Editorial

Quality Improvement of Coating by a Prespray and Postspray Process

Lech Pawlowski

Introduction

As a young project manager working in the German company of W. Haldenwanger in Berlin, I was asked to develop the technology of anilox rolls. This technology (Ref 1) is composed of many steps, beginning with a prespray processing (old coating removal then sand blasting of the roll surface) followed by coating the roll with the APS technique. Finally, the coating is submitted to a couple of postspray treatments such as a mechanical grinding, polishing, and engraving of small cells in the coating with the CO_2 laser.

As a coating specialist, I put all my ambition into developing a perfect deposit: well adhering, low porosity, and so forth. My surprise was great when the customers showed much more interest in the shape of engraved cells than in the microstructure of the coating. I realized then that the quality of coated products depends at least as much on the prespray and postspray treatments as on the spraying itself (Fig. 1).

Prespray Processing

The prespray processing would include the powder and the substrate preparations.

The powder preparation processes are (in a rough approximation): manufacturing, storage and drying, and the injection of the powder. The powder manufacturing techniques influence the morphology of particles; for example, the particles of a powder produced by a

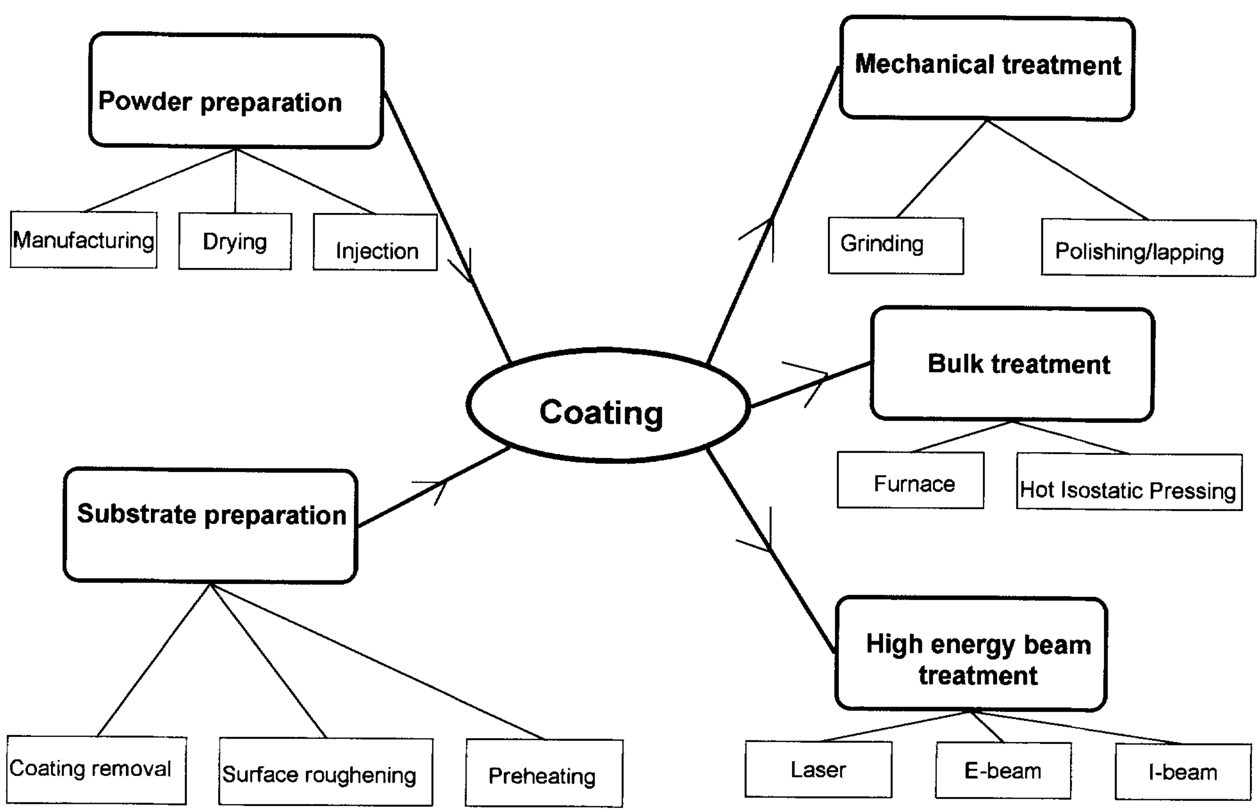

Fig. 1 Diagram of prespray and postspray processing

spray drying method are porous. The heat transfer to such porous particles in the flame of a torch is poor. That is why the spray dried powders need to be sprayed using a flame that is relatively hotter than that used to spray dense powder particles. The powder production techniques such as atomization for metallic powders or fusing and crushing or sintering and crushing are well known throughout the thermal spray community. However, there is still a need to diffuse a knowledge concerning the emerging techniques of manufacturing such as, among many others, freeze-drying, sol-gel, and mechanofusion processes.

