OPTIMIZATION OF SOME SPRAYING PARAMETERS UNDER LOW PRESSURE
AND CONTROLLED ATMOSPHERE: APPLICATION TO TUNGSTEN
CARBIDE - COBALT COATINGS

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ABSTRACT

Two plasma spraying parameters under low pressure and controlled atmosphere
were studied in this paper. The study of the particles injector location inside
the nozzle shows that its position has to be between 0 and 10 mm from the nozzle
exit, after the probable internal shock wave, in order to introduce them. A
pictorial distribution of the particles crash is obtained by the flattening test
which allows to realise dense coatings. An example is given of a coating obtained
with a WC + 20 % Co coated powder, in a low pressure plasma spraying chamber
(60 torrs).

1. INTRODUCTION

Low pressure plasma spraying has now a wide development [1, 2, 3], because
like the atmospheric plasma spraying it combines in one operation melting,
quenching and consolidation but it also allows to obtain dense coatings with
fine grain structure for metals or alloys and avoid oxidation for non-oxyde cera-
mics (carbides, nitrides, borides).

However in such plasma jets, obtained with the controlled atmosphere chamber
with pressures round 40 to 80 torrs new problems arise : the plasma is no more
in thermal equilibrium with mean heavy particles temperatures lower than 6000K
and with non continuum effects (the particles diameters being of the same order
of the mean free paths : Knudsen effect [4]). Thus in the long plasma jets obser-
vied in the spraying chamber (up to 60 cm), the heat and momentum transfer
to the particles are greatly reduced. That is why one tries to inject the particles
inside the nozzle of the plasma generator where the heat and momentum transfer
will be much higher near the injection. However the hot gases inside the nozzle
have to expand in the low pressure chamber and this results in the existence
of shock waves (characterized by steep pressure gradients) which position near
the nozzle exit depends on the nozzle dimensions, power level of the arc and
nature and flow rate of the plasma gas. It is then of primary importance to
determine the position of these shock waves to avoid high back pressures
in the particles injector. But even with a well positioned injector it is necessary
to control the melting of the particles before their impact onto the substrate.
This paper is devoted to the study of these two phenomena to achieve a good
control of the spraying parameters of tungsten carbides - cobalt coated particles.
2. STUDY OF THE INJECTOR POSITION INSIDE THE NOZZLE

This experiment consists in measuring simultaneously the pressure in the powder-feeder (P_d) and in the nozzle at the powder injector location (P_t) which is at a distance X from the nozzle exit, for different spraying conditions. The pressure in the chamber is maintained at 40 torrs and the plasma gases are argon and helium, the flow rate of argon being constant and equal to 82 l (STP)/mn. Argon is used also as a carrier gas for the powder and its flow rate is varied 5 up to 17.5 l (STP)/mn. The whole experimental device is described in details elsewhere [5].

The results of this study bring the following remarks:
- the pressure in the powder-feeder remains almost equal to the atmosphere, whatever are the spraying conditions, for the carrier gas flow rates studied;
- when increasing the flow rate of the auxiliary gas (He), but keeping the power level constant, the pressure in the nozzle (P_t) increases (see Figure 1) and becomes higher than the one in the powder-feeder. The helium flow rate value for which we have P_t = P_d (defined as A.G. max in Figure 1) delimits the spray conditions available to introduce the particles in the nozzle and Figure 2 represents the limiting curves (P = f (A.G. max)) for different carrier gas flow rates;
- when changing the position (x) of the particles injector we observe a sudden steep variation in the evolution of the nozzle's pressure as a function of this position (x). This phenomenon (see Figure 3), typical of a shock wave, is observed always for the same powder injector's position (x = 10 mm) whatever is the gun power level.

As a conclusion from these experiments, we can say that the particles will penetrate inside the nozzle, only if the position of the injector is between 0 and 10 mm from the nozzle exit.

3. PARTICLES FLATTENING TEST

The particles flattening test (Figure 4), consist in intercepting the particles in flight into the plasma jet by glass slides traversing rapidly the jet at different distances from the nozzle exit. This method allows a rapid control of particles melting and flattening, by optical microscopy observation without any preparation of the sample.

An example of the pictorial distribution of the particles flattening along the plasma jet is represented in Figures 5, 6 and 7, this test was realised with a chamber pressure of 80 torrs and a power level of 40 kW. For this test we used a W_2C carbide cobalt coated (20 % wt) powder, because W_2C melt without decomposition. The grain size range of the powder is very narrow + 22 - 44 μm. We observe in this pictorial distribution a good particles crash for a spraying distance of 22 cm; the particles, probably overheated are desintegrated for a spraying distance equal to 42 cm and there's no good particles melting for a spraying distance of 7 cm.

4. CONCLUSION

These two simple tests allow a rapid control of the spraying conditions in controlled atmosphere chambers. The optimization of powder injector location has been carried out whatever may be the spraying conditions. The main advantage of the flattening test is its fluency use allowing to define rapidly the spray conditions for a given powder. As an example we can see in Fig. 8 how a dense coating can be obtained using this flattening test with a WC/Co (20 % wt) coated powder (5 - 45 μm) sprayed in controlled atmosphere (60 torrs) with a gun power level.
of 50 kW, the plasma gas being an argon-helium (68/32 in %) mixture and the spraying distance 30 cm.

REFERENCES


Figure 1 - Evolution of the pressure in the powder feeder (Pd) and in the nozzle at the powder injector location (Pt) with the auxiliary gas flow rate (helium)
Figure 1 - Evolution of the pressure in the nozzle (P_x) versus the position of the powder inlet (x), for different values of the gun powder. The plasma gas is 82 l(STP)/min of Ar and 56 l(STP)/min of He. The carrier gas flow rate is 9.5 l(STP)/min.

Figure 2 - Evolution of the maximum value of the auxiliary gas (He) flow rate (A,G_max) allowing the introduction of the powder in the nozzle versus the gun power level (P) for different carrier gas (C,Cr) flow rate.
Figure 4 - Flattening test device

Figure 6 - Cross-section of a coating realized with a WC/Co (80/20) coated powder
Chamber pressure : 60 torrs
Power level : 50 kW
Spray distance : 30 cm
Plasma gas  Ar-He (68/32)