MASTERBOND®
CASE STUDY

EP15ND-2: Used in a Comparison of Tests Evaluating the Bond Strength of Thermal Sprayed Coatings

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Overview of EP15ND-2

Master Bond EP15ND-2 is a single component, heat curing epoxy specifically designed for testing the strength of thermal sprayed coatings as indicated by ASTM C633. Featuring exceptionally high tensile strength exceeding 12,000 psi, as well as unlimited working life at room temperature, the formulation is 100% reactive, forming dimensionally stable bonds with minimal shrinkage upon cure. In this study, EP15ND-2 was utilized per the ASTM C633 test to analyze the tensile strength of a wide variety of thermal sprayed coatings.

Application

Scratch testing is frequently used to determine the strength properties of thin coatings, but for thick, thermal sprayed coatings, the accepted protocol to determine the strength is ASTM C633. However, the authors of this study attempt to develop an appropriate scratch test for thermal sprayed coatings, as scratch testing is simpler and would "reduce testing time and cost"[1] compared to the conventional ASTM protocol. By testing a variety of thermal sprayed coatings using both methodologies, the authors aim to determine the validity of the scratch test by correlating the results of the two techniques, as well as exploring any trends discovered. Since the ASTM C633 protocol requires a high tensile strength adhesive to prepare samples for testing, the authors used EP15ND-2 for this purpose.

Key Parameters & Requirements

The study investigated a variety of materials, selected to represent frequently used commercially available thermal sprayed coatings. All coatings were thermally applied, using spraying techniques appropriate for the material type, to a stainless-steel substrate with a high surface roughness to ensure bonding (**Table 1**). After spray coating, each specimen type was further prepared in two different ways as the scratch and ASTM tests have different requirements. For the scratch test, the specimens were mounted in an epoxy resin, whereas for the ASTM C633 test, the specimens were prepared per the protocol, using EP15ND-2 as the adhesive.

Table 1: Coating type and spray techniques.[1]

Coating Type	SPRAYING TECHNIQUES		
	Electric Arc Spray (EAS)	Plasma Spray (PS)	High Velocity Oxygen Fuel (HVOF)
Mo		Mo	
Mo-25%NiCrBSi		Mo-25%NiCrBSi	
Mo-50%NiCrBSi		Mo-50%NiCrBSi	
Mo-75%NiCrBSi		Mo-75%NiCrBSi	
NiCrBSi		NiCrBSi	
NiCrA1Y		NiCrA1Y	
NiCrA1Y			NiCrA1Y
ZrO_2 – Y_2O_3		ZrO_2 – Y_2O_3/NiCrA1Y	
Al_2O_3 – 40%TiO_2	NiAl	Al_2O_3 – 40%TiO_2	

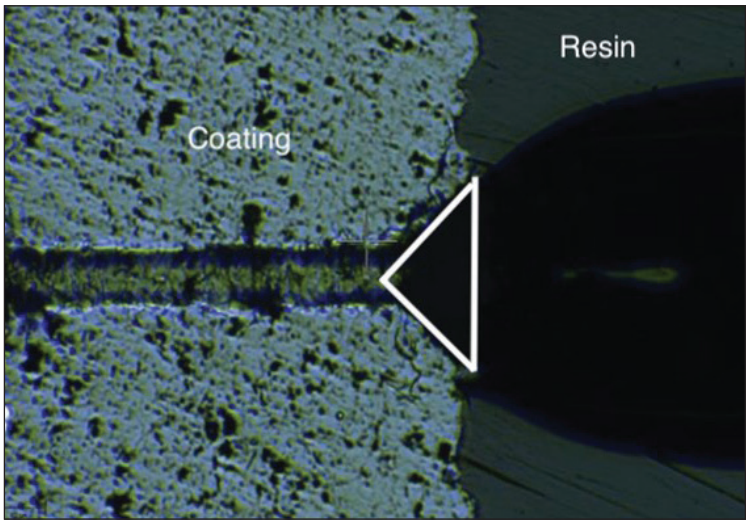

Figure 1 A cone area projected on a cross-section of a ZrO_2- Y_2O_3 coating after performing the scratch test.[1]

The scratch test developed in the study employed a diamond indenter (radius of 200 µm) for Rockwell hardness testing. The indenter was drawn across the cross-section of the specimen, from the substrate through the coating into the epoxy, with a load of 16N at a rate of 3 mm/min. The cone area left by the indenter is then measured and inversely correlated to the cohesive strength of the coating, with larger areas representing lower cohesive strength (***Figure 1***). The ASTM C633 test was carried out using a tensile strength testing machine (Instron 8801) at a 10,000-kg load with a rate of 1 mm/min.

