HVOF PROCESS
ITS CHARACTERISTICS, ADVANTAGES AND USE (1)

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ABSTRACT

This paper aims to inform about the HVOF origin, characteristics, advantages and use.

Its main objective is to give detailed information about the HVOF specifications. It also aims to increase its use in industrial operations that want to optimize some characteristics of coating materials.

The high velocity involved in this process, leads to high levels of adherence and layer compression, while reducing the porosity to levels that are inferior to those obtained with the use of the conventional thermally spraying process. This fact guarantees a high quality of protection against corrosion and wear.

Key Words: HVOF, hard coating, wear

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1. INTRODUCTION

Metallic materials are largely used in the industry and have therefore had a big progress in their production processes.

These materials suffer high levels of corrosion and wearing and for this reason many forms of protection have been developed recently.

The HVOF process has proved to be one of the best solutions for the industries, specially because it is difficult to afford the high cost of production with special material.

High demands in the field have led to the evolution of the HVOF process and have in this way offered different alternatives to meet special characteristics in the different areas of the industry.

The standard structure offered by the thermal sprayed coating has shown to be unable to resist the high levels of abrasion, for example.

High hardness materials have required more sophisticated spraying processes. The raw material that used to be utilized only in the manufacturing of cutting tools and sinterized pieces, can today provide a high level of protection when coating some specified parts of machine elements.

A real isolation to abrasion and corrosion needed to be developed in order to efficiently protect the substrate and in this way maintain its integrity.

So the Hypersonic Thermally Sprayed System - HVOF or High-Velocity Oxy-Fuel was developed.

The HVOF is the result of the conventional spraying process evolution and it has brought solutions to problems that were unsolvable through the conventional process.

This paper aims to present some characteristics of the HVOF process and its resulting coating as well as to explain its increasing use nowadays.

2. OBJECTIVE

As we study the main characteristics of the HVOF process, the action of the spraying process on the metallic surface becomes evident.

Microstructural aspects of the resulting coat, the stress involved and tribological results show the innate qualities of the HVOF process that we have noticed throughout this paper.

3. HOW THE EQUIPMENT WORKS

While operating at hypersonic velocity, the particles are launched against the substrate and then they splat against the substrate and over other particles previously launched.

The efficiency of the equipment is based on the precise control of the combustion temperature during the mixture of the gases, creating uniform heating and melting, through the circular flame; the air flow specific to each powder feeding; the careful control of the powder feeding flow and the proper cooling of the gun. Its performance depends basically on the efficient use of the kinetic energy, momentum and the heat produced.

4. PROCESS CHARACTERISTICS

4.1 - Coating low porosity

There is a substantial reduction of the porosity due to the high velocity involved in the process as well as the high density of the particles. The particle impact deforms the existing coating, coalesces into the available pore sites. This transfer of kinetic energy and momentum produce a high compressive stress inside the coating. When this stress is properly controlled it may be beneficial to the coating.

The low porosity that results from the HVOF process may be used as a shield to the effect of chemical products, in its solid of liquefied state . However the sprayed material must be chemically inert in order to efficiently isolate the substrate.
The porosity obtained through the conventional thermal spraying process is around 25%, while those obtained through the most advanced HVOF process is between 0.5% to 1.0%.

4.2 - High Hardness

This is basically the result of the material used, the adherence and the cohesion between the particles and, in some cases, of the porosity, of the quantity of oxide and the intersticial hardening agents.

4.3 - High Coating Thickness

It is probably the result of the excellent figures obtained due to the cohesion and adherence strength and to the reduced levels of stress within the coating.

4.4 - Adherence

The particles high velocity associated with the axial powder feeding in the center of the combustion flame provides levels of tension superior to 12.000 psi for WC-Co.

4.5 - Wear Resistence

In general hard materials are more resistant to wear than soft materials. In the specific case of HVOF sprayed coatings, the results obtained are better than those obtained through other thermal spraying processes. This is due to the high hardness, low porosity and excellent particle cohesion.

The high velocity in HVOF process creates microstructures with decarburating levels much inferior to those obtained through other thermal processes, because the permanence time in the flame is reduced.

Concerning the microstructure, the HVOF process creates carbides of different sizes (submicronic) and more coalesced than the Plasma, for example.

5. DISCUSSION

The HVOF process must be considered as an evolution in the thermal spraying area permitting to solve the problems that were present in the conventional spraying processes.

The high velocity involved in the hypersonic process can be seen a "virtual sinterizing", that is the strength exerted by the particles "build" a plate of tungsten carbide, on the steel substrate.

The reduced porosity, even in thin coatings, tends to efficiently isolate the base in relation to the environment. If proper material is used, the thermally sprayed coatings by the HVOF system can be largely used in chemical and petrochemical industries, paper and cellulose industries and food companies.

When we compare the coatings sprayed by the HVOF system (CDS of Plasma Technik) and Plasma (VPS), we find out that the protection against wear is three times higher when the WC-Co is applied by the hypersonic process.

Researches performed by X. Provot and others (1) have demonstrated that the HVOF (CDS) produce decarburizing effects inferior to those produced by Plasma (APS). Due to the high temperatures involved the Plasma process, some immediate changes of phase happen so the carbon (for example: WC-17% Co), can be oxidized and/or diffused into the matrix material. Since the HVOF operates at temperatures inferior to those of the plasma and the powder is kept during a short period of time in contact with the flame, the original characteristics of the WC are better kept and consequently its microstructure will have no molten state and is more resistant to wear.

This process is highly used in Siderurgical Industries, Mining Industries, paper and cellulose and mechanic in general because they work with high levels of wear.

The HVOF also produces a microstructure of carbides and subcarbides thinly distributed that reduces the coating porosity and increases its adherence.

