Thermal spray coatings: busting the chipping myth

In this article, Jan Lourens, managing director of Thermaspray, debunks the myth that thermal spray coatings 'always chip off' because of the lack of a metallurgically fused bond between the substrate and the coating.

One frequently hears that customers are apprehensive about using thermal spray coatings because, in their experience, the coatings "always chipped off". The adhesion of thermal spray coatings has been a primary concern in industry ever since the processes were introduced, because thermal spray coatings are not metallurgically bonded to the substrate, as is the case with weld cladding processes.

During the early years of thermal spray technology when thermal spray processes such as arc and flame spray were in use, the limiting factor was inadequate bond strength between the coating and substrate. This could lead to delamination or peeling of the coating, especially coatings experiencing high shear stresses such as wear rings, bushings and sleeves. But this occurred mainly due to the limitations of the thermal spray technology at the time. These poor-quality earlier coatings caused a major impact and, unfortunately, this negative impression still lingers today. The key lesson learned is that poorly prepared surfaces will, inevitably, lead to lack of adhesion and thus delamination of the coating.

Thermal spray coating technology has, however, made such rapid advancements, particularly via the emergence of the high-velocity oxy-fuel (HVOF) process, that the bond strength between the coating to the substrate now exceeds the bond strength of most epoxy adhesives used for the adhesion testing of these coatings.

The HVOF coatings of today are successfully applied to a variety of substrates and typically exhibit higher densities, superior bond strengths – typically greater than 80 MPa – and less decarburisation than many of the other thermal spray processes. This is due to the higher particle impact velocities and the relatively low peak particle temperatures associated with the HVOF process.

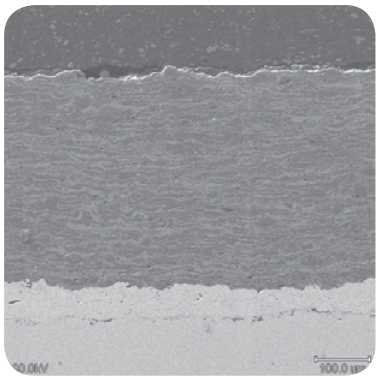
Coating adhesion strength, defined as the bonding between the coating and the substrate, and the coating microstructure are both strongly influenced by the residual stresses present in a coating. The level of residual stress can change the coating-substrate interface significantly and create delamination that can lead to spallation, where fragments of the coating are ejected (spalled) due to impact or stress.

Compressive residual stresses at the interface inhibit the formation of through-thickness cracks and improve adhesion bonding and fatigue strength. The adequate bonding of the coating is extremely important for the use of thermal spray coatings in engineering applications and all factors that affect the adhesion of a thermal spray coating have to be identified and controlled to ensure the adhesion strength.

The adhesion of the coating, however, is not solely dependent on the coating-substrate interface, but also on bonding between the sprayed particles. The two main types of coating failure are cracking and de-bonding. The characterisation of thermal spray coatings – through the use of measurement methods like the adhesion test in accordance with EN 582/ASTM C633, and the micro indentation test – is critical in defining coating quality.

To obtain a complete picture of the adhesion of thermal spray coatings, the influence of the base material, as well as

Adhesion tests in accordance with EN 582/ASTM C63 (above), along with the micro indentation tests are critical in defining coating quality.



While thermal spray coatings do not produce a metallurgically fused bond between the substrate and the coating, the bond strength between an HVOF coating and the substrate often now exceeds that of the epoxy adhesives used for adhesion testing.

the degree of surface roughness prior to thermal spraying, should be evaluated together with testing for the adhesion strength of the coatings. Surface contaminants, especially for HVOF coatings, are not solely responsible for low bond strength. Factors such as residual stresses due to incorrect spraying parameters – insufficient pre-heat, excessive inter-pass temperature, excessive deposition rates, improper sized powder or improper/over grit blasting – can all contribute to a decrease in the adhesion strength of HVOF thermal spray coatings.

The importance of proper surface preparation and adequate thermal spray process control cannot be overemphasised. Although it has been observed that for HVOF coatings, surface contamination might not be the most important factor, good practice in thermal spraying is to ensure that surface contamination is prevented and adequate process control is maintained during the thermal spraying process. Prepared surfaces, for example, should never be handled by an un-gloved hand and has to be cooled down within a maximum of one hour.

The HVOF coatings of today are successfully applied to a variety of substrates and typically exhibit higher densities, typical bond strengths greater than 80 MPa and low decarburisation levels.

Conclusion

A skilled spray coating operator will ensure that both surface preparation and coating application is done in a manner that will guarantee that the thermally sprayed coating does not chip off. If one experiences chipping in an application, the service quality of the thermal spray coating supplier needs to critically be evaluated. If done properly using an appropriate modern process, thermal spray coatings should never chip off.

References

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