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Effect of Substrate Preheating, Roughness and Particles Size on Splat Morphology of Thermal Sprayed Coatings

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Abstract: In thermal spraying process, a commercial powder is heated and accelerated simultaneously using a heat source and deposited in a molten or semi-molten condition on a prepared substrate. Coating quality highly depends on some important surface parameters such as the thermo-chemical and physical properties of both powder and substrate, the surface state, the preheated temperature, and the existence of oxidation. In pratice, it is commonly accepted that pre-heating the substrate, prior a thermal spray operation, have a great benefits to increase adhesion. However, this method is not routinely used. In this work, the preheating effect of XC18 steel substrates on the flattening behavior of two commercially available flame-sprayed powders was investigated in a temperature range from ambiant to 500 °C. The conventional flame spray gun was used to accelerate molten particles and Infra-red pyrometer was used to monitor the substrate temperature during a preheating process. Tthe coatings cross section microstructure and elements distribution was performed using SEM with EDS and optical microscope.
With an increasing substrate temperature, the splat morphology changes from a splash type to a disk type. The change of the splash form to disc form is transient. It corresponds to a temperature which is called the transition temperature. This temperature depends on the deposit / substrate pair. Preheating the substrate surface causes its oxidation. In our study, the oxide layer becomes more thick after a preheating temperature of 300 ° C. Beyond this temperature, the oxide layer becomes detrimental to the adhesion of the coating onto its substrate.

1. Introduction

Thermal spraying is one of the means used for the application of various coatings, they are used to protect substrates against corrosion, friction, The wear coatings are constituted by a stack of individual particles more or less melted; optionally comprising oxides, microporosity, inter and intra-lamellar cracks, areas of contact between the slats and with more or less perfect substrate [1]. A lamina is the main building brick in a thermal spray deposition. Successful application of the coatings by thermal spraying technology to use depends strongly on the first coating layer which also depends on the morphology of the lamellae deposited on the substrate. In thermal spraying the particles reach the substrate extending over the surface, spreading lamellae strongly depends on physicochemical states of the particles and the substrate. For the particles depends on their size, their speed and their melt and also their oxidation state. On the other hand the physical states of the substrate also play a key role in the spread of particles, the temperature of the surface cleanliness and oxidation. [2].

V. V. Kudinov et al. shown a qualitative ranking of 30 different morphologies of alumina particles based on their spreading speed and temperature at the time of impact (Figure.1). Molten particle would be spread properly with a low speed (eg case 1) but break out at the time of impact under the action of surface forces at high speed (eg, case 6). A particle with a low temperature would melt partially (case 30). The solid core would remain trapped in the center of the plate or ejected leading

to a ring-shaped strip (case 17) (in all these cases the nature of the substrate is not taken into account). [3].L. Bianchi took into account the parameters of the substrate, a poor interface (gaseous occlusions, roughness, surface oxidation of the substrate) reduce the lamella surface / substrate contact, increase the cooling time and thus promote bursting. The quality of the spreading depends on the cooling rate, which is connected directly to the nature of contact. Areas lamella contact / substrate are heterogeneous. Those good contacts allow quick access from the melting point of cooling, resulting in the formation of germs and the solidification interface in the form of fine, columnar grains, and those poor thermal contacts do not allow rapid evacuation of heat: the grains would be more coarse and oriented towards the central area of good contact lens forming patterns "petals". [4]

2. Experimental Procedure

The substrate was made from carbon steel XC10. The chemical composition of the steel is given in the table. 1. Two commercial powders from Castollin Eutectic were chosen in this study: Lubrotec 19985 and Frixtec 19850. The substrate is heated at different temperatures from ambient to 500 ° C, with a step of 100 ° C.

The individual splats are formed after preheating the sheet substrate form. The preheating is carried out with the same projection and the torch temperature control is performed by the Raytek infrared pyrometer which is directed towards the substrate surface as shown in the figure 2.

