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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. To sign up for the discussion group visit www.asminternational.org. Go to Affiliate Societies, Thermal Spray Society, *and choose* Technical Resources *for subscribing information. Sign up for e-mail discussion list or simply send e-mail to join-tss@maillists.com.*

Question 1

Anticorrosion Ceramic Coating. We are looking for the following thermal spray material that has following characteristics:

- Same as glass or enamel
- Aim: anticorrosion
- Some companies are using the above materials mainly for anticorrosion pipeline for oil industries, etc. However, we need the above materials for many other anticorrosion projects.

Answer 1.1: Several years ago I sprayed a borosilicate glass porcelain frit using oxyacetylene flame spray on steel substrates. After the coating deposition, we fused the porcelain coating with the flame spray torch, like a sort of self-fluxing alloy. The coating only exhibited closed pores, i.e., no through porosity. As an alternative I would like to say that HVOF sprayed ceramic coatings may be an alternative. I have sprayed nanostructured and conventional TiO_2 powders via HVOF (DJ2700-hybrid). The porosity levels of the coatings are less than 1%.

Question 2

Anticorrosion Coating on Stainless Steel. I am in need of a recommendation for a nonskid traction for stairs used in a food processing plant. I tried 316 stainless steel coatings using arc spray, and they turned brown right away. I need a corrosion-resistant material to be sprayed onto stainless steel.

Answer 2.1: Why not stick with Ni/20Cr? It should work well against the stainless steel tread.

Answer 2.2: We have tried this application with 13% Cr arc spray coating of about 1.5 mm finished thickness to fairly good results; however, I will recommend spray fused coating of NiBSi alloy having hardness of 45 to 50 HRC.

Question 3

Problems in the Powder Feeder. This query may be specifically a cold spray problem, as the 1264HP powder feeder is the high-pressure model, but others may have come across it. When I complete a spray run and turn off all the gas lines, the remnant pressure in the powder feeder passes out through the nozzle. The problem is it also causes powder to pour out of the nozzle in huge quantities. The only way the powder should get through is when the rotating disk is moving. Have I got a major sealing problem or is there something obvious that I am missing here?

Answer 3.1: I am using the same model (high-pressure 1264) for a thermal spray system and had a similar problem. Although the motor was switched off, large amount of powder would still come through. The only solution I could find was to substantially reduce the amount of powder inside the canister. You can check it by making a small experiment. Remove the tubing from the outlet of the feeder (situated at the bottom of the feeder). Put gas through without switching on the motor. If powder is coming through then you probably have too much powder in. Theoretically one could fill the whole canister, but for some reason it does not seem to like it. If this is not the case check your tubing. Powder gets trapped in corners and connector fittings and long lengths of tubing do not help either.

Answer 3.2: The simple solution would be to add a valve between the feeder and the torch. Turn the valve off prior to shutting down the torch and do not open the valve until the torch is at full operation. The valve should be located as close to the torch as possible to prevent gases from the process to back feed into you powder line. Also it is critical not to have a leak in the valve or in the powder feed line, as powder will migrate into the line even when the wheel is not in motion, similar to your current method. Another alternative is to add a by-pass circuit to the powder feed line. This would allow clean carrier gas to by-pass the feed hopper using a pinch valve to close off the line to the torch when the feed wheel has been stopped. When you want powder feed, the pinch valve opens and the by-passed circuit is closed off with a similar pinch valve.

Answer 3.3: You have residual amounts of powder in the line. It is normal and will continue to flow to the powder port until the line clears or until carrier gas is turned off.

Answer 3.4: Release gas pressure from the canister after the gun is stopped.

Answer 3.5: There is far more powder coming out than the feed line and connections would hold. The seals have recently been replaced, but the powder is very fine (5 to 30 μm) so it may be escaping through the seals. Keeping the feeder low is a bit of a pain, because of the 20 high-tensile bolts that need undoing and tightening for each fill. However, this may be the only answer. I very much like the idea of putting a valve in the line between the feeder and the gun, but I have been struggling to find a supplier of a high-pressure (+30 bar) valves that will accommodate powder in the line (such as a ¼ in. pinch valve).

