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Bond Strength in Thermally Sprayed Gas Turbine Shafts

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***Abstract*—**In this paper, the bond strength of thermal spray coatings in high speed shafts has been studied. The metallurgical and mechanical studies has been made on the coated samples and shaft using optical microscopy, scanning electron microscopy (SEM).

***Keywords*—**Thermal spray, Residual stress, Wear mechanism, HVOF, Gas compressor shafts

I. Introduction

THERMAL spray processes are widely used to deposit protective coatings in a large variety of applications such as power plants, oil drilling, turning, cutting and milling, where abrasion, erosion and other forms of wear exist. Over the last years, the substitution of hard chromium plating has been promoted due to the new legislation concerned to hazardous wastes of Galvanic Industries. Thermal spray technology has been proposed as an alternative to hard chromium plating showing in some applications promising results. For instance, one requirement for tungsten carbide coatings is to have better wear and fatigue properties than hard chromium when applied in aircraft manufacturing [1], [2]. Thermal spraying with high velocity oxygen fuel (HVOF) has been very successful in spraying wear resistant WC–Co coatings with higher density, superior bond strengths and less decarburization than many other thermal spray processes. This is attributed mainly to its high particle impact velocities and relatively low peak particle temperatures [3]. As a class of hard composite materials of great technological importance, WC–Co powder cemented carbides are widely used by various thermal spray processes to deposit protective coatings in a large variety of applications such as power plants, oil drilling, turning, cutting and milling, where abrasion, erosion and other forms of wear exist [4]. Less attention has been given to develop thick coatings for repair applications, which is significant interest for the aerospace industry. One challenge is to control the residual stresses through the deposit thickness when a coating to be sprayed is several millimeters thick, and to understand the relationship between these stresses and coating adhesion. The adhesion strength of a coating is depends on the bonding between the coating and substrate as well as on the coating microstructure. Both the bonding and the microstructure are strongly influenced by residual stress distribution. It is commonly known that the level of residual stresses can significantly change at the coating substrate interface creating delaminations, which in worst cases can cause spallation. Compressive residual stresses at the interface are known to inhibit the formation of through thickness cracks and to improve adhesion bonding and fatigue strength [5], [6].

In this study the bond strength of thermal spray coatings in high speed shafts has been studied. The metallurgical and mechanical studies have been made on the coated samples and shaft using optical microscopy, scanning electron microscopy (SEM).

II. Experimental Procidure

The coating was deposited industrially by employing a HVOF gun type Metjet III onto AISI 1045 steel substrate. Fig.1 shows the mechanism of deposition by High velocity oxy fuel process. Bonding strength samples were prepared according to ASTMC633. Before the deposition, substrate was grit blasted with SiC particles (16μm mesh) and ultrasonically cleaned in acetone. The WC-12Co powder used had a particle size between ~15 and 40μm. A spraying distance of 340±10 mm, a spraying angle of 90^o, kerosene flux of 25 l/min, oxygen flux of 83 l/min, were the main parameters indicated by the spraying company. Before deposition the substrate was grit blasted with alumina particles with 16μm mesh. The average roughness value (R_a), determined by optical profilometery. Coatings with thickness of 400±50 μm were thermally sprayed. In the as deposited condition, the coating had an average roughness of ~4 μm. Subsequently, the coating was ground in order to achieve uniform thickness of 160 μm. The roughness of as ground coating was ~0.2 μm. The coating hardness was 1000-1200 HV_{30N}. The microstructure of the coatings was inactivated by canning electron microscopy (SEM). The observations were done both on the cross section and the deposition top surface. The average coating porosity was determined by optical microscopy and image analysis of the cross section of the samples. The present phases in the powder and coating were investigated using X-ray diffraction.

