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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

Aluminum Coatings in Contact with Sodium Hypochlorite. We are experiencing coating failure on traveling screen baskets arc sprayed with 10 to 12 mils of aluminum and seal-coated with epoxy. They are rotated in fresh water (<500 ppm chloride) with sodium hypochlorite injected into the cooling pond at 3 ppm. Each assembly has a stainless steel mesh attached by bolting. Failure is not localized near the stainless steel; it is localized across the entire assembly. Coating age varies from approximately 6 months to 1 year. Looking for suggestions on different wire or similar failures.

Answer 1.1: Aluminum alloys have their Al_2O_3 protective film destroyed by the OCl anion in the hypochlorite, which is why the aluminum coating is failing (probably at pinholes in the epoxy). If you want to continue to use the aluminum, you need to inhibit the water with something such as Na_2SiO_3. I think using a 300 series stainless steel for the screen would be a better choice as coating as well as the frame. Watch the design to reduce chance of crevice corrosion. The 300 series stainless steel will be attacked by pitting.

Answer 1.2: In general, aluminum is not considered corrosion resistant in sodium hypochlorite (NaOCl) solutions. In addition to chlorides, the presence of silicates and phosphates might change the performance dramatically (the latter two are inhibitors). Stainless steels with molybdenum (316, 317 grades) are much better. Hastelloy C-276 is the next upgrade. However, there are known unpredictable failures of above alloys in NaOCl, while in rather similar conditions they performed excellently. Tantalum is very resistant, but the cost is a killer. Titanium grade 2 is one of the few alloys that provides consistently good performance in NaOCl, including elevated temperatures.

Question 2

Upper Temperature Limits for WC-Co in a Nonoxidizing Environment. I am looking for information on any testing on the upper temperature limits for WC-Co in a nonoxidizing environment.

Answer 2.1: (1) WC-Co (including WC-CoCr) is normally limited by the oxidation of Co above ~500 °C. For few hundred degrees higher temperature usage, the CrC-NiCr type is mostly preferred—the reason being that the binder Ni-20Cr alloy used in this case is oxidation resistant to higher temperatures compared with the Co or CoCr in the WC-based coating. (2) If oxidation is not an issue, there should be in theory no limit on WC-Co due to the oxidation of the Co phase. Purely from this point of view, the WC-Co can be used to much higher temperatures until the temperature starts to affect the mechanical properties, mainly of the binder Co such as the creep (or any other mechanical properties due to loss of strength at high temperatures). Indeed, practically, where oxidation is not a major issue, Co-base superalloys are superior than Ni-base ones because of such higher ability to retain strength when the temperature is raised. For this reason only, the temperature limit should be higher than the ~500 °C.

Answer 2.2: We have tested WC-Co at high temperatures in air. WC-17Co can operate at 400 °C on steel and AISI 316. Above 400 °C, it peels off and starts to oxidize quickly. We also have tested WC-Co in high vacuum up to 1000 °C; no oxidizing problems were observed, but microcracks and phase changes in the coating did occur. Theoretical calculations have shown that Co and WC start to oxidize at low partial pressures of oxygen bellow $pO_2 < 10^{-6}$ bar at 1000 °C. Also WC-Co system does not have a protective oxide layer (Al_2O_3 or Cr_2O_3) against oxygen, water vapor, and CO_2, like alloys or cermets containing Cr and Al. WC is not a very stable compound, it starts to decompose at low temperatures (<500 °C) at oxidizing atmosphere. Therefore we recommend you to test your coatings at elevated temperatures and check the adhesion (bend or pulling test) and microstructure after 100 h. The adhesion should not become lower (50 MPa), and you should not find black oxidation layer in the coating. The black oxidation layer can be found on the surface and in the cracks of the coating. Magnification of 200× is enough. However, we recommend Cr_2C_3-NiCr coating; it has tested successfully in many applications.

Question 3

Coating with Hydrophilic Properties. I have been asked to coat a roller for the printing industry, and it must have hydrophilic properties.

Answer 3.1: Practically any thermally sprayed metal, carbide, or oxide ceramic would have strong hydrophilic properties because of the remaining porosity (read "capillaries"). Carbides (specifically, sprayed of agglomerated/sintered powders) and oxides are somewhat better candidates than metals.

Question 4

Anticavitation Coating. I am looking for anticavitation coating for stainless steel 316L impeller (seawater pump). I plan to use WC-Co or Stellite 6 or any comparable HVOF powder. Any suggestion on which one is the best? Is there any specific minimum thickness to apply?

Answer 4.1: Generally Stellite 6 has better cavitation resistance than WC composites. I would think a coating 0.010 to 0.015 in. thick would be sufficient.

