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. Any further discussion can be submitted to the Editor of the JTST.

Question 1

Coating on a Galvanized Sheet. We have a request from a customer who wants a coating of zinc and aluminum on a galvanized sheet. The previous coating thickness on the galvanized sheet is 10-15 µm. We have explained to the customer that we need to prepare the surface by grit blasting, so, therefore, the previous coating will be removed during this process. They want the coating without grit blasting. Has anyone tried this before? Is it possible that we only clean the surface and the coating will adhere to the previous zinc on the surface? The surface on the previous zinc coating is very smooth.

Answer 1.1: Unless you remove the galvanizing you will compromise the bond of any coating applied. High-velocity oxyfuel sprayed coatings of WC-Co bond very well to the galvanizing; unfortunately the galvanizing will likely fail, as it has poor bond strength once the coating has been applied.

Answer 1.2: The surface preparation by sand blasting does introduce mechanical stresses that may deform the sheets that will be coated. Moreover, it may modify their microstructure. What can you do about this? You can still use sand blasting, but in a gentle way: lower blasting pressure, use smaller and less hard grit. I have had positive experiences with silica.

Chemical etching is also a solution. Care must be taken, however, concerning safety during the etching process.

You can try a surface preparation by laser ablation.

Finally, you can recommend another coating technology that might match better to this particular substrate, for example, PVD (evaporation of aluminum).

Question 2

Rockwell C Scale for Thermal Spray Coating. What would be the expected maximum hardness on the Rockwell C scale for molybdenum coatings using a slow wire speed, acetylene fuel, and excess oxygen with the wire flame spray process?

Answer 2.1: Do not use the "standard" Rockwell scales for thermal sprayed coatings. The loads used will cause the platelets (i.e., the lamellae) to collapse on each other and deliver a false reading. Beside you would need too thick coatings. Use the superficial scales such as 15N and 30N. Avoid going to higher loads. This includes the Rockwell A scale.

Question 3

Corrosion Resistance of Self-Fluxing Alloys. We are involved in a project concerning improvement of corrosion resistance of flame sprayed self-fluxing alloys. The background of the problem is as follows:

The component surface, centrifugal cast stainless steel, is first grit blasted. Immediately after grit blasting the surface is coated by oxyacetylene flame spraying, the powder being a nickel base self-fluxing alloy (Ni-16Cr-4Si-4B-3Cu-3Mo-2.5Fe-0.5C). The thickness 1.6 to 1.8 mm.

The fusion process after thermal spraying is made by oxyacetylene flame heating by moving the torch along the surface until the whole surface reaches 1050 °C. The thickness after this fusion process is 1.0 to 1.2 mm.

In order to increase the corrosion resistance of the covered components, our client now wants to change the nickel-base alloy to a cobalt-base self-fluxing alloy (Co-27Ni-18Cr-6Mo-3.5Si-3B-2.5Fe-0.2C). All of the covering processes (grit blasting, thermal spraying, and fusion process) are the same as those used for the nickel-base alloy, but the adherence of the coating is lower. The question is: What has to be changed in the coating process to obtain the same adherence for the cobalt-base alloy as compared to the nickel-base alloy (~200 MPa)?

Answer 3.1: Is your flame truly reducing? Are you putting enough heat into the powder to get fusion and dissolution of the material? I recommend that you look at the microstructure to see if you are producing oxides and/or if some of the components of the powder being applied are remaining as discrete nonfused/nondissolved particles. I would say that you probably need more heat and a more reducing atmosphere in your flame.

Answer 3.2: The melting point of the alloy (Ni-16Cr-4Si-4B-3Cu-3Mo-2.5Fe-0.5C) is 1010 °C, and the melting point of the alloy (Co-27Ni-18Cr-6Mo-3.5Si-3B-2.5Fe-0.2C) is 1120 °C. Since the melting point of the cobalt-base alloy is higher, it is probably safe to assume that the fusing temperature is also higher. If possible, try fusing at a higher temperature.