Prior to deposition, the powder can be dried at the temperature slightly above 100 °C to remove humidity and to improve its flowability. The drying can take place in a vacuum furnace or directly in a powder feeder. The injection of the powder to the torch is a phenomenon that influences the state of the sprayed particle on their impact with the substrate. The spatial and temporal distribution of powder in the injector depends mainly on the design of a powder feeder type. The injection velocity distribution of the powder particles determines their trajectory in the flame, and its importance has been recognized for many years (Ref 2). Less known and less studied is preheating the powder just before injection to the flame (Ref 3). This method is certainly worthy of further exploration because an increase in the temperature of a particle impacting the substrate is equal to a value of its initial temperature. Thus, preheating the powder to a few hundreds degrees may dramatically increase the fraction of fully melted particles in the portion impacting the substrate. This may result, in turn, in better adhesion and lower porosity of the sprayed coating.

Table 1 Modern industrial lasers

Property	Laser		
	Excimer	Nd-YAG	CO_2
Wavelength, μm	0.15-0.35	1.06	10.6
Energy or power maximum, J or W	1 J	150 J (pulsed) 3000 W (continuous)	Up 45 kW (continuous or pulsed)
Pulse duration	10-30 ns	0.5-20 ms	...
Pulse frequency, Hz	Up to 500	Up to 1000	Up to 20,000

