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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 to the discussion group visit http://www.tss.asminternational.org/portal/site/TSS.

Question 1

Spraying Al via HVOF. Has someone already tried to apply pure aluminum coating with HVOF process?

Answer 1.1: You will not get an Al coating; instead, you will get an Al/Al_2O_3 composite. Consider the oxidation kinetics for Al.

Answer 1.2: It is a matter of getting the right powder sizing and spray parameters. We have sprayed dense coatings of pure Al and Al/Si to thicknesses of many millimeters.

Answer 1.3: Take a look at the following paper. Al was sprayed via HVOF by using H_2 and O_2. Special sizing of powder, and proper parameters were required. Article: R. Chow, T.A. Decker, R.V. Gansert, D. Gansert, and D. Lee, Properties of Aluminium Deposited by a HVOF Process, *J. Thermal Spray Technol.*, 2003, **12**(2), p 208-212.

Answer 1.4: Why not use cold spraying? It is easy to deposit pure Al coatings.

Answer 1.5: HVOF-applied aluminum and AlSi coatings can be HVOF sprayed very dense, thick, and with relatively low oxide levels if you match the particle size to the HVOF equipment and parameters used. I have sprayed many coatings like these using air-cooled DJ torches at high feed rates, using a fuel-rich (oxygen reducing) flame. I have also sprayed HVOF wire coatings, using a reducing flame. Arc sprayed aluminum coatings sprayed with N_2 wire atomizing and possibly an N_2 shroud are also very low in oxides and dense.

Answer 1.6: I would like to add that using diagnostic tools to measure in-flight particle characteristics (i.e., temperature, velocity, and their distributions in the spray jet) may also help you to reduce the oxide content in metallic coatings.

Question 2

Decarburization of nanostructured WC-based coatings. Are there documented results in the public domain that nano "carbide" and "metal" powders (e.g., agglomerated or cryomilled) sprayed with thermal spray (e.g., HVOF and cold spray) are being found to work and/or being implemented in industrial applications? I am aware of a great deal of excellent work being done by a whole host of research organizations and universities. I am not referring to nanophases formed from thermal spray (e.g., wires sprayed), but nanosprayed powders. Is the community overcoming the issues of nanocarbide powders undergoing decarburization? And do nanometals typically lose their nanophase from the processing (e.g., HVOF)? Some of the research I have read in documented papers, HVOF sprayed nanopowders appear a little underprocessed (e.g., particles not flattened enough) from possibly trying to keep from losing these nanophases.

Answer 2.1: Conventional and multimodal (nano« submicron) WC-12Co powders were HVOF sprayed over different ranges of particle temperature and velocity values, that is, different spray parameters, using the following torches: JP5000, DJ (H_2), and DJ (propylene). The abrasion wear resistance of these coatings was evaluated using the dry sand/rubber wheel test (ASTM G 65). The multimodal coatings were harder than the conventional ones; however, there was no significant difference in the performance of the "best-performing" conventional and multimodal coatings concerning abrasion wear. On the other hand, the multimodal coatings exhibited a larger processing window, that is, these multimodal coatings exhibited enhanced abrasion wear resistance over a wider range of particle temperature and velocity values when compared with those exhibited by the conventional coatings. Consequently, decarburization cannot be avoided; it may be "controlled." In addition, the multimodal coatings exhibited significantly higher deposition efficiency (DE) values. Therefore, it may be suggested that the multimodal material offers the possibility of better quality control and improved coating reliability. The results of this research (including cross-section microstructures and x-ray diffraction spectra) can be found in the following reference: B.R. Marple and R.S. Lima, Process Temperature/Velocity-Hardness-Wear Relationships for High-Velocity Oxyfuel Sprayed Nanostructured and Conventional Cermet Coatings, *J. Thermal Spray Technol.*, 2005, **14**(1), p 67-76.

Question 3

Cleaning coatings after oil spilling. One of our TBC coated component has machining oil spilled at some locations (accidentally). Is there any way to get rid of this oil, other than respraying the whole component again?

