	...	...	X
Gas turbine, industrial	X	X	X	X	...	X	X	X	X	...	...	...	...	...	X
Turbine, steam	X	X	...	X	X	...	...	X	...	X	...	...	...	...	...
Engines, automotive	X	X	X	X	...	X	X	X	X	X	X	X	...	X	X
Engines, diesel	X	X	...	X	...	X	...	X	...	X	X	...	...	X	X
Transportation	X	X	...	...	...	...	X	X	X	X	...	X	X	...	...
Oil and gas exploration	X	X	...	X	...	...	...	X	X	X	...	...	...	X	...
Chemical processing	X	...	...	X	...	...	...	X	X	X	...	...	...	...	X
Paper and pulp	X	...	...	...	X	...	...	X	X	X	...	...	...	X	...
Defense and aerospace	X	...	...	...	...	X	X	X	...	...	X	...	...	...	...
Medical and dental	...	...	X	...	...	...	...	...	X	...	...	...	...	...	...
Electric and electronic	...	X	X	...	...	...	...	...	...	...	...	X	X	...	...

Table 4 Thermal Spray Powder Materials Used by Industry

	Materials															
Industries	Ce-mented Co-WC	Chro-mium carbides	Mixed WC, TiC or Cr_3C_2	Oxide ceramics	Non-oxide ceramics	Fluxed alloys	Iron and steel alloys and composites	Nickel and nickel alloys	Super-alloys, MCRALY's	Cobalt and cobalt alloys	Refrac-tory metals	Plastics	Special com-posites	Glasses	Cermets	Non-ferrous metals
Gas turbine, aircraft	X	X	...	X	X	...	X	X	X	X	X	X	X	...	X	X
Gas turbine, industrial	X	X	X	X	...	X	X	X	X	X	X	...	X	...	X	...
Turbine, steam	X	X	...	...	...	X	X	X	...	X	...	...	...	...	...	X
Engines, automotive	...	...	...	X	...	...	X	X	...	X	X	...	...	...	...	...
Engines, diesel	X	...	...	X	...	...	X	X	...	X	X	...	...	...	X	...
Transportation	...	...	...	...	...	...	X	X	...	...	X	...	...	...	...	X
Oil and gas exploration	X	...	...	X	...	X	X	X	...	X	...	X	...	...	...	X
Chemical processing	X	...	...	X	...	...	X	X	...	X	X	X	...	X	...	...
Paper and pulp	X	...	...	X	...	X	X	X	...	...	X	...	...	...	...	...
Defense and aerospace	X	X	...	X	...	...	X	...	X	X	X	...	...	X	X	...
Medical and dental	...	...	...	X	...	...	...	...	...	X	...	...	...	...	...	X
Electric and electronic	...	...	...	X	X	...	...	...	...	...	...	...	...	...	...	X

major market for stabilized zirconia powder by the year 2000. The need for bond coatings and plasma systems will also provide new business. Half of the yearly production of engines in the year 2000 could be produced with thermal barrier coatings. Thick thermal barrier coatings suggest enormous potential for materials, equipment, and systems.

Transportation industries manufacturing automobile, bus, and truck components, excluding diesel and gasoline engines,

are exploring new thermal spray applications. Four applications identified include:

- Abradable/clearance control coatings for superchargers
- Nonferrous coatings for molding and finishing sheet metal contours
- Corrosion control coatings for external surfaces
- Thermal spray coatings as replacements for bearing inserts and seals

Oil and gas exploration and related industries, although slow through most of the 1980s, are creating new demands. Applications activities include wear-resistant coatings applied by high-velocity oxy-fuel (HVOF) processes, plasma spraying for corrosion control, and polymer coatings for chemical resistance.

The chemical processing industries are expected to use vacuum plasma-sprayed (VPS) refractory metal coatings for corrosion control, creating demand for vacuum plasma-sprayed systems and powders. Use of thermal-sprayed polymer coatings for corrosion control of large structures and tanks looks promising.

The paper and pulp industries could expand use of thermal spray coatings for corrosion control on digesters and boilers. High-velocity oxy-fuel coatings are expected to perform more reliably in corrosive environments, because they are denser and powder chemistry is unaltered during spraying, resulting in new and broad acceptance by mill operators.

Defense and aerospace-related industries continue development of plasma spray forming, taking advantage of cost-effective net-shape component fabrication, thus creating opportunities for vacuum plasma spray systems.

Medical and dental companies producing prosthetic devices are expected to increase their use of porous titanium coatings and hydroxyapatite coatings to enhance tissue growth. Demand for chemically pure titanium powder and vacuum plasma spray systems will increase as a result of this activity.

Two applications of the electric and electronic industries, including business equipment producers, worth noting are plasma-sprayed alumina for dielectric coatings and tribological coatings for recording heads.

3. Thermal Spraying Analysis by Industry

The broad base of end user activity with thermal spray coatings for the 12 industrial sectors are profiled in Tables 2 through 4. Each industrial sector was analyzed for the level of spray activity, involving thermal spray processes currently in use or projected for use (see Table 2), thermal spray coating application identified by service function (Table 3), and completing the profile, thermal spray powder materials (Table 4). Combining the information contained in Tables 2 through 4 provides the reader with broad market information, from which both market niches and business opportunities can be found. The Gorham thermal spray study provides these analyses on all 34 surveyed industries. It also analyzes powders and materials by type and industrial consumption to the year 2000.

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