Coating adhesion: A misunderstood defect

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Of all the possible coating defects, adhesion failure is often the most misunderstood. This misunderstanding is prevalent because the lack of coating adhesion can be a defect of its own or can be caused by another coating failure. In either case, the coating has disbonded from the substrate, resulting in a defective part.

What is coating adhesion?
Let’s start with the definition of “pure” adhesion failure. The coating bond to the substrate is broken when sufficient force is applied and the coating becomes dislodged from the surface. Pure adhesion failure occurs in the absence of any other factors that may influence the coating bond strength, such as corrosion, softening, impact, abrasion, or chipping.

This is where the misunderstanding often occurs because coatings can become dislodged from a surface as the result of many conditions. If the coating bond is broken before it is subjected to any other force or condition, this is a pure adhesion failure. However, the coating bond can be broken after it has been subjected to corrosion, softening, bending, impact, abrasion, or chipping conditions. These are not pure adhesion failures, but rather they are loss of the coating-to-surface bond as a result of the condition that initially stressed the coating. Therefore, a coating that has been disbonded after corrosion testing is a corrosion failure, not an adhesion failure. Just as a coating that cracks and flakes off after impact or flexibility testing are impact or flexibility failures and not adhesion failures. The same applies to chipping and abrasion which may also result in coating loss to the substrate.

How do you test for coating adhesion?
There are several test procedures for judging coating adhesion. The most popular test is the crosshatch method using the ASTM D3359 test procedure. The less popular scraping adhe-

sion method using the ASTM D2197 test procedure can also be used. Defined procedures, equipment, and pass/fail criteria are clearly described in each of these test methods. The test results are rated as different degrees of passing on a scale from perfect (no coating loss) to complete coating disbondment, as each application can require different degrees of coating bond.

Testing for initial adhesion should occur after the part has been allowed to cool to room temperature. However, some companies state in their in-house quality documents that adhesion should be checked no less than 24 hours after the test part has been cured. Select the timeline that works best for your production operation. For instance, a high volume operation probably cannot wait for 24 hours to test adhesion because failure of the test part may mean thousands of suspect production parts were produced.

Coating adhesion testing is considered a destructive test, meaning the coating has been destroyed as part of the test. For this reason, most people test coating adhesion in hidden areas where the affected test site is not visible or subject to corrosion exposure. Test panels made from similar materials as run in the process are the most accepted specimen for testing coating adhesion. Just be sure that the metallurgy, mass, and soil loads of the test panels are the same as the production parts to ensure reliable test results.

What causes coating adhesion failures?
Once you have determined that you are dealing with a pure coating adhesion failure and not an adhesion failure caused by some other condition, it becomes necessary to look for solutions. The most obvious cause for adhesion failures are poor substrate cleaning, where soils not completely removed from the substrate prevent the coating from properly bonding to the substrate surface. This defect is most easily solved by improving cleaning techniques or chemistries to remove the offending soils or going upstream in the manufacturing process to eliminate the soil entirely.
Coating adhesion is also affected by surface profile or “tooth.” Smooth surfaces do not hold coatings very well; therefore, roughing up the surface will improve coating adhesion. Surface profiles can be roughened by mechanical methods, like media blasting or sanding/grinding, or by using chemically created crystals. Crystals are created on substrate surfaces using conversion chemistries. It is said that iron phosphate can increase a part’s surface area by 75 percent by the crystalline structure it creates on a ferrous substrate. Zinc and chrome phosphate create similar crystalline structures, as well. Zirconium will provide a similar structure, although much smaller, which is why they are referred to as nanotechnologies. Select the conversion chemistry that is compatible with the substrate metals you process, as not all are effective on all metals. Be careful not to over treat the substrate, as most conversion coating chemistries will leave a powdery residue on the substrate surface that will prevent proper coating adhesion.

A coating must wet-out properly on the substrate surface to provide surface bond and proper adhesion. Coating wet-out is affected by coating viscosity, mostly controlled by formulation, but it may be adversely affected by part temperature bring-up time. For instance, powder coatings must be rapidly heated to their melt point to ensure proper wetting of the substrate surface. Heating the substrate too gradually will not allow thermoset powder coatings to fully wet-out the substrate surface before crosslinking occurs, causing poor coating adhesion.

A coating must be properly cured to provide its expected adhesion. Uncured powder coatings often fail adhesion testing because the crosslinking is not fully developed. Always cure your coating to ensure acceptable results. Conversely, over-curing powder coatings causes embrittlement that can create poor adhesion of the coating to the substrate surface.

In summary

Surprisingly, many experienced coaters do not recognize the different mechanisms of adhesion failure and therefore cannot perform the proper corrective action to eliminate the underlying problem. It is not unusual for someone to focus on part cleaning to correct a loss of coating adhesion caused by an impact blow when they should be looking at the cure oven instead.

Editor’s note

For further reading, see the “Index to Articles and Authors 1990-2015,” Reference and Buyer’s Resource Issue, Powder Coating, vol. 26 no. 6 (December 2015), or click on the Article Index at www.pcoating.com. Articles can be purchased online. Have a question? Click on Problem Solving to submit one.

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