Answer 4.2: Up to now the substantial numbers of the thermal spray coatings have been tested for cavitation resistance. Usually the performance is not satisfactory due to the nature of the thermal spray coatings, but the Stellite 6 (HVOF) coatings have found their application niche. More than that, the Stellite 6 coatings in a couple with A572 or A36 carbon steels may have low potential difference, lower than stainless steel 304-A572 or A36 carbon steel. Therefore Stellite 6 would reduce the galvanic corrosion problem because of smaller electrical potential difference. This would be especially critical in view of your seawater pump application.

Question 5

TBCs for Intensive Thermal Shock. We have an application that requires to a certain degree similar thermal barrier coatings known for gas turbine applications, but there are several other critical peculiarities. These are:

- Complex and bulky shape of the application, weight is about 21 lb
- Base material: heat resistant alloy, grade HL composition
- Very intensive thermal shock and thermal cycling conditions that vary from 70 to 1250 °C approximately every 90 min
- Substantial local overheating of the application due to limited cooling and thermal conductivity toward surrounding structural elements
- Exposition directly to combustion products having elevated sulfur content

In fact, we experience similar problems as it was described for gas turbine blades and we consider we have a good option for the top coating, but MCrAlY bond coat would require a relevant improvement. I am wondering if there were any trials on cold spraying, reduced spray spot diameter, or some other techniques in order to increase the target efficiency and bond strength for the MCrAlY bond coatings.

Answer 5.1: HL alloys have approximately 28% Cr as the main scale former in higher-temperature applications. Chrome oxide is not stable at above 950 °C. Therefore, these alloys will be limited in that application without an aluminum reservoir (to form a stable alumina scale). We had a similar application (to 1200 °C) in an incinerator grating. We solved the problem by heavily grit blasting followed by aluminizing, light grit blast, NiCoCrAlY plasma spray followed by yttria zirconia (only 0.005 to 0.008 in. thick) only in areas at highest heat flux. The reason for aluminizing prior to NiCrAlY was to increase the aluminum content in the HL alloy. There was a fourfold improvement. We also tried aluminizing on top of NiCrAlY in this application, but at high heat the thick alumina scale growth at the TBC interface lead to early failure. The relatively thin TBC helped in thermal cycling.

Question 6

Coating for Blast Furnace Slag Pump Housing. What is the best HVOF coating for blast furnace slag (granulated slag) pump housing? The temperature of the environment is lower than 150 °C.

Answer 6.1: What do you think about WC-Co-Cr, WC-Ni, or NiCrBFeW powders HVOF applied? The temperature from the environment is not higher than 150 °C. The granulated slags are carried with the water, so we have high abrasive and corrosive environment.

Answer 6.2: WC-Co-Cr worked best on Pelton Wheels, to which this sounds similar.

Question 7

Hardness and Wear Resistance of Al-Cr-Fe. We are currently repairing sleeves made of 420 stainless steel that have been worn by the packing that goes on the outside. We are using Al-Cr-Fe. These sleeves are only exposed to regular water. My question is: are there any better materials out there that will still give a good machine finish? We are happy with the Al-Cr-Fe, but my only concern is hardness and wear resistance.

Answer 7.1: We use the Al-Cr-Fe all the time for a lot of different repairs. We have found that the Al-Cr-Fe material has good corrosion resistance in a lot of applications. As far as hardness is concerned, I have not found a better material that still machines as well and is as hard. We machine and polish this material on a daily basis. When it is used to repair bearing diameters and seal diameters I have found it to outlast the original material in many cases.

Question 8

Standards for Bond Strength Test. Can anyone help me regarding the specimen preparation standards such as size, coating thickness, etc. for testing the bond strength of plasma sprayed coatings?

Answer 8.1: Get yourself a copy of ASTM C 633-01 "Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings." All the information is there, together with suggestions for adhesives and assessing the locus of failure.

Answer 8.2: Just a friendly reminder—this standard, plus most other ASTM standards, AWS, ISO, NACE etc. standards are available through the ASM website at http://www.asminternational.org. Click on the "standards" tab.

Question 9

Coating Protection Against Denting. We coat pipeline (pipe joints) using arc spray coating technology. The coating alloy is Zn-Al. After being coated, the pipeline is transported to the field to be buried in the ditch/trench. While lowering the pipe in the trench/ditch for burial, there is a concern that a dent/damage could happen to the coating, which will cause accelerated corrosion later on after burial. Could someone advise on if there is any procedure to avoid such coat denting?

Answer 9.1: We use a gel-like material to apply a ~50 μm thick coating with a brush on our ceramic coatings. This forms a plastic film that can be peeled off when not required. The coating remains protected against scratches and rough handling during transportation. This film passed a 200 h salt-spray test for corrosion resistance.