

## Discussion Topics and Threads on Thermal Spray

*Compiled and edited by Dr. R.S. Lima, National Research Council of Canada (NRC). These questions and answers were extracted from the discussion group of the Thermal Spray Society of ASM International. The content has been edited for form and content. Note that the comments have not been reviewed. Any further discussion can be submitted to the Editor of the JTST.*

### Question 1

**Effect of Moisture Content on Powder Flowability.** Are there any studies or papers written on the effect of moisture content on powder flowability or coating properties? Most of us keep the feedstock powders in a dryer before spraying to prevent flowability or coating problems. Is there a percent of moisture that affects flowability or coating properties?

**Answer 1.1:** The exact percentage of moisture that causes flow problems depends on particle shape, density, and size distribution; plus chemical composition and other factors. Feeder-related issues are also important, such as feeder design, feed parameters, and so forth. It is a common practice to dry powders in an oven as an "insurance policy" against moisture, but in many cases this is unnecessary.

**Answer 1.2:** As for coating properties, anything that causes even momentary variations in feed rate could lead to coating inhomogeneity. Thus if the feed rate fluctuates due to powder moisture, you should dry the powder to the point where the feed rate with the equipment and parameters you are using is consistent and the coating microstructure is uniform. A moisture balance could tell you what the moisture content of the powder is at that point.

**Answer 1.3:** The amount of moisture that will affect powder flowability depends on many factors including powder size, composition, distribution, morphology, and so forth. I doubt that moisture in the powder will directly affect coating properties, as it will be vaporized. However, it should be noted that moisture will affect powder flow and in particular the flow uniformity. Interruptions in flow or heavy "gulps/hiccups" will adversely affect the coating's properties.

**Answer 1.4:** There is a publication dealing with the effect of moisture content on powder flow entitled, "Effects of Humid-

ity on the Flow Characteristics of PS304 Plasma Spray Feedstock Powder Blend" (NASA TM-2002-211549, May 2002), which is available on the web at: <http://www.grc.nasa.gov/WWW/Oilfree/publications.htm>.

### Question 2

**Effect of Moisture Content on Compressed Air.** I would like to know the effects of moisture content in compressed air that could affect the coating quality or the operation of the spraying equipment, like the powder feeding. Has anybody ever investigated the problem?

**Answer 2.1:** Air quality certainly matters in wire arc spray, and similarly in HVOF. Impurities from oil (from the compressor) may dissociate and result in inclusions in the coating microstructure.

**Answer 2.2:** The presence of moisture in the air supplied for arc/flame spray is likely to lower temperature of the atomizing gas/air, thus leading to lower particle temperatures. This will result in poor-quality coatings and lower deposition efficiency.

**Answer 2.3:** As moisture levels raise, equally so do the chances of the coating failure. Any shop using air for cooling or atomizing must have high-quality air dryers to prevent water droplets from causing adhesion/cohesion defects. Oil is worse because it does not have the chance to evaporate like moisture, prior to the next layer being applied. It definitely will become trapped under/inside the coating layers, increasing the chances of coating failure. Moisture entrapped on the powder is another problem. Most shops will keep opened bottles of powder in oven or cabinet heated to a low temperature. The temperature is just high enough (110 to 150 °F, or 40 to 65 °C, and some may go higher) to drive out moisture from the absorbent powder by keeping moisture in its vapor state and above the dew point. Heated moisture will rise to the top and be driven out and not return. That is why wet powders are laid out on a large flat pan (clean) and heated to around 220 °F (105 °C) for an hour or two when needed for spraying and found to be wet. The powders are recollected, tumbled and a sample is sprayed and checked for quality verification prior to running a job. Many shops will even heat the hoppers to prevent the moisture from collecting within the powder. Some also choose not to use

air for transfer of powder as well to prevent the moisture from causing problems and reduction of oxides within the coating.

**Answer 2.4:** In the spray process, the moisture is burned off. In air powder feed systems any moisture can hinder or even stop the powder from feeding. This is the reason why many people put a dryer in the line between the compressor and the air reservoir or powder feeder.

### Question 3

**Plasma Ar-N<sub>2</sub>-H<sub>2</sub>.** I would like to test a plasma spray system using three gases (Ar, N<sub>2</sub>, and H<sub>2</sub>). There are three flowmeters on the unit, one for the primary gas and two secondary gas flow meters, which are tied into one circuit. Has anyone tried using 95/5 Ar/H<sub>2</sub> premixed gases? Normally they are used in welding applications as a plasma gas. What problems or concerns with the console or plasma gun should I be aware of when trying this mixture?