Answer 3.3: You may try to spray a coat of the nickel-base alloy first as a bond coat and then the cobalt-base alloy.

Answer 3.4: Your stainless steel substrate may contain nitrogen. If it has nitrogen, it is not suitable as a substrate material for fused self-fluxing alloy coatings. The reason is that the boron from the coating material will combine with the nitrogen from the substrate to form boron nitride at the coating/substrate interface. It is the boron nitride that prevents the bonding between the coating and the substrate. A diffusion process causes the formation of boron nitride. When you flame-fuse the nickel-base self-fluxing alloy it is quick and it takes place at relatively lower temperatures (than the cobalt-base alloy). Perhaps your fusion process was so short that formation of boron nitride was very limited and did not impair the bond too much (200 MPa is not very high for a metallurgical bond, even for this substrate). Cobalt-base alloys, on the other hand, are another matter. They are much more difficult to fuse since they have higher melting temperatures (>1070 °C). As well, they do not reflect light very well, and so it is difficult to visually judge if the coating is fused or not during the process. Because of this characteristic the fusing time is longer. Therefore, there is more time to allow boron nitride to form, and more importantly, the higher temperature accelerates the boron-nitrogen diffusion process. Consequently, you have a weak bond or no bond at all. You may consider an alternative coating material, an alternative substrate material (e.g., a nitrogen-free austenitic stainless steel) or alternative coating process.

Answer 3.5: I was going to make a comment about not using NiCrSiB coating over a CoCrNiWSiB self-fluxing alloy. Problems would be caused in the bonding and/or even in the fusion of the initial layer due to the different melting points. We have had issues with nitrogen from the substrate, and if the base metal exhibits this type of outgassing, cobalt-base self-fluxing alloys should be avoided to prevent potential cracking and gas porosity of the overlay. I do not recall that we have experienced bond issues unless the substrate had been nitrided. Poor bond can be a result of inexperience or poor technique. Cobalt-base self-fluxing alloys are much more difficult to become glazed during fusing. So if you are not familiar with the alloy you could be fusing only the surface and not the whole coating, thus resulting in a very poor bonding.

Answer 3.6: Indeed, the critical point here is the coating-substrate-process compatibility issue. CoCrNiWSiB alloys can be fused very well, for example, in a controlled atmosphere or in vacuum. However, it is generally difficult to fuse it with a flame torch, particularly when a large part is to be spray fused.

Question 4

Molybdenum Coatings in Casting Molds. We have a requirement from a steel mill regarding the coating for continuous casting molds of steel. The molds are made of copper alloy with a coating inside. When the coating wears down, the mold ceases to cool the liquid metal. Usually for a 5 in. thick billet, the mold cools down about 20-25 mm of the liquid metal. When the coating is removed/damaged it only cools down 10-12 mm of the liquid metal. We have only arc spray equipment, and we spray molybdenum.

Answer 4.1: There are reasons to doubt the long-term success for the pure molybdenum coating application on copper molds of continuous steel casting. Molybdenum oxides sublimate at about 1000 °C (in fact, I have seen this happening at lower temperatures). Noticeable oxidation of molybdenum occurs at above 350 °C in air and heavy oxidation above 600 °C. Oxidation occurs unless there is no access of air to the mold.

Question 5

Propeller Shaft-Bearing Areas. I would like to know if anyone has arc sprayed aluminum-bronze onto propeller shaft areas. Also I would like to know about the service life of these coatings.

Answer 5.1: This is a very good application for thermal spray coatings. Extensive experience has been accumulated in the recuperation of bearing sleeves with arc spray coatings for several types of propeller shafts including service tugs, offshore patrol vessels, torpedo boats, missile boats, and even in an icebreaker. In our experience, the best overall coating is a NiAl-bronze coating, although straight aluminum-bronze has also worked. In certain applications and with extreme care, coating thicknesses up to 8 mm have been achieved, and these have been in service for several years.

