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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

Evaluating Porosity via Image Analysis. I am evaluating porosity by freeware image analysis software on coating cross-sections. Is there a standard micrograph magnification, analysis area, threshold, etc. used by the industry for porosity of coatings, or for each material? Are these accessible somewhere? Alternatively, are there reference micrographs available?

Answer 1.1: There is a specific ASTM standard for measuring the porosity of thermal spray coatings by using metallographic specimens, i.e., coating cross sections. The standard is: ASTM E 2109-01, “Test Methods for Determining Area Percentage Porosity in Thermal Spray Coatings.” This standard covers procedures to perform porosity measurements using cross sections of thermal spray coatings by direct comparison to standard images or via the use of automatic image analysis equipment.

Question 2

Crevice Corrosion. I have plasma coated some aluminum alloy rolls with a bond coat of Ni20Cr (~25 μm) and a top coat of alumina-titania or chromium oxide (100-110 μm). After 10 days of operation, I found pitting on coated surface. I was told that after plasma spraying the coating surface was sealed with polyurethane. The rolls are used in textile mills, and they are located in a very humid environment. How do I overcome this problem? Should some treatment be made on plasma coated surface before sealing, or should the sealant be changed?

Answer 2.1: I would say it is unlikely that the ceramic layer itself is attacked since the environment you described is not that corrosive. It is more likely that the aluminum alloy substrate is being attacked. I am not familiar with the polyurethane sealer you use, and you should make sure it penetrates deep enough into the coating. Depending on this, along with how much of the sealed coating is removed during the abrasive wheel-grinding step, you might have unsealed areas. If this is the case, along with the relatively thin bond coat, you would have a problem where corrosive media will penetrate to the aluminum and start a subsurface corrosion process causing blistering and delaminating of the coating. I recommend that you:

- Investigate the penetration depth of the sealer and perhaps use a different sealer.
- Increase the bond coat thickness to 125 μm.
- Increase the ceramic thickness to 250 μm.

Question 3

Cutting HVOF Sprayed Coatings. I would like to be advised on preferred means to cut HVOF sprayed coatings for metallographic preparation. Diamond saws are generally used to cut the coating. Other saws/cutters may damage the coating. Is there an alternative to the diamond saw? The substrate is a 3 mm thick while the coat thickness is 300 μm.

Answer 3.1: The preferred method for sectioning carbide and most very hard-alloyed HVOF coatings is to use a low-speed diamond cutoff machine. For soft metallic coatings, especially Fe-base alloys, a SiC wheel would be preferred.

Question 4

Spraying Copper on Glass. We currently spray a ¼ in. copper buss bar onto thin film (tin oxide) tempered glass. The thickness of the sprayed copper is approximately 0.003 to 0.004 in. We are currently using oxygen/acetylene flame spray process. The customer would like to improve the adhesion. I am interested in possibly using methylacetylene-propadiene (MAPP) gas or natural gas with the current system, or completely changing the system to an electric arc spray if the results will prove worthy.

Answer 4.1: Changing to arc sprayed coatings will definitely give a better coating. Better bond and a denser coating as well as process temperature.

Answer 4.2: Wire-arc using maybe Ar or N_2 as atomizing gas instead of air ought to (i) improve adhesion and (ii) by reducing the oxidation, improve electrical conductivity.

Answer 4.3: Electric arc spray produces much higher bond strength than flame spraying when spraying aluminum onto glass. I would expect the same result with copper. Or, perhaps you could use a thin bond coat of aluminum before applying the copper to enhance adhesion. I agree with the fact that the use of inert gas with arc spray would improve conductivity. However, according to my experience, using nitrogen or argon as the atomizing gas lowers the bond strength of most arc sprayed coatings. The oxidation seems to help, probably due to the exothermic reaction and subsequent particle heating.

Answer 4.4: My investigation of arc sprayed steel (onto a steel substrate) confirms that spraying with nitrogen, rather than air, reduces the temperature of the spray and significantly reduces the bond strength. Air sprayed material had a bond strength higher than the cohesive strength of the coating itself. Indeed, metallurgical welding of some of the splats with the substrate was observed. When nitrogen was used, the coating could be removed very easily (it usually fell off during preparation for metallographic examination) leaving a very clean substrate. Of course, spraying with nitrogen dramatically reduces the amount of oxide in the coating. However, spraying needs to be carried in a backfilled chamber to reduce the amount of oxide (and alloy loss) to very low levels.

Answer 4.5: Aluminum reacts exothermically with air when arc sprayed and provides a very good bond with glass. Copper hardly reacts at all, and it is difficult to deposit any significant thickness of material. As arc sprayed aluminum is highly conductive, it may be beneficial to consider using a two-wire arc spray approach with one wire spool with aluminum and the other with copper. This will still increase bond strength, maintain conductivity, and avoid the hassle of switching feedstock or running two processes.

Question 5

Anti-Erosion Coatings at High Temperatures. I am looking for anti-erosion coatings deposited by HVOF or arc spray. Service condition: 1000 °C or higher (1200 °C). The substrate is carbon steel.