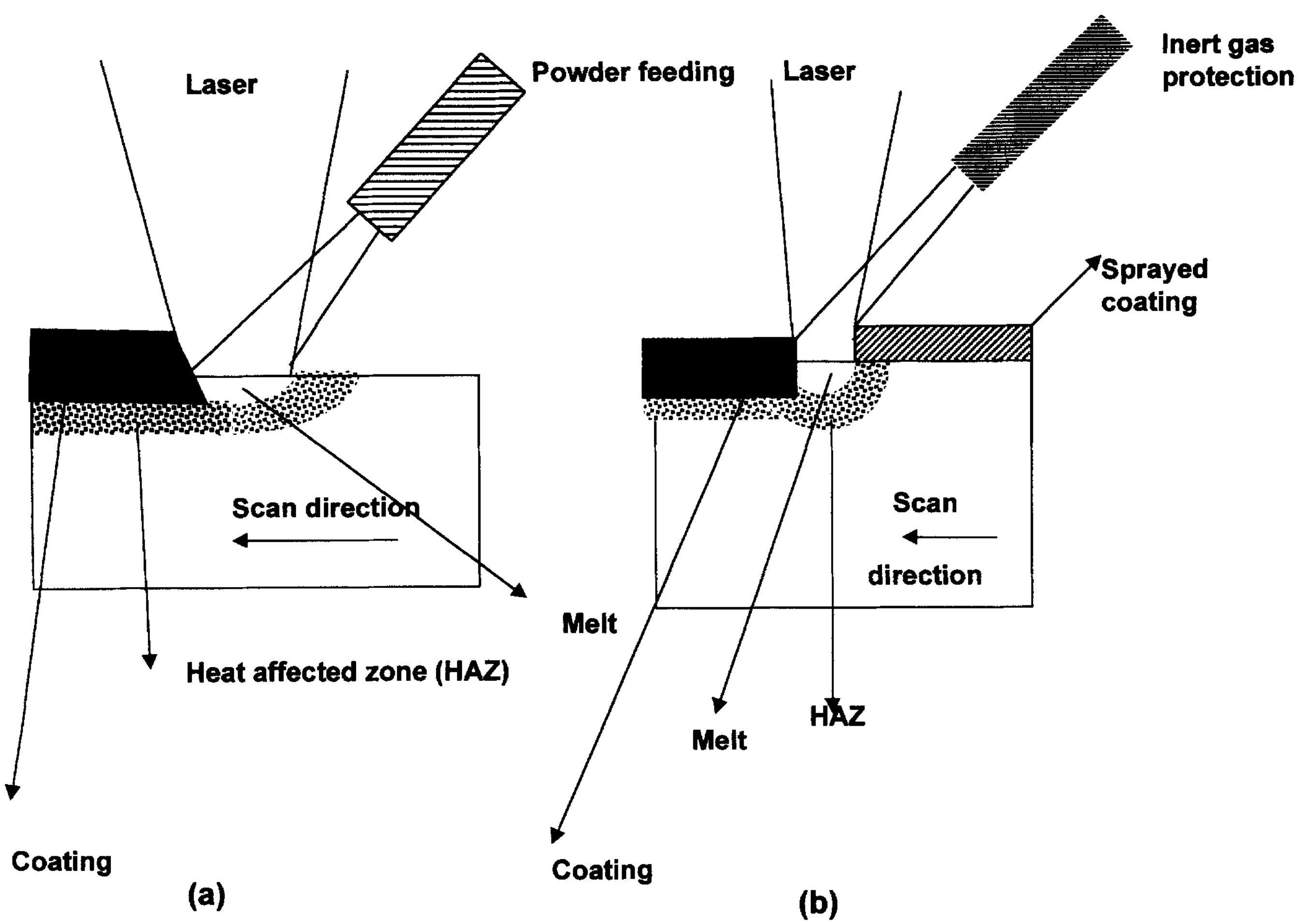

Fig. 2 One-step (a) and two-step (b) laser processing. Source (Ref 12)

The substrate preparation starts often with a coating removal. Metallic coatings are easy to remove with a traditional turning lathe. Well-adhering ceramic deposits may need sand blasting or high-energy waterjet processing to be removed. Another step in the preparation is machining of the substrate to get the desired geometrical dimensions and to get rid of sharp angles and sharp ends. Although it is generally well known that sharp forms of the substrate induce additional stresses inside the coatings deposited thereupon, it is difficult to find a systematic study on this topic.

The substrate is finally submitted to surface roughening. This process determines the adhesion of a coating to a substrate. Among many possible ways of surface roughening (Ref 4), sand blasting is the most popular and most frequently studied (e.g., Ref 5). The emerging process in this field is related to shocks generated by a pulsed Nd-YAG laser. These shocks result from an expansion of a plasma created during the interaction of this laser beam with a substrate (Ref 6), and this process is already used to remove a paint from the surfaces with the device called Laserblast (Quantel, Les Ulis, France). The prespray operations can finish with preheating of the substrate. Large pieces are typically preheated with the flame of the torch used subsequently to spray coatings. Small components could be also preheated in the furnace.

Postspray Processing

Almost all industrially sprayed coatings are mechanically ground and polished. These processes, however, are seldom studied in a systematic way (a study published in Ref 7 is an exception). Thus, grinding and polishing still remain an art rather than a science. On the other hand, the hot isostatic pressing (HIP) process came to thermal spray from the ceramic industry and is increasingly often studied, for example, for VPS superalloys (Ref 8) or for APS zirconia (Ref 9). The furnace annealing is also well known and has been employed for many years. Probably the greatest technical progress has been achieved in recent years in the high-energy beam treatment and, especially, in laser treatment. The performance of industrial lasers (Table 1) enables treatment of coatings in the following ways:

- In the solid phase, when the laser beam power density is lower than 1 kW/cm^2
- In the liquid phase, when the density is in the range 1 to 100 kW/cm^2
- In the gaseous phase, for densities above 1 GW/cm^2

Laser treatment in a solid phase enables a change in the proportion of the crystal phases in a sprayed coating. An example, studied in Ref 10 and 11, is the treatment of APS hydroxyapatite (HAp) to increase the relative crystallinity of an as-sprayed coatings. The growth of crystalline HAp was supplied by a transformation of amorphous phase during a laser treatment at the temperatures up to 1170 K, well below the melting point.

The treatment in a liquid phase offers many different processes enabling coatings manufacturing (one-step processing*) and the modification of sprayed deposits (two-step processing, Fig. 2). Each of these processes can be carried out in one of three ways (Fig. 3): *alloying, cladding,* or *hard-phase dispersion* (Ref 12, 13).

The two-step *alloying* process enabled synthesis of a Ti-TiC composite coating by melting with Nd-YAG laser of a graphite deposit onto a titanium substrate (Ref 14). One-step *alloying* was applied to obtain a titanium nitride by CO_2 laser melting of a titanium substrate in a nitrogen atmosphere (Ref 15). Two-step *cladding* can be applied to alloys sprayed by VPS (Ref 16) or oxides sprayed by APS (Ref 17). One-step *cladding* is widely applied to deposit Stellite alloy (e.g., Ref 18). Finally, a two-step *hard-phase dispersion* technique was applied to improve the wear resistance of WC-Co coatings by APS (Ref 19) and a one-step process enabled dispersion of hard TiC and TiB_2 particles in a pure aluminum substrate (Ref 20).