Results

In order to supplant the standard ASTM C633 test for adhesion or cohesion strength of thermal sprayed coatings, the results of the scratch test must correlate with ASTM C633 findings. However, as can be seen from the results of the two different protocols (***Figure 2***), there is no correlation between cone area and tensile bond strength as measured by ASTM C633. For example, the HVOF NiCrA1Y specimen had a tensile

bond strength of more than double of the Mo specimen (75 and 32 MPa respectively), but these coatings had similar cone areas of 13 and 14 mm^2 respectively, leading to the conclusion that there is no apparent relationship between the two measurements. In fact, the authors hypothesize that the discrepancies in the results arise because the two tests measure different aspects of the cohesion/adhesion phenomena. The scratch test "induces a cohesive failure through the thickness of the coating" whereas ASTM C633 "measures the lowest strength across the coating, which in thermal sprayed coatings tends to be at the substrate-coating interface,"[1] indicating that the scratch test measures cohesion, whilst the ASTM test "measures mainly the adhesive strength of the coating."[1] While the results show that it may be possible to use the scratch test to compare cohesive bond strength of similar materials, this test cannot be used to compare cohesion strength between different materials, and it cannot be used for measuring adhesion at all. Therefore, the scratch test developed in this study cannot replace the more robust ASTM C633, which remains the primary protocol for accurately testing cohesive and adhesive strength of thermal sprayed coatings.

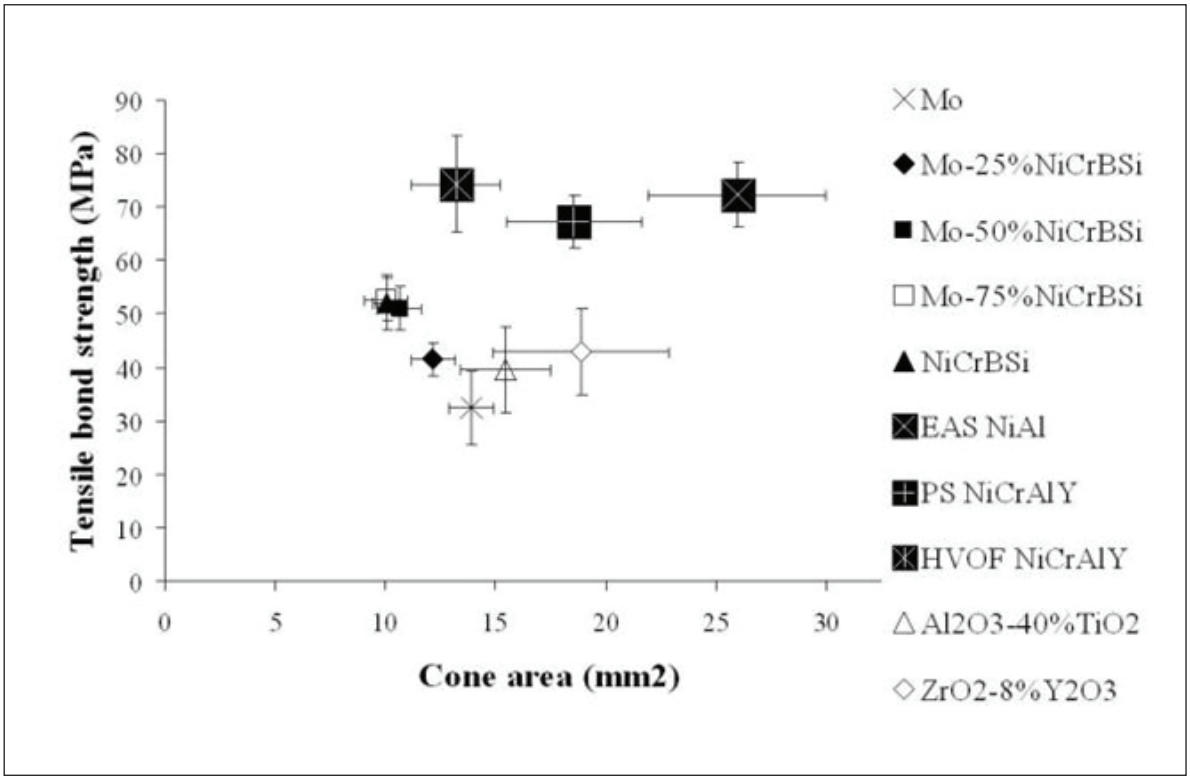

Figure 2 Correlation of cone area to tensile bond strength.[1]

References

[1] Koipraset, H., Thaiwatthana, S., Sheppard, P. (2015, Jan 12-16). Scratch Testing for Evaluating Cohesive Bond Strength of Thermal Sprayed Coating. The International Symposium on Fusion Science and Technology. Phra Nakhon Si Ayutthaya, Thailand.