Question 6

Coatings Sprayed on Carbon Fibers. I am trying to bond arc sprayed coatings to flat pieces of carbon fiber. I have been successful with round parts, but not with flat substrates.

Answer 6.1: Assuming that the carbon fiber is bonded with some type of resin or glass, you can create effectively a bond coat layer of epoxy resin and metal powder (if your application permits). The coating will adhere very well to the powder/resin surface.

Answer 6.2: Arc spraying is really not the process of choice for the flat components. I have successfully sprayed many different materials on carbon fiber composites and just fibers using high-energy plasma and HVOF processes that produce compressive stresses and high bond strengths.

Question 7

Measuring Coating Thickness. We are applying arc sprayed coatings of Ni/Al bondcoat and a topcoat of Fe/Cr/B amorphous material. We are measuring coating thickness, but the magnetic instrument produces erratic readings due to the non-magnetic property of the NiAl bond coat. Our customer wants to measure the coating thickness after a year to check the extent of wear on the coating. Can anybody guide us on how to measure the thickness of the above combination of arc sprayed coating-substrate (base material is low-carbon steel)? Up to now we are measuring the coating thickness by placing a coupon alongside the area to be coated and measuring its coating buildup.

Answer 7.1: A better way to measure thickness would be to use a micrometer. If the job has some area suitable to measure the thickness by a micrometer, then using it is relatively simple. However if you have to use coupons alongside the job, then care must be taken to ensure that the gun traverses on the coupon for the same amount of time that it does on the job; otherwise you will get variation between the coating thickness on the job and on the coupon.

Answer 7.2: Thanks for the input, but it is not possible to measure the thickness of the job (workpiece) with a micrometer or with an ultrasonic thickness gage.

Answer 7.3: If the base metal is magnetic you could try a magnetic pull-gage, which has a scale built into it. This would read the thickness through a nonmagnetic coating. It might not be the most accurate measurement, but it will give you an estimate.

Answer 7.4: This is not a problem due to bond layer properties. If it is magnetic, it would not affect the measurements by the magnetic induction mode, and you are supposed to read the thickness of a topcoat only (Fe/Cr/B). More likely, the erratic readings come from instability of magnetic properties of Fe/Cr/B layer. I assume this is a cored wire material. The strip (sleeve) can be made of carbon steel or ferritic stainless. In a former case, your coating is partially magnetic and alloying of iron by chromium in the arc (i.e., magnetic properties of coating) would strongly depend on spray parameters. In the stainless steel strip case, the magnetic properties of the coating might change when loosing chrome from the strip material (and initial content of chrome might also vary in the strip), while this would be a less noticeable effect than in the case of using carbon steel strip in the wire. On the other hand, the amount of amorphous phase and the size of nanocrystals formed in the coating would greatly affect the coating magnetic properties. Those would depend on the spray parameters. So, check the strip composition and try to specify it to 420 SS, or better, to 430 SS. Another way is to make thickness calibration samples and stay within a narrower thickness range and better control of spray parameters. Say, stable pressure of air would atomize wire to the same particles with more stable distribution of elements, including chrome. Better surface temperature control would stabilize the size of crystals (some say, amount of amorphous phase), thus stabilizing the magnetic properties of the coating. Frankly speaking, this way seems very difficult, but possible. Also note that magnetic thickness readings would depend on coating roughness (as well as substrate roughness after grit blasting). To my experience, 50 μm in roughness-related errors for arc sprayed coatings are quite possible.

Question 8

Discoloration Spots on WC-Co-Cr Coatings. We have had WC-Co-Cr coatings applied on 4340 substrates. The coatings were superfinished. The parts were wrapped in standard sheet packing material and were kept in a laboratory environment. After approximately three weeks, discoloration spots were noticed over the entire surface. Spots resembled small freckles in size and spacing. Their color seems to be a dark gray. Attempted removal of the spots with alcohol and acetone was ineffective. Microscopic examination has been limited to stereo magnification, which did not confirm if the spots are pits or raised, only discolored. One would say that the spots are corrosion products, but this coating is reputed to provide corrosion protection.

