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Modern Proficiency in Thermal Spray Coatings to Enhance Wear Resistance of Material

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Abstract: *Various techniques are employed to protect the material from degradation. As the wear is a surface phenomenon and occurs mostly at outer surfaces. Most industry segments, significant financial losses may be incurred due to accelerated wear of various components. In order to minimize the effects of mechanical wear and extend product life, thermal spray coating solutions introduced into production and is further developing them to meet even more demanding wear applications. Therefore it is more appropriate and economical to use surface engineering for making surface modifications. High-velocity oxy-fuel (HVOF) is one of the thermal spraying techniques known for providing hard, wear resistant and dense micro structured coatings. Applying coatings using thermal spray is an established industrial method for resurfacing metal parts. The process is characterized by simultaneously melting and transporting sprayed materials, usually metal or ceramics, onto parts. Now a day's*
High-velocity oxy-fuel (HVOF) spray coatings are gaining popularity due to exceptional hardness, wear resistance and cost effectiveness. In this paper some studies on Thermal sprayed wear resistant coatings have been reviewed.
Keywords: *Thermal spraying, Wear, HVOF.*

I. Introduction

The different coating technologies now a days are more often applied to the surface covering of intermediate products and industrial goods [1]. The wear resistant coats can be deposited by the physical vapour deposition Technologies (PVD) [2]. This method is especially used for tools coating. The titanium aluminum nitride, chromium carbides coatings are by this technique easily deposited on different substrates. The main limitation of PVD is the size of a vacuum chamber, which restricted the size of coating elements. Therefore the techniques commonly used in the industry conditions are the plasma sprayed methods [3]. Thermal spraying methods are a well-established processes and preferred technique for deposition of corrosion, wear protection, and thermal barrier coatings [4]. Using the High Velocity Oxy-Fuel (HVOF) method the coatings with low porosity, high hardness and microstructure with small or nanograins is possible to obtained. The coatings have very high bond strengths, fine as-sprayed surface finishes and low oxide levels. Coatings from chromium and tungsten carbides are very often used in the industry conditions for protection against the wear and erosion [5]. Opposite to HVOF, plasma sprayed coats showed larger porosity, the existence of more not molten droplets and oxides [6]. Coatings consist of lamellas elongated in the direction parallel to the coating surface. Plasma spraying and HVOF method have been successfully used to produce different kinds of coatings.

As the wear is a surface phenomenon and occurs mostly at outer surfaces. Therefore it is more appropriate and economical to use latter method of making surface modifications i.e. surface engineering. Dimensional changes or roughening due to metal transfer in the absence of loose particle formation, the cracking of brittle noble metal plating's with the resultant exposure of base metal substrates, and even mechanically induced metal flow without measurable transfer or loss, termed burnishing (as can occur with well lubricated ductile metals), may also be considered to be definitions of wear in special cases. Although wear cannot be eliminated completely, yet it can be reduced to some extent by different wear prevention methods, such as: using protective coatings on surface, selecting better wear resistant materials, Lubrication to reduce severity of friction and wear, keeping the actual contact pressure less than allowable contact pressure.

II. Methodology

To reduce the wear problem, wear resistant coatings are deposited on the grey irons. Standard test methods for wear testing with pin-on disc apparatus are employed to study the wear behavior of the uncoated and coated grey irons as well. Thermal spray processes that have been considered to deposit the coatings are enlisted below:

(1) Flame spraying with a powder or wire, (2) Electric arc wire spraying, (3) Plasma spraying, (4) Spray and fuse, (5) High Velocity Oxy-fuel (HVOF) spraying, (6) Detonation Gun.

Among the commercially available thermal spray coating techniques, detonation spray (DS) and high velocity oxy fuel (HVOF) spray are the best choices to get hard, dense and consequently wear resistant coatings are desired.

High Velocity Oxy Fuel Spray Process

The HVOF (High Velocity Oxy-Fuel) Thermal Spray Process is has been developed to produce extremely high spray velocity. Fuel (kerosene, acetylene, propylene and hydrogen) and oxygen are fed into the chamber. Combustion produces a hot high pressure flame which is forced down a nozzle increasing its velocity. Powder is preferably fed axially into the combustion chamber under high pressure or fed through the side of nozzle where the pressure is lower. Due to higher velocity the bond-strength of the coatings are higher. The powder to be sprayed are often not melted but accelerated in a high temperature and high velocity gas stream causing the phase of the sprayed material to change from solid to plastic (semi-molten) form. When these particles strike the prepared substrate, they solidify to form a very dense and low porosity coating.

