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AN ARC SPRAY POWDER FEEDER FOR ULTRA-FINE PARTICLES WITH A WIDE RANGE OF DENSITIES

by

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AN ARC SPRAY POWDER FEEDER FOR ULTRA-FINE PARTICLES

WITH A WIDE RANGE OF DENSITIES

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Introduction:

The available literature on plasma arc and flame spray coatings makes numerous allusions to the effect that "better" coatings are attainable from fine than from coarse spray materials. No specific data was found to substantiate this, however. Nor was it specifically spelled out exactly what "better" meant. In recent years, a considerable amount of unpublished work has been done in the Ceramics Section of CNB-6, Los Alamos Scientific Laboratories toward obtaining higher density in plasma arc and flame sprayed coatings. This work has included some studies of ordinary spraying variables such as heat, spray distance, feed rates, etc., as well as impregnation and post-spray sintering of coatings. Most of the coating work done in the Ceramics Section was with commercially available spray powders in the U.S. standard sieve range of -200 +325. Norton 38-500 Fused Alumina was successfully plasma-arc sprayed in 1964, but this material seemed to present a lower limit in particle size which could be successfully fed with the available Continental Coatings Corporation powder feeder. Excepting more recent models by this same company, this powder feeder is judged by most investigators to be the best equipment available. The Norton 38-500 Fused Alumina has a particle size range of approximately 2 to 25 microns (Fisher sub-sieve average of 12 microns). Attempts

to feed Norton 38-900 Fused Alumina with ordinary feed gas flow rates met with failure due to erratic, puffy feeding of the material. This material has a particle size range of approximately 1-15 microns (Fisher sub-sieve average of 5 microns). Bliton and Hatveit¹ mention that a barium titanate powder in the particle size range of 0.3 to 5 microns was not sufficiently free flowing to be sprayed with Continental Coatings Corporation equipment. Our own experience has shown that very fine, well dispersed materials may be fed with this equipment, but in order to accomplish this, the gas flow rate must be adjusted prohibitively high. This results in the particles passing through the flame at such high velocity that they do not melt. With this background, it was decided that if the effect of particle size on quality of arc and flame sprayed coatings was to be studied further, a means of effectively feeding finer particles must necessarily be determined. It was decided that the proof of the feeder must be in the qualities of the coatings produced. Efforts would be directed toward designing and building a powder feeder capable of effectively feeding sub-micron particles of a wide range of densities into a plasma arc spray gun. The results of these efforts are the subject of this paper.

Methods, Materials, and Equipment:

The first material chosen to work with was Norton 38-900 Fused Alumina since it had been the material on which our powder feeding equipment had balked. Very early in the program tungsten powder with an average particle size of 0.7 micron from Cleveland Tungsten Company was chosen as the second of the two materials which would be used to evaluate the various designs of powder feeders. These two materials

have a difference in density of approximately 15.4 grams per cc.

A Plasmatron SG-1 spray gun coupled with a Plasmatron Model P-140 Control Panel and Power Supply Unit was used in all tests. Late in the program, a Plasmadyne No. 901 High Velocity Attachment was installed onto the spray gun for preparation of tungsten coatings. Argon was used throughout the program as plasma arc sustaining and powder feed gas.

A number of different powder feeder designs were tried unsuccessfully and their principles of operation will be mentioned only briefly. The first of these employed a pressurized hopper with a porous ceramic bottom. Argon gas forced through the porous ceramic was to fluidize the powders in the hopper. A portion of the gas was allowed to escape from the top of the hopper for fluidizing effect only. A variable size orifice led the powders from the fluidized bed through a tube to the spray gun. Neither the alumina nor the tungsten powders fluidized or dispersed sufficiently to yield a uniform feed. The next design employed a high-velocity jet of feed gas directed downward onto the powders maintained at a constant level inside of a pressurized dust cloud chamber. The spray gun was fed by a tube leading from the dust cloud thus evolved. From first appearances, this method yielded a uniform continuous feed of well dispersed powders. When connected into the spray gun, however, a good coating simply could not be obtained. If the feed gas flow was lowered to a point allowing fusion of the particles of powder, the deposition rate was prohibitively low. If the feed gas flow was raised to increase the number of particles, the heat quenching effect of the additional feed gas and the increased velocity of the particles disallowed their fusion. It was at this