Answer 3.6: We have experienced similar problems with 1264 powder feeder while operating the cold spray system. Have you checked the felt ring kit in the powder feeder? If it is worn down the powder will accumulate below the powder wheel disk and then flow out through the nozzle as the pressure in the canister is released. The powder flow problem is more serious when using highly flowable powders. It is difficult to avoid a small amount of powder from flowing out, but installing a new felt ring kit can minimize this. What powder wheel are you using? If it is a slotted wheel then there will be more residual powder in the area after the powder wheel as slotted wheel is a high-volume wheel. Try using either a 120 hole or 240 hole powder wheel.

Answer 3.7: Maybe you could install a three-way valve under the pressure relief valve at the top of the hopper. This would allow you to vent the hopper at the end of the spray.

Question 4

Fly-Ash Corrosion. I have a customer that incinerates hazardous waste and has a few components that "wear out" rapidly. After the waste is incinerated the hot gases (~2200 °F) flow through a "duct," where they carry fly ash that (in time) accumulates on the duct walls to the point where it eventually creates a "hot spot" that damage the duct. I guess what we are looking for is a slick surface at that temperature.

Answer 4.1: Basically, the best composition we are looking for perhaps is primarily a high-chromium- and secondly a high-aluminum-containing alloy. A start would be a simple binary Ni-Cr with at least 20 wt.% of the alloying element, then a tertiary Ni-Cr-Al, or a higher-order Ni-Cr-Al-X one when X could well be Mo, W, or Y, etc., having the additional role of strengthening of the alloy. In powder or wire form, such compositions are readily available.

Answer 4.2: It is a typical case of fly-ash corrosion. General approach is creating corrosion-resistant layer. You did not mentioned what the waste was. However, I assume a bit of chlorine is there. So, no aluminum-containing materials (such as MCrAlY). It must be Ni-Cr-Mo-type (alloy 625 is the first candidate). The Cr_3C_2-NiCrMo has a good chance, but powder availability would be a problem. HVOF is better. If you feel there are molten salts present beneath the ash deposit, you may spray thin ceramic layer over alloy 625 (zirconia works fine). Silicone is ideal sealant.

Question 5

Anticorrosion Coatings in SO_2 and NO_x Environments. What kind of arc spray coating would be ideal for internal coating of an exhaust stack? The temperature is between 100 and 200 °C. SO_2 and NO_x are both present in the environment. A temperature of 140 °C is maintained constantly; however, when that does not happen and the temperature drops, the moisture mixes with the gases forming diluted H_2SO_4 and HNO_3. What kind of an arc spray coating would be ideal, and is a sealant required and what is the kind of sealant that is recommended? What is the life that can be expected of the coating? Would stainless steel 316 be ideal for such an environment?

Answer 5.1: Hastelloy C-276, or alloy 625, or stainless steel 316 (if you are sure that chlorine is low), 8 to 12 mils. Sealant: FEP (fluorinated ethylene-propylene), or silicone, or siloxane (better, organic borne).

Question 6

Constant Feeding in the Powder Feeder. Currently I am working with a Metco 4MP powder feed system that is used with a Metco MBN plasma gun. The powder feeder has a feed rate meter, but the powder seems to fluctuate although the meter reads the same. I have checked the pressure and tube diameters, and so far it all checks out. I have tried to spray into a bag and weigh the bag, but I have a problem containing the material. Is there a procedure out there that I can use to verify my feed rate to my meter, and how often is this recommended? Also, are the newer spray feeders that are more accurate? What are the drawbacks between the mechanical and the fluidized bed? We are a research group and do not spray large volumes of powder at once. Our feed rates are from 3 to 50 g/min, and we are using a 40 to 60 μm diam particle size of powders.

Answer 6.1: To check the feed rate using the "catch method," you can check the feed rate with the powder port attached and let it feed into a bottle filled with a little water (if you do not need to reuse the powder). The water should catch all the dust. If you need to reuse the powder, feeding it into a powder bottle through a mesh-type air filter should capture enough material. If you are running up to 50 g/min, you can also try weighing the powder before it is put into the hopper, then draining the hopper after your feed rate check and weighing it again. Also, you can spray a deposit efficiency plate or standard part (which has been weighed) for the normal time to see if your actual deposit weight has changed. Pulsing in the plasma stream does not always mean that the actual feed rate is changing.