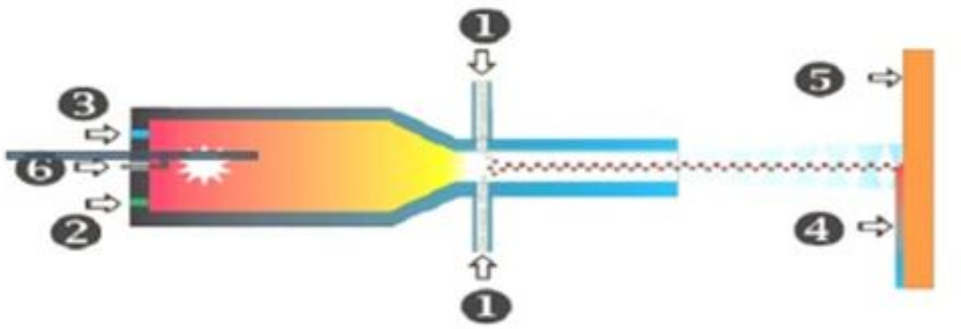
HVOF is best recommended for Carbide matrix coatings. Carbide coatings sprayed by HVOF renders good hardness, wear resistance and abrasion resistance characteristics. HVOF Sprayed Carbide coatings have a perfect alternative for Hard Chrome platings.

Characteristics of HVOF Coatings

Material Form	Powder
Heat Source	Accelerated Oxy-fuel flame
Flame Temp (^{o}C)	> 3000
Gas Velocity (m/sec)	700 to 1200
Porosity (%)	< 1
Coating Adhesion (MPa)	> 70

Advantages :

- Coatings are dense with very low porosity
- Excellent, tenaciously bonded
- Low oxide metallic coatings Optimized microhardness



1. Added Material Powder
2. Kerosene inlet
3. Oxygen inlet
4. Spray
5. Background
6. Sparkling plug.

III. Literature Review

An overview of literature collected on surface engineering is given Below

Lima *et al.* [7] aimed to verify if high-velocity oxy-fuel (HVOF)-Sprayed Al2O3-13 wt.%TiO2 coatings produced using hybrid (nano + submicron) powders could improve even further the already recognized good wear properties of the APS nano structured coatings. According to the abrasion test results (ASTM G 64) there was an improvement in wear performance by a factor of 8 for the HVOF sprayed hybrid coating as compared to the best performing APS conventional coating. When comparing both hybrid and conventional HVOF-sprayed coatings. There was an improvement in wear performance by a factor of 4 when using the hybrid materials The results show a significant anti-wear improvement provided by the hybrid material.

Scanning electron microscopy (SEM) at low/high magnifications showed the distinctive microstructure of the HVOF-sprayed hybrid coating, which helps to explain its excellent wear performance.

Singh *et al.* [8] evaluated that High-velocity oxy-fuel (HVOF) spray ceramic oxide coatings have immense potential in industrial applications. Two such ceramic coating powders, Al2O3 + *(*40%*)*TiO2 and Cr2O3, were deposited by the HVOF spray technique, in order to enhance its wear resistance. The as-sprayed coatings were characterized by XRD and SEM analyses. Subsequently, the sliding wear behaviors of the uncoated, HVOF spray Al2O3 + *(*40%*)* TiO2 and Cr2O3 coated were investigated according to ASTM standard G99-03 on a pin-on disc wear test rig. Cumulative wear rate and coefficient of friction (μ) were calculated for the coated as well as the uncoated specimens for 30, 50, and 70N normal loads at a constant sliding velocity of 1 m/s. Some of the worn-out surfaces were characterized by SEM analysis. Both the as-sprayed coatings exhibited typical splat morphology of a thermal spray process. The XRD analysis indicated the formation of Al2O3 and TiO2 phases for the Al2O3 + *(*40%*)*TiO2 coating, and Cr2O3 phase for the Cr2O3 coating. It has been concluded that HVOF spray Al2O3 + 40%*)*TiO2 and Cr2O3 coatings can be useful in minimizing the wear problem. These coatings were found to be successful in retaining their surface contact with the substrate after the wear tests. The HVOF spray Cr2O3 coating can be recommended as a slightly better choice to reduce the wear in comparison with the Al2O3 + *(*40%*)*TiO2 coating.

