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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 e-mail 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 e-mail discussion group, previous and new subscribers will have to follow the instructions listed below:

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Question 1 edited

WC-based coatings versus hard chrome. We were invited to spray the undercarriage pistons on top dressing (crop duster) aircraft as a trial. They were having a history of occasional failure due to corrosion under the hard chrome. This had been identified as being caused by the corrosive nature of the fertilizer being spread and the chrome being porous. The idea was that we would replace the hard chrome with an HVOF-applied tungsten/cobalt/chrome coating. We tried two pistons, and they have been in service for 1 year. When they were removed for evaluation, we noticed a coating failure down the very front of the legs. The failure is in small "spots" approximately 3 mm across, but all appear to have a "crack" perpendicular to the axis of the piston. Is it possible that the "cracks" were the result of stress in the coating? These planes normally operate out of grass runways that are no better than an ordinary paddock. Therefore, it must place tremendous loads on the pistons when the plane is taking off fully loaded, or normally overloaded. Has anyone experienced this issue? I believe this situation occurs when the coating is more rigid than the hard chrome.

Answer 1.1: It is not a secret that HVOF WC coatings are inferior to chrome for crack resistance (fatigue, bending, etc.). There are many reasons for it, but density and hardness are evidently of the greatest importance. When we learned how to vary hardness/density of our HVOF-sprayed WC coatings (new hardware, technology developments, use of different powders, etc.), we learned that harder is not always better. Now we analyze working conditions of the coating before making a choice of how "hard" it should be. The failure of your coating does not mean that HVOF cannot be used in this application.

- If you have a choice, choose the powder with more porous particles ("under-sintered"—those usually have lower level of WC decomposition, too). You would produce softer and, likely, more porous coatings, but with better resistance to cracking. Besides, you would enjoy higher deposition efficiency levels.
- Take care of residual stresses. Before spraying, it is important to heat the spray part through, not only its surface (many specs require 150 °F preheating). The thicker the substrate, the more difficult if is to heat it through with the gun flame. Wrap electrical tape-heater around and preheat the part for an hour or so. This device would ensure you will avoid the most common error, resulting in high level of residual stresses in the coating.

Those two are very strong factors to improve your coating crack resistance marginally. I have already seen specs, limiting maximal hardness of WC-Co-Cr coating.

Answer 1.2: HVOF-sprayed WC-Co coatings have been demonstrated by many to outperform hard chrome plating in numerous OD-coating applications. More info on the subject could be found on HCAT website: http://www.hcat.org/about.html.

As to the specific problem of cracks described here, the most likely reason is the lack of substrate temperature control during HVOF spraying operation. Last year, we ran a series of tests including squeezing of WC-Co-Cr-coated, heat-treated 4340 steel pipes. It turned out that the coatings sprayed without proper cooling developed cracks much faster than those that were cooled by forced air (plus interpass cooling breaks) or by cryogenic cooling medium (without the need for cooling breaks). The key factor responsible for the difference appears to be a very steep interfacial residual stress gradient inside the grit-blasted zone (buried under the WC-Co coating) that develops if the substrate and coating are not cooled enough during spraying. "Hot spraying" results in increased compressive stresses in the coating and, at the same time, thermal softening of the substrate with its grit-blasted asperities. Combined, these lead to an accelerated delamination and/or to coating cracking. My suggestion is to keep the part within the "proper" temperature ranges while WC-Co spraying.

Question 2

Interdendritic electrolysis. There is a metallurgical condition called interdendritic electrolysis or interdendritic galvanic attack that is caused by the chemical gradient that forms when liquid metal cools to the solid state. Basically, the high melt point elements in the melt solidify first, and the lower melt point elements solidify last. The chemical composition gradient that results produces a difference in the electrical charge of different regions of the same crystal or grain of the metal. My question is, where can I find a definition for interdendritic electrolysis? The online ASM Handbooks, and the other online ASM reference information I have access to, do not provide a straightforward definition. Neither does my Materials Engineering Dictionary. I appreciate any references to a credible source for the information.

Answer 2.1: Check the ASM Materials Engineering Dictionary again—page 228. There is a definition for interdendritic corrosion in the right-hand column, along with a micrograph on the next page.