**Answer 3.1:** That combination of gases should run okay. I would make sure of doing a thorough leak check to avoid leaks and buildups of hydrogen anywhere in the system. Since the two secondary flowmeters are connected, you might want to install backflow-prevention valves to keep the two gases apart. With the presence of both N<sub>2</sub> and H<sub>2</sub>, you may have the formation of more NO<sub>x</sub> than usual for APS and maybe even some NH<sub>3</sub> formation. The use of two diatomic gases should also increase the enthalpy of the plasma jet, so increased erosion of the anode may be a possibility.

### Question 4

**Applying Chrome Oxide Coating on Electroless Nickel.** We are currently involved in applying chrome oxide onto a ring that has been plated with electroless Ni. The drawing specifies that we coat the surface with chrome oxide after Ni plating. While the entire ring has been plated, we are only applying the chrome oxide to a 1 in. strip of the outside diameter. It is intended that the electroless Ni remain underneath the chrome oxide. Has anyone done this in the past? Or should the electroless Ni be entirely removed by grit blasting? Our current procedure is:

1. Blast with 60 grit aluminum oxide at approximately 50 psi.

2. Apply 2 mils bond coat of arc sprayed nickel aluminum.
3. Powder combustion spray with chrome oxide 0.005 in. (0.125 mm) finished thickness, subsequently to be ground.

One of my concerns is that at times the Ni plating blisters off during grit blasting while most of the time it remains intact.

**Answer 4.1:** We did something similar years ago and found that by going to a 220 grit we could keep the plating intact; however, you do lose some mechanical bonding properties. The thickness of the Ni plating may also have an impact on its ability to remain bonded.

**Answer 4.2:** We have come across this type of application several times in the past. Initially, we approached the issue the same as you. We have since found it reasonable to apply the coating onto the Ni plating, but we look for the part to be grit blasted prior to flash plating and a maximum of 0.001 in. (0.025 mm) of plating (typically 0.0005 in., or 0.125 mm). We would probably use the bond coat also.

**Answer 4.3:** I do not have experience with blasting the plating and coating over it, but I have to say I do not agree with this approach. The bond has to be damaged even if the plating appears to remain intact, so complete removal under the area to be coated is the way I would want it done (if the above is not possible).

#### Question 5

**Surface Preparation of Composite Materials.** Is there any consensus now on how best to prepare the surfaces of composite materials (e.g., reinforced thermoplastic polymers, reinforced thermoset polymers, C-C) for thermal spray coating? This could include roughening treatments, application of interlayers, etc.

**Answer 5.1:** My experience with composites has found that surface preparation is very specific to the type of composite material and application. The variety of material surface types makes preparation unique to each, taking into account substrate thickness, hardness, temperature limits, coating thickness, finish requirements, and so forth. Grit blast has worked for me on many types of composites, but the process is more sensitive to grit type, size, and especially air pressure.

**Answer 5.2:** Generally, given the basic idea in designing a composite, we mostly find that composites are of either the

weak-matrix/strong-reinforcement type, or the strong-matrix/weak-reinforcement type. This may be the main factor dictating the surface preparation; that is, it has to be such that it does not become too aggressive or not aggressive enough. The preparation to be used may be further complicated by the fact that many composites contain an architecture and are highly anisotropic; therefore, be careful in choosing which plane to coat if having a choice. Specifically to C-C, the problem is that however perfect your grit blast may be, the profiled surface is always covered by a layer of C film—a film derived from both the matrix amorphous C and the reinforcement highly crystalline C having excellent frictional properties. This persistent surface C film poses some problem to adhesion of thermal spray coating on the composite. Further, C does not wet with most of the coatings in the temperature range that thermal spray powders experience. If allowed, a melt infiltration of the surfaces of the C/C to form a C/SiC (or C/C-SiC) surface case should solve this problem—coating on SiC is easier than on C.

#### Question 6

**Coating for Molten Zinc.** I want a recommendation for a suitable thermal spray coating on molten zinc (Zn) bath inner walls, service temperature is 500 °C—continuous. The coating should resist corrosion by molten Zn, erosion by Zn dross, and should have good thermal conductivity also as pot is being heated from outside. We have an arc spray and an HVOF system.

**Answer 6.1:** HVOF sprayed WC-Co coatings have been previously used for molten Zn pots. Recently WC-6Co-4Cr coatings have been found to be more resistant to corrosion by molten Zn and I believe the current trend is to spray WC-6Co-4Cr for this application.

#### Question 7

I need advice on a brake friction application. The application method would be arc spray. The brake drum is 42 in. (1050 mm) diameter with a 4.5 in. (112.5 mm) wide brake friction surface. The brake friction works over the outside diameter of the drum. It is worn approximately 4 to 5 mm per side. It is used intermittently, but when it is used it is subject to sudden temperature increases of up to 700° at surface. The original surface was cast iron (Fe). Has anybody had experience on a similar application?