Sahraoui *et al.* [9] Hard chrome plating is used to restore the original dimensions to worn surfaces of gas turbine shafts. However , its use is about to decrease due to some intrinsic limitations of its deposits and the toxic and carcinogenic characteristics of the hexavalent chromium.During the last decade high velocity oxy-fuel (HVOF) thermal sprayed cermet coatings play an important role in industrial applications where exceptional friction and wear resistance are required. The purpose of this study is to investigate and to compare the microstructure, wear resistance and potentials of HVOF sprayed Cr3C2–NiCr and WC–Co coatings for a possible replacement of hard chromium plating in gas turbine components repair. It has been shown that coatings exhibit high hardness with a high volume fraction of carbides being preserved during the spraying, and have different wear behaviour.

Yasunari *et al*.[10] Sprayed WC–20 mass%Cr3C2–7 mass% Ni powder onto low carbon steel substrates by a commercial high velocity oxygen-fuel (HVOF) spray process as well as by an improved HVOF process equipped with a gas shroud attachment. The latter process utilizes a nitrogen gas flow to shield the region between the spray gun and the substrate in order to suppress the material's degradation caused by reaction with air such as oxidation and decarburization. Some coatings were further heat-treated in air at 773 K for 30 h to form a thin oxide film on the surface. The sliding wear properties of these coatings against an iron pin were evaluated by using a pin-on-disk wear tester. The specific wear rate of the as-sprayed cermet coatings prepared under the conventional spray condition was about three times higher than that of the chrome plating but by using the gas shroud, the wear rate was reduced to the same level with the chrome plating. The specific wear rate could be further decreased by the oxidation heat-treatment. It was found that a proper amount of oxides existing on the surface or within the coatings have a great beneficial effects *Study on Enhancing the Wear Resistance of Grey Cast Iron* 187 on the wear properties such as to promote the transition from severe wear to mild wear and thus to reduce the wear rate remarkably. XPS analysis of the transfer particles collected from the wear track revealed a shift in the oxidation state of iron depending on the wear condition.

Berghaus *et al* [11]. Micro-laminates and nanocomposites of Al2O3 and ZrO2 can potentially exhibit higher hardness and fracture toughness and lower thermal conductivity than alumina or zirconia alone. The potential of these improvements for abrasion protection and thermal barrier coatings is generating considerable interest in developing techniques for producing these functional coatings with optimized microstructures. Al2O3-ZrO2 composite coatings were deposited by suspension thermal spraying (APS and HVOF) of submicron feedstock powders. The liquid carrier employed in this approach allows for controlled injection of much finer particles than in conventional thermal spraying, leading to unique and novel finescaled microstructures. The suspensions were injected internally using a Mettech Axial III plasma torch and a Sulzer-Metco DJ-2700 HVOF gun. The different spray processes induced a variety of structures ranging from finely segregated ceramic laminates to highly alloyed amorphous composites. Mechanisms leading to these structures are related to the feedstock size and in-flight particle states upon their impact. Mechanical and thermal transport properties of the coatings were compared. Compositionally segregated crystalline coatings, obtained by plasma spraying, showed the highest hardness of up to 1125 VHN3 N, as well as the highest abrasion wear resistance (following ASTM G65). The HVOF coating exhibited the highest erosion wear resistance (following ASTM G75), which was related to the toughening effect of small dispersed zirconia particles in the alumina-zirconia-alloyed matrix. This microstructure also exhibited the lowest thermal diffusivity, which is explained by the amorphous phase content and limited particle bonding, generating local thermal resistances within the structure.

Branco *et al.* [12] The use of PET in Brazil has increased significantly during the last decade and so has the demand for its recycling. The combination of good mechanical properties, thermal and chemical stability as well as impermeability to gases make PET a good choice for surface protection of materials. Therefore, thermal spraying is being investigated as both a route to recycle PET and a means to deliver good material protection against corrosion and wear. This paper reports the results of a pin-on-disc wear study of unlubricated PET, used in three conditions: as molded, as HVOF thermally sprayed and as quenched after thermal spraying. The wear process was monitored by friction force and acoustic emission, light and scanning (electron and mechanica) microscopy.The crystallinity of PET was assessed by XRD. The results are discussed to indicate that the coatings have lower friction and wear rates relative to virgin PET

IV. Conclusion

HVOF sprayed coatings can play important role in protecting materials and alloys from wear and corrosion phenomena. Work has been done by various researchers to investigate the performance of HVOF sprayed coatings. There is no doubt that considerable progress has been made in the HVOF sprayed process by optimizing the process parameters like Fuel Ratio, flow rate, and spray distance over the last few years. More improvement can be done in the design of spraying device. Process parameters of Detonation spraying influence the microstructure, mechanical and other properties of the coatings. Research is needed in optimization of the process parameters of detonation spraying process. However more research is needed to evaluate the performance of HVOF sprayed coatings in actual environment.

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