Laser treatment in a gaseous phase is frequently used to engrave a pattern of fine cells in the chromium oxide APS coatings to manufacture anilox rolls (Ref 1). The treatment is presently made using a CO_2 pulsed laser, but the solid-state Nd-YAG laser was recently tested to achieve a higher density of engraved cells (Ref 21).

The electron and ion beam treatments take place under vacuum, and this limits the dimensions of the treated samples. An example of an e-beam treatment is a densification of titanium and tantalum coatings sprayed by APS (Ref 22). This treatment reportedly improved the corrosion resistance of deposits.

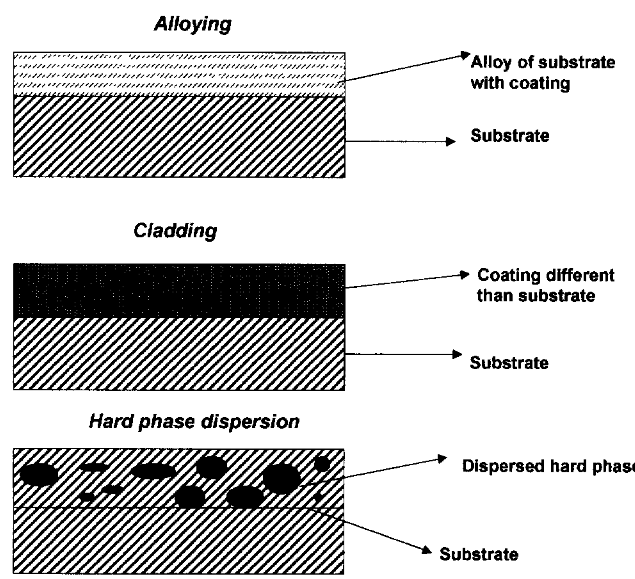

Fig. 3 Schematic representation of the coatings deposited or modified in the alloying, cladding, and hard-phase dispersion processes

*One-step treatment is in fact a coating process rather than a postspray one. It is discussed to complete the description of laser-related techniques.

Conclusions

The topics related to prespray and postspray processing are of primary importance for the coatings quality and are of great interest to the thermal spray community. This conviction is shared by the author of this editorial, by the journal editor (Prof. Berndt), and by the chairman of the editorial committee of the *Journal of Thermal Spray Technology* (Prof. Heberlein). Consequently, the journal is expected to come up soon with a special edition on prespray and postspray processing. Potential authors are kindly invited to (1) indicate their interest and/or (2) send their papers to either the journal editor (at SUNY at Stony Brook, USA) or the author of this editorial (at Laboratory CLFA).

Lech Pawlowski
Professor at University d'Artois
Laboratory CLFA
Arcueil, France
16 bis, Avenue Prieur de la Côte d'Or
94114 Arcuell Cedex, France
Fax: 011-33-1-42-31-97-47
E-mail: Lech.Pawlowski@etca.fr