Answer 3.1: In the old days here in the United States, non-aircraft parts could be hot vapor degreased with something like trichlor-ethane in order to remove oil. Nowadays, chlorinated solvents are largely history as they are so harmful to the environment. Since TBC is usually quite porous, I would try using a steam degreaser followed by an acetone rinse while the component is still hot. You can check for the presence of residual oil by rinsing the component after processing with acetone and allowing the acetone to drip on a clean mirror. If oil is present on the component, some of the oil will dissolve into the acetone and drip on the mirror. As the acetone evaporates, the oil will leave a residue on the mirror that diffracts light. Repeating the steam degreasing and acetone rinse a couple of times should give you a clean part. If you are located in some other part of the world, you probably can avail yourself of a vapor-degreasing process.

Question 4

Coating system that can protect graphite furnace parts against molten metal and slag. We need to find a coating system that can protect graphite furnace parts against molten metal and slag. There are some coatings (e.g., water-base boron nitride and SiC coatings) that can be sprayed or brushed on graphite without need for curing heat. Of course, there are several references on coating of graphite by sintering the coating, including Si-SiC and also boron nitride system, but these types of coatings are not feasible for this particular application.

Answer 4.1: A thermally sprayed coating of Ti_3SiC_2 may be an excellent candidate for this application.

Answer 4.2: You can apply yttria over graphite for protection. This material can be applied with plasma or is available in a paint that can be brushed or sprayed. Just be aware that the paint is a once-through coating and will need to be applied again between furnace runs.

Answer 4.3: I applied alumina and zircon coating onto graphite crucibles with plasma spraying, about 200 μm thick, for the same reason. To ensure good bonding, graphite had to be preheated to at least 550 °C (I did it in the oven). There are also ceramic adhesives and paints, which allows formation of reliable layers on graphite, baking at 400 °F only. You may look into combination of two above technologies.

Question 5

Removing Cr-C coatings without damaging the substrate. What is the best method for removing Cr-C coatings with out damaging the substrate?

Answer 5.1: You may try sandblast, which damages the substrate a little.

Answer 5.2: You should use alumina-zirconia, because it is a very tough material and much better than white or brown fused alumina.

Question 6

Cold sprayed nanostructured coatings. Is there information available about the potential of cold sprayed "nanograined" coatings for improved performance for industrial applications? I have had some nice input on the nano efforts being done by research centers and companies working in plasma and HVOF (e.g., NRC, Perpetual Technologies). Can anyone comment if there are efforts being done in the "cold spray" community with nanomaterials as well? I have read a paper on nanograined cold sprayed carbides that looked interesting (Lima, Karthikeyan et al., *Thin Solid Films*), and read some literature on a nano aluminum (Perpetual Technologies) via cold spray. I am interested to learn more on what has been published or efforts that can be shared in public.

Answer 6.1: There are different interesting references available in the literature about cold sprayed coatings produced from nanostructured powders. These are some of them:

- L. Ajdelsztajn, B. Jodoin, G.E. Kim, J.M. Schoenung, and J. Mondoux, Cold Spray Deposition of Nanocrystalline Aluminum Alloys, *Metall. Mater. Trans. A*, 2005, **36A**(3), p 657-666
- S.-Q. Fan, G.-J. Yang, C.-J. Li, G.-J. Liu, C.-X. Li, and L.-Z. Zhang, Characterization of Microstructure of Nano-TiO2 Coating Deposited by Vacuum Cold Spraying, *J. Thermal Spray Technol.*, 2006, **15**(4), p 513-517
- G.E. Kim, T. Addona, P. Richer, B. Jodoin, A. Al-Mathami, and M. Brochu, Characterization and Evaluation of Nanostructured Bond Coats from Non-Cryogenically Milled Feedstock, *Proc. ITSC 2007*, p 604-609
- H.-J. Kim, C.-H. Lee, and S.-Y. Hwang, Superhard Nano WC-12%Co Coating by Cold Spray Deposition, *Mater. Sci. Eng. A*, 2005, **391,** p 243-248
- M. Yandouzi, E. Sansoucy, P. Richer, B. Jodoin, and L. Ajdelsztajn, Deposition and Characterization of WC-Co Coatings Prepared by Continuous- and Pulsed-Cold Spray Processes, *Proc. ITSC 2007*, p 660-664