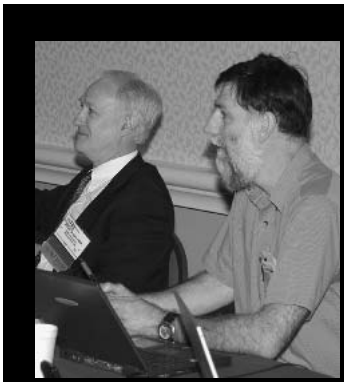
Answer 8.1: The only thing we had ever seen in production, which does not sound like what you have got, was when someone nital etched some parts of a WC-Co-Cr coating. Those parts looked great when they were final inspected prior to shipping to us; however, upon the receiving inspection (about 1-2 weeks later) the surface looked like an as-sprayed coating across the surface. We also did some chemical testing a few years ago while developing a color-check method to see if something was WC-Co-Cr HVOF sprayed or chrome plated. Various acids would stain the finished coating in different ways. You might check to see if any wet chemicals were introduced to the coating unknowingly.

Answer 8.2: Here are some possibilities:

- *Abrasive particle entrapment:* If steel grit was used and remained lodged, it may be that the particle became trapped in the coating and is sufficiently close to the surface to be corroding. You should be able to rule this out by using alumina abrasive.
- *Air contamination:* This is possible if the air was not sufficiently dry. Some, if not most. air systems have carbon steel components in the line. If you trace from your compressor through whatever drying means you have, it is likely that there are some carbon steel parts. We may have witnessed such iron contamination of air several years ago, although it is very difficult to verify. It may just come and go with the humid days or the dryer may not be functioning properly.
- *Powder contamination:* Perhaps the feeder was last used to spray a dark ceramic such as titania or chromia and was not properly cleaned. If the effect is in a particular location, this may be the cause. Although I think this is unlikely, I add it for consideration.

Answer 8.3: One other possible way of powder contamination comes from powder manufacturing. It was said that the ball mill machine used to agglomerate the powders might introduce iron. Maybe an expert from powder manufacturer can better analyze the possibilities of this issue.

Answer 8.4: We had a similar problem a few years ago, using bubble-wrap packaging protection to the components. Soluble oil residue caused a chemical reaction with the polythene bubble wrap, thus staining the coating. Another problem we have had is grinding hardened carbon steel components using diamond wheels and then grinding carbides. We found that the wheel was leaving small flecks of steel on the coatings; hence we were forming oxidation spots after the components were received by the client.



Bill Scott, TSS Executive Director, and Chris Berndt, TSS President, in Marketing Committee Meeting

Peter Hanneforth chairs Marketing Committee Meeting

Joachim Heberlein, Chair of JTST Committee

Chris Berndt chairs TSS Board Meeting

ITSC-2003

Plenary speakers and chairman: Dr. Teruo Kishi (NIMS, Japan), Peter Hanneforth, plenary chair (Sulzer Metco US), Anne Stevens (Ford, Michigan) and Dr. Bruno Walser (Sulzer Ltd., Switzerland)

Plenary audience

Rick Knight, TSS Vice President, enjoys the awards banquet

Bob Tucker (ASM Vice President), Albert Fuerstein, and Merle Thorpe chat during the Wednesday night reception

ITSC attendees enjoy the reception before the awards banquet

Andrew Nicoll enjoys the awards banquet with ITSC colleagues

Chris Berndt, TSS President, makes remarks at the Awards Banquet

D. Harland Harris gives an acceptance speech after accepting the TSS Hall of Fame Inductee Award for his father, the late Douglas Harris, while sister, Joy Huber looks on