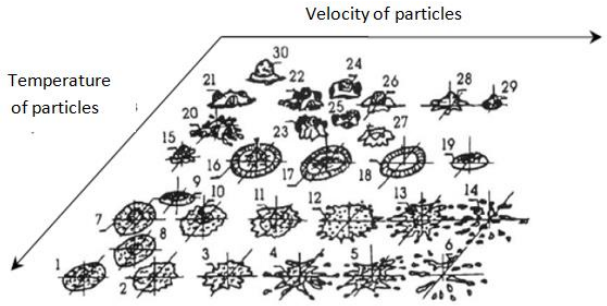

Figure 1. *Morphology of the alumina particles projected by plasma according to temperatures and impact velocities at their impact onto substrate*

3. Results and Discussions

The morphology of the lamellae was examined using optical microscopy, to see the effect of preheating the substrate on the spreading of particles. The following figures (figure 3 and figure 4) show these morphological changes. After screening and examination by optical microscope results are the following:

It is noted that although there are two different morphological forms of lamellae. An exploded form or splashed with fingers under the coverslip. The other form is considered to be a disk, a phenomenon frequently observed on the smooth substrate [5]. The most interesting feature is that there's a morphological change does not occur gradually but transiently at a substrate temperature. The morphology of the sipe changes transiently shape splash or a reduced form of disc [6].

In our case study for the torque Frixtec / substrate is the transition temperature of about 250 ° C. For torque Lubrotec / substrate, the transition tem perature is around 300 ° C. The temperature change of lamellar form is called "transition temperature" [7]. On the other hand, it is also noted from figures 5 and 6, a difference in the morphology of the resulting splats in different preheating temperatures of the substrate. Indeed, the case where the preheating temperature is lower than the transition temperature, the morphology of the lamellae is reduced or completely splashed with ejections (fingers) flowing toward the periphery. This splash is noticed particularly in the case of smooth substrates. Splashing is due to poor spreading of particles on the substrate surface. Then, the flow of the deposited material is decelerated (reduced form), which is the result of rapid cooling (quenching) of each particle during impact the substrate. Also cracks on the blades can be seen, these cracks are generated through the thermal gradient existing between the particles and the substrate, especially for near ambient temperatures. The reduced form or splashing is observed well as on smooth rough substrates, for the roughness of the substrate and limit splashing as the flow of material.

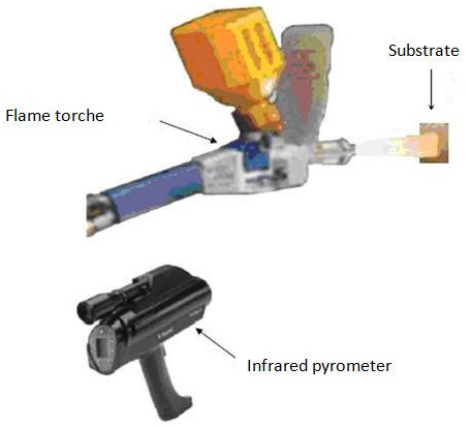

Figure 2. *Experimental Setup.*

Table 1. *Substrate chemical composition*

Elements	%
C	0.06
Si	0.18
Mn	0.35
S	0.0052
P	0.066
Mg	0.011
Ni	0.02
Cr	0.03
Mo	0.017
Cu	0.004
Al	0.032
Pb	0.007

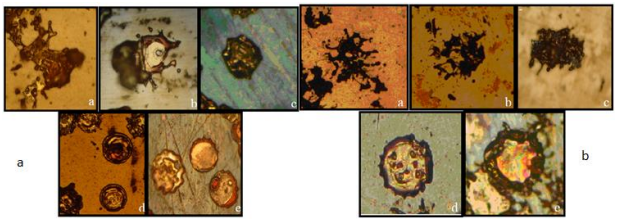

Figure 3. *Splats morphology of Frixtec (a) and Lubrotec (b) sprayed at the different temperatures on smooth substrate XC10*

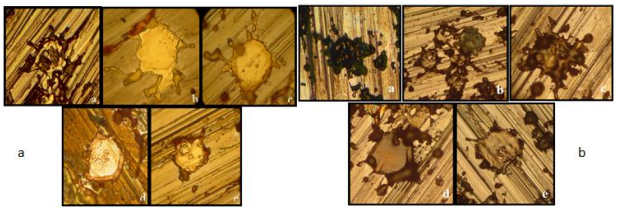

Figure 4. *Splats morphology of Frixtec (a) and Lubrotec (b) powders sprayed at different temperatures on the rough substrate XC10.*

4. Conclusions

In our study the effect of preheating temperature on the spread of the two powders (Frixtec and Lubrotec) deposited by torch flame, we noticed that the lamellar changing the shape from splashed or exploded form to disc form. It corresponds to a temperature which is called transition temperature. This temperature depends on the deposit / substrate couple.

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