Answer 6.2: I have both volumetric and fluidized bed powders feeders in the shop. All of the feeders have closed-loop feedback, but we routinely measure the powder feed rate by capturing powders, such as partially stabilized zirconia (or any spray powder), by feeding the powder for a set amount of time into a clean, dry, used powder container with an opening sufficient to fit a powder port. Usually the feed rate monitor and the physical measurement of the fed powder are in good agreement, i.e., experimental error. Regarding the feed rates you mentioned, both types of powder feeders are going to experience difficulty feeding powders at rates of less than 10 g/min. Commercial feeders are geared toward production spray rates.

Answer 6.3: There may be some more reasons for pulsations in your powder flow:

- Maybe your old powder feeder system has an internal carrier gas leak. You have to measure carefully the gas amount on the output and compare with the input.
- Sometimes problems with changes of the pressure relationship between entrance and output of the carrier gas occur.
- Some powders have bad flow characteristics. There are methods to increase the flowability of your powders.
- Very small feed rate (down to 3 g/min). I do not really know your Metco 4MP system, but I could imagine that your powder feeder is in general not constructed to work with such small feed rates.

In my opinion the mechanical powder feeding is still the choice for thermal spray applications.

Answer 6.4: I would try using three empty powder containers each with two holes punched in each lid. One hole to insert the tube or powder port, the other hole to allow the carrier gas to escape. Ultimately, in an R&D environment you would want to perform this check with every new batch or lot number of powder in order to verify consistency of the feeder settings and can also help in determining the condition of the feeder hardware. Flowability, variances in size range distribution from batch to batch, material density from one material to another, moisture, temperature, volume of material in the hopper, etc. all can greatly influence how the powder will flow and therefore will require subtle adjustments of the feeder settings in order to maintain the desired accuracy from one experiment to the next. Once you get down to the real low feed rates such as below 15 g/min, I would have to lean more in the direction of a mechanical/volumetric type feeder.

Question 7

Masking Tapes for HVOF Spraying. Could anybody help with an HVOF thermal spray tape resistant to WC particles sprayed with a JP5000 gun?

Answer 7.1: Depending on the geometry of your part you may try stainless steel sheets as masking devices. These sheets have thicknesses around 150 μm, and they work pretty well with HVOF torches, including WC-Co spraying using the JP5000. You can also use these sheets during grit blasting to protect the parts.

Answer 7.2: If what you are spraying is a relatively simple component, i.e., shafts etc., try shadow masking; we tend to use ¼ in. plate × 3 to 4 in. wide and clamp it in front of the job (not to the job) in the area you do not want coating.

Answer 7.3: We use sheet metal shading for continuous masking and Teflon for grooves or keyways.

Question 8

Coatings to Resist Copper and Zinc Wires. I have an application where a drawing block is used to manufacture copper and bronze wires. Does anyone out there have experience with a coating that will stand up to soft wire being pulled by this drawing block without cracking or peeling off?

Answer 8.1: Chrome oxide, WC-Co, or clad WC based coating. The former two (sealed) are widely used.

Answer 8.2: Much of the coating selection depends on the diameter of the wire being drawn, customer history, and your shops capabilities. Some guidelines that I can offer are:

- Very fine diameter wires of soft materials normally work well with a chrome carbide ceramic coating.
- Larger diameter wires will often work best with a carbide material.

However, over the years people have used molybdenum flame spray, WC, CrC-NiCr, Cr_2O_3, high carbon wire, and Metcolloy 2 with success. A ceramic coating will work better on this application due to low coefficient of friction and good sliding properties that will prevent soft wires from tearing or getting damaged. We have got fairly good success in this application with ceramic coating (chrome oxide) on drawing rings used for copper wire drawing. The success of this application will depend on how best you can finish the coating and also finishing of the end radius is very important. We have done this with flame sprayed chrome oxide, but plasma sprayed ceramic will work far better.

Question 9

Increasing the Plasma Enthalpy by the Addition of H_2. I am studying the deposition of VPS tungsten coatings for potential plasma facing component purposes. I am heading into a presentation in a few days time and have just realized that while I am aware that increasing the flow of a secondary gas, such as hydrogen, increases the "flames" enthalpy, I do not know why this is the case.