Concerning the stress involved, we can say that they are the direct result of the hypersonic velocity reached by the particles. When the solid and semi-solid particles collide with the hard substrate or the already sprayed particles, they produce the so called shot peening effect, relocating even the material against which they collide. As a result of this the compressive residual stress is created. It is then the main cause for the adherence to the substrate. (Fig. 1).

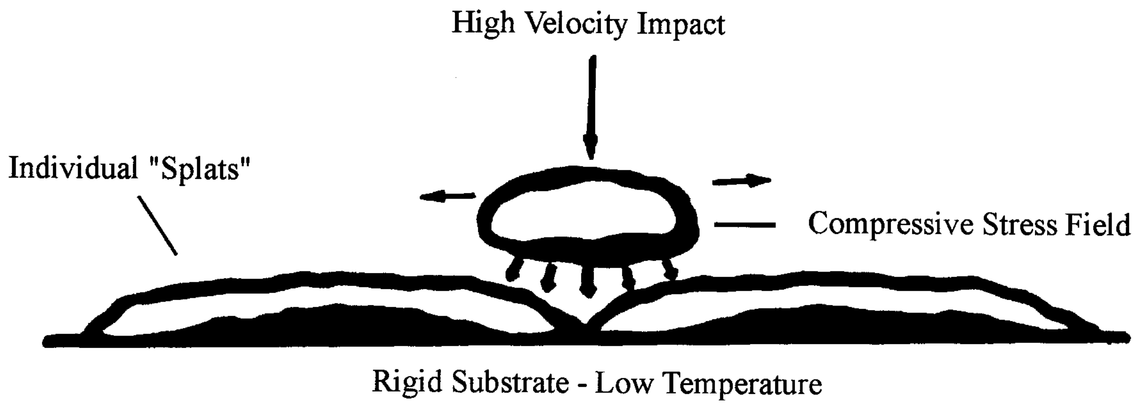

Fig .1 - Magnified View of Deposition Process. Impact Related Residual Stresses – Velocity Dependent. Reproduced of (5).

Researches performed by R. Night and others (2) show that the process thermal energy reduce the compressive tension, thermically induced. This is similar to what happens during annealing.

It must be clear that the high levels of compressive stress can create shear stress in the coating/substrate interface.

According to X. Provot and others (1) the residual stress has a specific distribution according to the depth at which residual stress levels were recorded. (Fig. 2). We can observe that the thicker the coating the higher the stress and tension levels within the coating. We also notice that the stress within the coating is basically a residual stress tension. However, on the interface and on the substrate (near the interface) the residual compressive stress action is clearly observed.

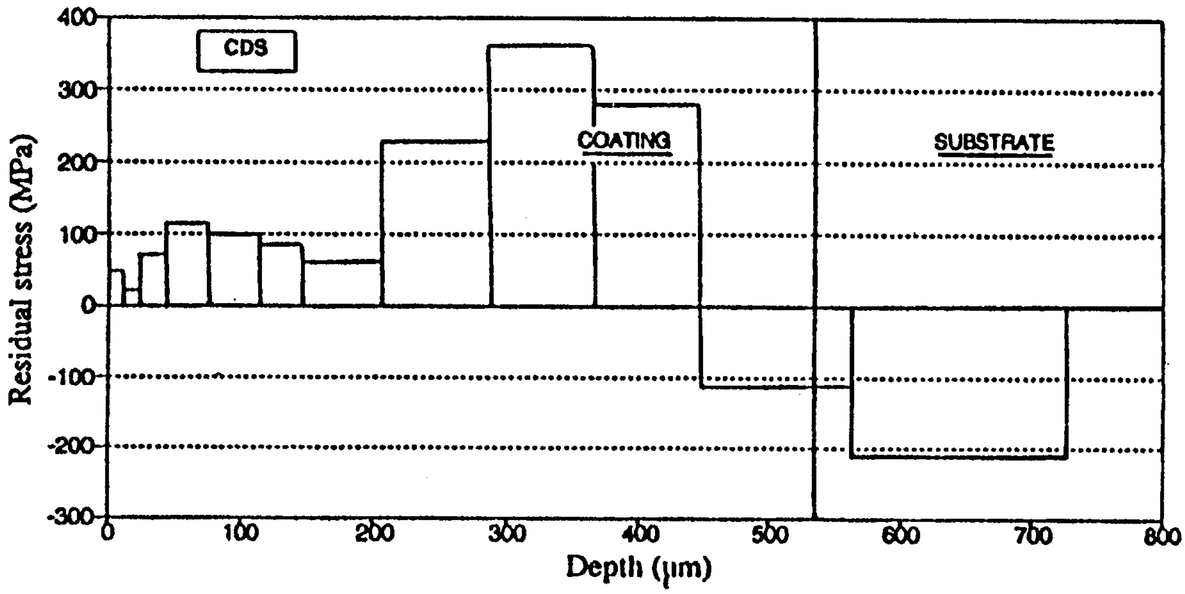

Fig .2 - Residual Stress Distribution for several coating thicknesses for HVOF (CDS). Reproduced of (1).

6. CONCLUSION

The HVOF thermal spraying process offers many advantages when compared to the conventional thermal spraying process.

The following characteristics: reduced porosity levels, high wear resistance, excellent adherence to the substrate and adequate microstructure prove that the hypersonic (HVOF) coating process is the most efficient form of protection against wear, abrasion and corrosion, for industrial parts.

The HVOF process, together with the adequate choice of spraying material and of the substrate, offer the industry an efficient alternative to optimize their operations, specially in their critical areas of the process. Production stop in order to perform machinery maintenance may be reduced or even eliminated if the HVOF process and the available material for the process are properly used.

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