point that it was realized that the powder-to-gas ratio must be maintained at a higher level than was attainable with the mechanical dispersing action of the feed gas alone, if effective feeding was to be accomplished. From our experience with commercial feeding devices, it was remembered that their primary fault was their puffy action; that is the powders either did not flow at all or else they came in spurts which the spray gun was incapable of handling. From this it was reasoned that a normal flow rate of feed gas might be capable of transporting a given mass of powders of greater volume, but that it might be expecting too much to have this same gas also effectively disperse this powder. It seemed that the solution might lie in employing additional means of dispersing the powders without relying on a greater flow of feed gas. Two such methods have been evaluated to date. The first employed a flexible auger which was constructed of piano wire wound on a mandrel. The resulting coil was stretched until its outside diameter was slightly less than the inside diameter of a teflon powder feed tube. The center of the coil was filled with a teflon rod of the proper outside diameter to fit snugly inside the coil. Vacuum couplings with teflon o-rings were positioned opposite one another at the bottom of a pressurizable powder hopper. One served as a gas tight bearing for a rotatable shaft and the other as a seal against the teflon powder feed tube. One end of the auger was attached to the rotatable shaft inside the powder hopper and the other end led to the spray gun. The shaft was driven by a variable speed motor. Feed gas was fed into the top of the pressure-tight hopper, down through the powder, along the rotating auger and into the gun. Large quantities of powder could be transported by means of this device, but the powder

was not well dispersed and mechanical difficulties were regularly encountered in its use. Before the flexible auger was fully evaluated, what seemed a more attractive concept was evolved. The first slide (Figure 1) is a schematic of a rotating brush powder feeder. It consists of a pressurizable hopper with a electro-mechanical vibrator and metering screw, a dust chamber containing a rotatable brush operating against a trip bar, a gas flow meter and valve and a means of rotating the brush at variable speeds. Before I go any further, I will tell you, finally, that this is the one that worked. The method of operation of this device is to place the powder to be fed inside the hopper and adjust the metering screw with the vibrator on to give the desired feed rate into the dust chamber. The position of the feed gas inlet may be changed to a point on the hopper at any desired distance above the metering orifice for powders which will not flow due solely to vibration. A more controllable arrangement is to locate feed gas inlets both in the hopper and in the left end of the dust chamber which may be operated simultaneously or independently. The feed tube to the spray gun was kept as small in diameter and as short as possible.

Results:

With this powder feeder, the Norton 38-900 fused alumina was fed and arc sprayed so easily that we were encouraged to try an even finer alumina for the record. Linde "A" with an average particle size of .3 microns was chosen due to its immediate availability from our stock. Slide two (Figure 2) compares the arc-sprayed coating obtained on grit blasted boiler plate with the Linde alumina fed by the rotating brush powder feeder and that obtained on the same substrate with a conventional commercial -200 +325 mesh flame spray powder fed from a

FIGURE 1
(SLIDE 1)

FIGURE 2
(SLIDE 2)