**Answer 7.1:** Rough machine your drum inside diameter so that it is practically threaded. Machine it without coolant. Apply arc wire nickel aluminide, and it will take the 700° temperature. Do not try to restore drum dimensions, just apply enough coating so that there is enough to machine.

#### Question 8

**Arc Sprayed Titanium.** Has anyone in the group ever seen a green discoloration when using an arc sprayed coating consisting of nickel aluminum bond coat with titanium over the top in a sodium solution? Is the sodium solution somehow reacting with the nickel aluminum?

**Answer 8.1:** If you arc sprayed titanium, you may have got titanium nitride and oxynitride formed. I recall, in water, titanium oxynitrides and sodium chloride form hydrated salts, some of them of green color.

**Answer 8.2:** A few days ago I read some information about arc sprayed titanium. My question is if it is possible to air spray titanium using compressed air, or do we need some special gas to spray it.

**Answer 8.3:** Titanium can be sprayed with compressed air; the coating has a golden look, obviously lots of oxides, but it is a solid coating.

**Answer 8.4:** The yellow is indeed nitrides. A bluish-yellow is a mixture of nitrides and oxides. This material generally has to be sprayed in an inert chamber with argon. A shroud will help marginally.

#### Question 9

**Plasma Spraying Copper on Polymers.** Due to constraints, we are trying to plasma spray (Ar + He) Cu onto a polymer substrate, but have not been successful. We are using a metal bond coat that forms a nice coating on the polymer before depositing copper (Cu). When we set the standoff distance to avoid damaging the polymer, the Cu does not adhere, appearing as if it is too cold. Efforts to increase the plume temperature and change powder feed geometry have not helped. Has anyone out there tried to do something like this?

**Answer 9.1:** Try using hydrogen gas to increase the voltage (heat) and the diatomic reaction of hydrogen (extra heat). Caution: use full safety precautions with hydrogen, that is, “zero” leaks in the system. A flammable gas detector is highly recommended. Make sure your water

flow is up around 10 gpm to keep the anode and cathode from overheating.

**Answer 9.2:** For plasma spray depositions on very thin substrates or low-temperature materials, we have used what we call “spray quench” to prevent the part and/or part surface from overheating. The objective is to remove heat and prevent part distortion (warping) or surface damage. “Spray quench” is whereby argon jets are used immediately before the in-flight particles impact the substrate surface. The process increases porosity levels and percentage of nonmolten particles in the coating.

**Answer 9.3:** Spray the Cu powder with argon alone; do not use a secondary, especially helium as it will produce an accelerated plasma stream.

#### **Question 10**

**Decreasing Porosity Levels in Thermal Spray Coatings.** In general, it is very difficult to decrease the porosity of plasma sprayed ceramic coatings through opti-

mizing spray parameters. If I want to get a  $\text{Cr}_2\text{O}_3$  coating with porosity less than 1%, what must I do? Remelting? Which method do I adopt?

**Answer 10.1:** Normally, a combination of higher-energy (hotter) plasma parameters, a shorter spray distance, and smaller powder particle size will provide a ceramic coating with reduced porosity.

**Answer 10.2:** If your equipment supports it, using nitrogen as a primary gas will tend to help.

**Answer 10.3:** Are you sure you do not want to use rods and flame spray to achieve very low porosity? It has been very well done before with  $\text{Cr}_2\text{O}_3$ .

**Answer 10.4:** Use very fine powders. Depending on your equipment, you should be able to use powders of  $-15/+5\ \mu\text{m}$ . The deposition rates will be low.

**Answer 10.5:** Very low porosity in chromium oxide coatings can be achieved with plasma spray on a consistent basis. In fact our coating quality criteria for

$\text{Cr}_2\text{O}_3$  is a guaranteed porosity of less than 1%. Most often we are under 0.7%.

Some important factors to consider are:

- Powder injection point and angle of the material (we prefer internal injection systems),
- Consistent powder feed,
- Consistent parameter control by use of closed-loop computerized plasma controllers, and
- Powder morphology, cut and production method.

We once thought that by using a smaller powder cut, we could reduce porosity in this coating. Although true to some degree, once we got below a  $15\ \mu\text{m}$  cut our numbers actually increased. Also we have DEs of 45 to 50% in our 40 kW system and up to 65% in our 80 kW system. It takes time to develop the  $\text{Cr}_2\text{O}_3$  coatings with these low porosity numbers, but it can and is being done on a regular basis. Lots of metallurgical work involved.