Answer 9.1: When a diatomic species such as N_2 or H_2 is added to an Ar plasma, the plasma jet gains enthalpy by virtue of the additional energy of dissociation required to ionize the hydrogen. There are also added benefits in terms of heat transfer by virtue of the higher thermal conductivity when species such as H_2 and He are added. Changing the composition of the plasma gas typically increases the voltage, and consequently the power does not remain constant. To keep a constant power it would be necessary to reduce the current to compensate for the higher voltage drop.

Answer 9.2: Hydrogen is a diatomic molecule and for forming a plasma it has to first dissociate from H_2 molecule into two hydrogen atoms, and then each hydrogen atom ionizes to hydrogen ion and electron. Since energy is required to dissociate, we need to "do work on it," which increases the gas enthalpy of any diatomic gas plasma (N_2, H_2, etc.), compared with monatomic gas (say Argon) plasma at the same temperature. When the atoms recombine, they release the dissociation energy, which can be transferred to the powder particle. One more advantage of using hydrogen is that it has higher thermal conductivity than Ar plasma. This higher conductivity not only increases the heat transfer to particles, but also to the nozzle walls. That is the reason why the hydrogen flow rate is limited to below 10 to 20% in plasma spray gun. If you want to read more about it, refer to *Plasma Technology* by Gross et al., Life Books, London, 1969.

Question 10

Drilling a Hole through WC-Co. We are intending to drill a 3 mm (0.118 in.) diam hole at 50° (i.e., not perpendicular to the coating) on a WC-Co coating sprayed over a component. Is it possible?

Answer 10.1: Try removing the coating using a diamond bit in an air grinder (carefully) then drilling.

Answer 10.2: You might consider waterjet drilling.

Answer 10.3: An existing hole can be plugged with a glass pin, before being coated with WC-Co. Then the glass pin can be grit blasted/shot peened to remove the glass. If a finish machining/grinding operation is going to be used, the mechanical action of the grinding wheel may be enough to fracture and remove the glass from the hole. Vibratory finishing will also remove small glass pins.

Question 11

Difference between Clad and Blend Powder. Does anyone know what the difference is between clad powder and blend powder?

Answer 11.1: Clad means two or more phases combined with one phase surrounding/encapsulating the other(s), like the skin on an onion. Blended is just a simple physical mixture of two or more different powders. Blends tend to segregate in powder feeders and spray jets, due to different densities and/or particle sizes, leading to inhomogeneities in the deposits. On the other hand, blending being a very simple manufacturing method, careful choosing of individual components coupled with proper processing can produce quite serviceable coatings in the commercial world. Cladding takes several forms—from a simple gluing of particles of one material onto another material to chemical plating processes. While cladding will normally result in more homogeneous coatings than blending, cladding is hardly a guarantee of homogeneous deposits.

Answer 11.2: Powder quality is very important for the coating process. In general, blends may result in lower quality, inhomogeneous deposits. There are many more powder manufacturing techniques than blending and cladding. "Gluing" is not cladding. Binders are used to "glue" together very small particles of already composite, very fine material to make a final product with particle size usable for TS processes. Cladding means covering each particle of one material with a layer or layers of different materials. Of course there are also the fused and crushed materials as well. Bottom line is, if you have a choice avoid using blended powders.

Answer 11.3: A clad powder is a composite where one component encases the second. Similar to chocolate-coated raisins. A blend is a mixture of two or more components like mixing salt and pepper. The components can be easily identified. Clad powders provide a uniform distribution of the components throughout the coating. Blends may show segregation or "islands" or both or either component.

Question 12

Power Feeder for Very Low Feed Rates. Can anyone recommend a small powder feed unit, preferably screw drive, that would handle small amounts of sample powders—of the order of 1 g or less per minute?

Answer 12.1: It is not a matter of being able to feed powder in the 1 to 5 g/min. range. The real issue is feeding consistently. The problem is short-term variations in the feed rate that are not normally picked up or measurable by those who are doing the testing and sampling. Variations of >10% are common at these lower feed rates. Issues are time constants, static electricity, backpressure variations, and a dozen other factors. There appears to be a "noise" level that is constant in the feeders. At higher feed rates it is insignificant, but at the lower feed rates it dominates the "signal." Under most conditions, a variation of ±0.5 g/min is tolerable at a feed rate of 15 g/min. However, at a feed rate of 1 g/min even ±0.1 g/min is intolerable. I am looking for a feeder that can deliver 5.5 g/min, ±0.3 g/min (±5%). So far absolutely no success.