ARC SPRAYED
.3 MICRON LINDE A
ALUMINA
MAG 500X

ARC SPRAYED
-200 +325 MESH
ALUMINA
MAG 500X

commercial feeder. Both are at a magnification of 500. Both coatings are approximately 3.5 mils thick, and show good metal-to-ceramic bonding. Slide three (Figure 3) shows a continuous coating of arc sprayed Linde alumina only 0.42 mils thick on grit blasted boiler plate. Bonding here is also very good. As might be noted in the slide preceeding this one, there were several voids in the coating produced from the -200 +325 mesh powder of a size sufficient to obviate the possibility of obtaining a continuous coverage of the metal substrate with a coating thickness of as little as 0.42 mils. Samples were prepared for density determinations and post-spray sintering by spraying an approximately 20 mil thick coating onto a 3/8 in. diameter graphite mandrel and subsequently oxidizing the graphite in air at 1000°C. The as-sprayed density of the arc sprayed Linde alumina was determined to be 85.29% of theoretical by weighing samples in mercury and in air, with sample volume determination being made by mercury displacement. Spraying conditions were: plasma gas--90 CFH, power--18 KW, feed gas--6 CFH, brush rotation-- 1725 RPM. The arc-sprayed Linde alumina reached a density of 91.21% of theoretical after being held in an oxidizing atmosphere at 1650°C for two hours. These densities are close to those obtained by David G. Wirth² with Norton 38-500 Fused Alumina, arc sprayed. He obtained an as-sprayed density of 84.03% of theoretical and 92.18% of theoretical with sintering at 1900°C for two hours.

Preliminary results with 0.7 micron tungsten powder obtained from Cleveland Tungsten Company indicated that oxidation of this material during spraying was more of a problem than feeding it to the spray gun. It was felt that going to a larger particle size might do much to relieve the oxidation problem. The substitute chosen was Hydrogen

FIGURE 3
(SLIDE 3)

ARC SPRAYED
.3 MICRON LINDE A
ALUMINA
MAG 500X

XERO
COPY

XERO
COPY

XERO
COPY

XERO
COPY

Reduced XXX brand tungsten metal powder with an average particle size of 5 microns made by Reduction and Refining Company. Slide four (Figure 4) shows, on the left side, a plasma arc sprayed coating on grit blasted boiler plate obtained using rotating-brush-fed 5 micron tungsten. This coating has a thickness of .3 mils. A plasma arc sprayed coating on the same substrate material from -200 +325 tungsten powder fed by a commercial powder feeder is seen on the right. Its thickness is around 3.5 mils. Both of the 5 micron particle tungsten coatings shown in the last two slides were obtained with the aid of argon shielding or cover gas. Spraying conditions were: plasma gas-- 60 CFH, power--11 KW, feed gas--3 CFH, cover gas--50 CFH Ar, rotational speed--1725 RPM. Slide five (Figure 5) shows a .06 mil coating of 5 micron tungsten on grit blasted boiler plate. This illustrates the covering power of very thin coatings of ultrafine powders.

A 50 mil coating of plasma arc sprayed 5 micron tungsten was peeled from a brass substrate for density determination. The as-sprayed density was found to be 84.91% of theoretical. Although some oxidation was apparent on this specimen, this is somewhat better than the 81.55% of theoretical density obtained by Wirth with commercial -325 mesh +7 micron tungsten powder.

Conclusions:

Although the rotating brush powder feeder is still in early stages of testing, we feel that we may safely make some claims for it.

1. It allows effective feeding and arc spraying of ultra-fine particles of widely varying densities, i.e., 3.9 to 19.3 gms per cc.
2. It does not require expensive, closely sized particles nor balk at feed materials with poor flow characteristics. It is expected

FIGURE 4
(SLIDE 4)

ARC SPRAYED
5 MICRON IV POWDER
MAG 500X
- 3 MIL THICK

ARC SPRAYED
-200 + 325 MESH
MAG 500X
3.5 MILS. THICK

FIGURE 5
(SLIDE 5)

ARE SPRAYED
5 MICRON W POWDER
MAG 500X
.06 MIL THICK

that most ceramic grades of powders finer than 200 mesh may be arc sprayed utilizing this feeder.

3. It makes possible arc spraying dense, continuous coatings less than 1 mil in thickness on a variety of substrates.

4. It is expected that smoother as-sprayed coatings will be attainable with the finer powders but no measurements other than visual have been made to support this claim to date.

It should be emphasized that, due to the press of time, virtually no experimentation has been done with ordinary spraying variables to enhance the properties of these fine-particle coatings, i.e., varying arc sustaining gas composition, etc. Further work is contemplated in these areas as time permits.

I have samples of some of the coatings if you desire to inspect them. I shall be glad to give anyone interested the details of construction of the rotating brush powder feeder.

REFERENCES

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²Unpublished work by David G. Wirth at Los Alamos Scientific Laboratories
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