Answer 5.1: Given the type of the substrate material and the exposure temperature, I am not sure any coating will offer the sought protection. Firstly, a carbon steel will not survive at temperatures of 400-500 °C without oxidation, which will undermine/reduce the effective load-carrying ability of any given component. In addition to the high temperature, if the environment contains corrosive species, there may be other degradation issues, such as hot corrosion, sulfidation, metal dusting, etc. For the best reduction of the substrate temperature, you would naturally turn to yttria-stabilized zirconia (YSZ) coating to be either thermal sprayed or deposited by electron beam physical vapor deposition (EB-PVD). Then you may find that the coated carbon steel now at most can withstand no higher than 550-650 °C, for example. Secondly, as far as the best erosion resistance is concerned, Cr_2C_3-NiCr is more temperature-tolerant than the WC-Co type. Of course, neither of these can match the YSZ as far as hardness and especially heat resistance is concerned. Indeed, the stabilized zirconia is an ideal high-temperature erosion-resistant material. The problem is that in this case its full potential may be limited by the oxidation of the mentioned carbon steel.

Answer 5.2: I would consider an alumina or alumina-based plasma-sprayed top coat over an FeCrAl bond coat. The bond coat could be applied by plasma or arc spray. Depending on the situation, alumina may be better than zirconia-based as an oxygen barrier, and it can be pretty erosion resistant. A zirconia-based top coat would also be compatible with a FeCrAl bond coat. For example, you can arc spray the bond coat using an iron-base Kanthal-type wire containing at least 20% Cr and ~6% Al. These wires were originally developed as heating element materials and are now available on welding-type spools from heating element wire manufacturers and from thermal spray wire suppliers. If you own an arc gun, check first with its manufacturer about obtaining this wire. NiAl or NiCrAl bond coats (plasma or arc spray) with or without rare earth additions could also work on your steel. As far as I know, the only reason why the usual bond coats for ceramics are nickel-based is that aerospace components are usually nickel-based, and iron from the bond coat could diffuse into the substrate and hurt performance. Here, your substrate is steel, so an iron-based bond coat makes the most sense. Arc spray can give you an ideally rough surface to overlay with ceramic. A properly arc sprayed bond FeCrAl coat has really good adhesion to steel.

Answer 5.3: For high-temperature erosion resistance, HVOF sprayed chrome carbide (75/25 or 80/20) with bond coat of CoCrAlY or NiCrAlY may be employed. These systems will work well where thermal conductivity is also required and may be suitable for continuous temperature of 800 °C on substrate. Plasma sprayed alumina or zirconia with suitable stabilizers like yttria, calcia, or magnesia with bond coat of CoCrAlY or NiCrAlY may also be applied. These systems will be good where thermal conductivity is not the criteria and thermal barrier properties are required. Concerning erosion resistance alumina will score over zirconia. These systems should be good for temperatures up to 1000 °C.

Question 6

Galvanic Corrosion. Has anyone ever done some research on galvanic corrosion between dissimilar metal/alloy coatings and substrates? For instance putting a NiCr coating on a cast iron substrate?

Answer 6.1: Galvanic corrosion occurs when both types of alloys are in direct contact with the solution. If just the NiCr coating is in contact with the solution, no galvanic corrosion occurs.

Answer 6.2: You should take in mind that if a coating is dense (no open porosity) and in the absence of open contact at edges, no galvanic corrosion related to the coating/base material combination will occur. However, if open porosity is present in the coating, galvanic corrosion can occur, and it can be quite severe, resulting in spallation of the coating depending on the corrosion conditions.

Question 7

Static Electricity. One of our customers is experiencing problems with static electricity being generated within a nylon powder feed tube. Basically the powder is being fed at reasonably high rates (6 kg/h) using argon as a carrier gas. When you disconnect the hose and empty the feeder contents, one receives an electrical shock (static) that I think is causing us problems within the PTA torch. Has anyone had success with earthing nylon feeder tubes?

Answer 7.1: I have earthed feed tubes in the past in order to stop the smaller particles sticking to the inner wall. I just wrapped copper wire around them and screwed the end to the base of the machine.

Question 8

Nonhomogeneity in Aluminum-Silicon Wires. I have been using aluminum wire with oxyacetylene flame for many years to spray a clearance coating on turbine engine compressors. This wire is nominal 6% silicon aluminum. Have never had much trouble before, but in the last few months we have noticed hard and soft areas in the sprayed material. This shows up when we are machining it to finished size. We sent wire samples, taken from random places on several rolls of wire and sent to a lab for tests. The results came back showing very inconsistent distribution of silicon. Some spots showed as high as 13% Si while others showed almost none. The results ranged from less than 1% to 13%.

Answer 8.1: Sometimes nonhomogeneity in the wire can cause differences in properties from one area to another in a coated surface. I have found that increasing the gun traverse rate can minimize these effects. The effects of a variation in the wire chemistry are spread over a greater surface area in a thinner deposit per pass. The net result is a more uniform deposit. Additionally, changes in flame stoichiometric, i.e., the flame becoming more oxidizing or reducing, can cause changes in coating properties. Loose connections or faulty pressure and flow regulators can cause this change in flame stoichiometry. Sometimes movement of the gun will cause loose connections to leak at different rates at different places in the spray pass. If your wire drive unit has become worn, it will cause variations in wire feed rate that can affect coating properties.