References

1. L. Pawlowski, Technology of Thermally Sprayed Anilox Rolls, *J. Therm. Spray Technol.*, Vol 5 (No. 3), 1996, p 317-334
2. H. Hantzsche, Bedeutung der Pulversfördergeschwindigkeit beim Plasmaspritzen, *Schweisstechnik*, Vol 21, 1971, p 399-403
3. A. Czernichowski and L. Pawlowski, Large, Preheated Ceramic Particles Make Thick Films, *Adv. Mater. Process.*, Vol 151 (No. 11), 1996, p 12-13
4. T.S. Laszlo, Mechanical Adherence of Flame Sprayed Coatings, *Ceram. Bull.*, Vol 40, 1961, p 751-755
5. M. Mellali, A. Grimaud, and P. Fauchais, Parameters Controlling the Sand Blasting of Substrates for Plasma Spraying, *Thermal Spray Industrial Applications*, C.C. Berndt and S. Sampath, Ed., ASM International, 1994, p 227-232
6. P. Peyre, R. Fabbro, L. Berthe, and C. Debouchet, Laser Shock Processing of Materials, Physical Processes Involved and Examples of Applications, *J. Laser Appl.*, Vol 8, 1996, p 135-141
7. R.B. Massad, Diamond Wheel Grinding of Thermal Spray Materials, *Thermal Spray Coatings: New Materials, Processes and Applications*, F.N. Longo, Ed., ASM International, 1985, p 139-146
8. H.-D. Steffens, R. Dammer, and U. Fischer, Post Treatment of Metal Composites by Hot Isostatic Pressing, *Surf. Eng.*, Vol 4, 1988, p 39-42
9. H.C. Chen, E. Pfender, and J. Heberlein, Structural Changes in Plasma Sprayed ZrO_2 Coatings after Hot Isostatic Pressing, *Thin Solid Films*, Vol 293, 1997, p 227-235
10. L. Pawlowski, H. Rapinel, F. Tourenne, and M. Jeandin, Traitement Laser des Dépôts Plasma d'Hydroxyapatite, *Galvano-Organo Trait. Surf.*, Vol 676, 1997, p 433-437
11. X. Ranz, L. Pawlowski, L. Sabatier, R. Fabbro, and T. Aslanian, Phases Transformations in Laser Treated Hydroxyapatite Coatings, accepted for Proceedings of 15th ITSC (Nice, France), 25-29 May 1998
12. A. Gasser, K. Wissenbach, E. Hoffmann, G. Schulte, and E. Beyer, Oberflächenbehandlung mit Zusatzwerkstoffen, *Sixth European Conf. Laser Treatment of Materials ECLAT'96*, F. Dausinger, H.W. Bergmann, and J. Sigel, Ed., Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e.V., 1996, p 287-297
13. W. Pompe, S. Nowotny, W. Reitzenstein, and B. Schultrich, Laser Oberflächenbehandlung zur Bauteilbeschichtung, *VDI Berichte*, No. 917, 1992, p 31-42
14. L. Fouilland-Paille, S. Ettaqui, S. Benayoun, and J.J. Hantzpergue, Structural and Mechanical Characterization of Ti/TiC Cermet Coatings Synthesized by Laser Melting, *Surf. Coat. Technol.*, Vol 88, 1996, p 204-211
15. B. Brenner, S. Bonss, R. Franke, I. Haase, and H.-J. Scheibe, Mechanical and Tribological Properties of Laser Gas Alloyed TiAl4V, *Sixth European Conf. Laser Treatment of Materials ECLAT'96*, F. Dausinger, H.W. Bergmann, and J. Sigel, Ed., Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e.V., 1996, p 477-484
16. B. Wielage, S. Steinhäuser, L. Pawlowski, I. Smurov, and L. Covelli, Laser Treatment of Vacuum Plasma Sprayed CoCrAlY Alloy, *Surface Modification Technologies XI*, T.S. Sudarshan, M. Jeandin, and K.A. Khor, Ed., The Institute of Materials, 1998
17. T. Troczynski, L. Pawlowski, N. Third, L. Covelli, and I. Smurov, Physico-Chemical Treatment of Zirconia Coatings for Thermal Barriers, accepted for Proceedings of 15th ITSC (Nice, France), 25-29 May 1998
18. J.M. Yellup, Laser Cladding Using the Powder Blowing Technique, *Surf. Coat. Technol.*, Vol 71, 1995, p 121-128
19. J. Mateos, J.M. Cuetos, E. Fernandez, and M. Cadenas, Effect of Laser Treatment on Tungsten Carbide Coatings, *Surface Treatment*, M.H Aliabadi and C.A. Brebbia, Ed., Computational Mechanics Publications, 1997, p 240-246
20. D. Fischer, W. Löschau, and W. Reitzenstein, Mit Laser erzeugte grobkörnige Hartstoff-Dispersionschichte auf Aluminium-Legierungen zum Verschleissschutz, *Sixth European Conf. Laser Treatment of Materials ECLAT'96*, F. Dausinger, H.W. Bergmann, and J. Sigel, Ed., Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e.V., 1996, p 455-460
21. E. Meiners, Mikrostrukturierung von Makrooberflächen-Laseranwendungen in der Druckformenherstellung, *Sixth European Conf. Laser Treatment of Materials ECLAT'96*, F. Dausinger, H.W. Bergmann, and J. Sigel, Ed., Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e.V., 1996, p 663-674
22. T. Kinos, S.L. Chen, P. Siitonen, and P. Kettunen, Densification of Plasma Sprayed Titanium and Tantalum Coatings, *J. Therm. Spray Technol.*, Vol 5 (No. 4), 1996, p 439-445