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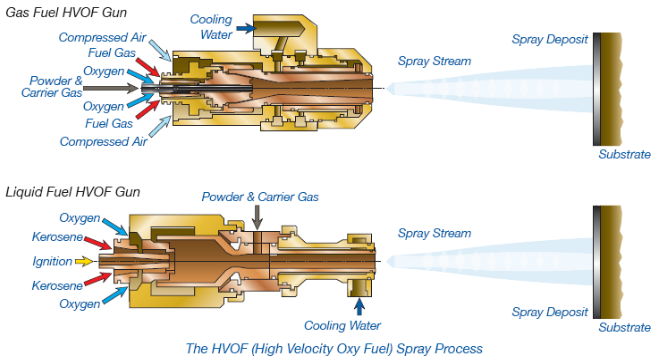

Fig.1: High velocity oxy fuel thermal spray

III. Bonding strength

In turbine and compressor and turbine tribosystem the mechanical property of component such as bonding strength, fatigue and residual stress have an important role in performance of repaired parts. Powder particles are mainly in solid state prior to impact on substrates in high velocity oxy fuel (HVOF) thermal spraying. The bonding between particles and substrates is critical to ensure the quality of coating. Bonding Mechanism from the Impact of Thermally Sprayed Solid Particles has been studied in year 2009 by S. GU and S. Kamnis[7]-[8]. Finite element analysis (FEA) model was developed to simulate the impingement process of solid particle impact on substrates. The numerical results confirm that in the HVOF process, the kinetic energy of the particle prior to impact plays the most dominant role in particle stress localization and melting of the interfacial contact region. The critical impact parameters, such as particle velocity and temperature, are shown to be affected by the shape of particles, while higher impact velocity is required for highly nonspherical powder. As mentioned in literatures the bonding strength is highly affected by the nature of residual stress in substrate-Coating interface. The ASTM C633 standard is used to evaluate the adhesive and cohesive strength of thermally sprayed coatings. The adhesive strength of binders is a important limitation in test procedure. (Fig.2)

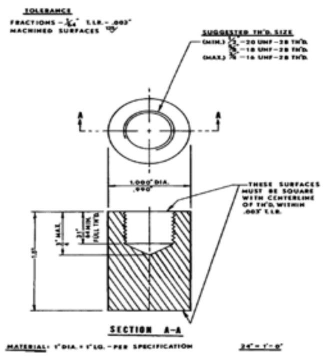

Fig. 2 bonding strength test sample

III. Result and discussion

Fig. 3 shows the SEM topography of the worn surface in gas turbine. The wear mechanism is seamed to be abrasion wear. The abrasion wear resistance is enhanced by applying a hard coating. Fig. 4 shows the SEM micrograph of WC-12%Co powder to be used. The shape of powder particle is spherical in range of 12-40 µm. As mentioned in [7-8] the spherical particles require less kinetic energy for good adhesion on the substrate.

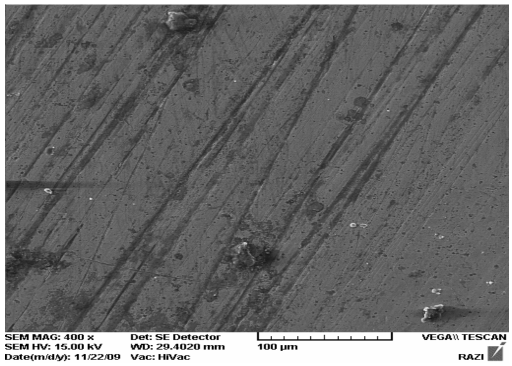

Fig. 3 SEM topography of worn shaft surface

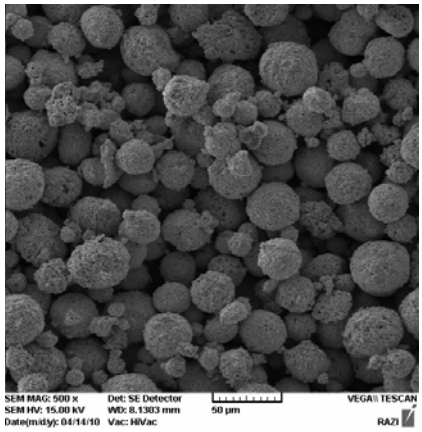

Fig. 4 powder Morphology by SEM micrograph

Fig.5 shows the SEM topography of as sprayed coating in high magnification. The porosity is intrinsic property in thermal spray coating because of process nature but must be limited by controlling the process parameters.

Fig. 6 illustrates a general view of the standard coated sample after adhesion test. The failure occurred from binder-coating interface in 75 MPa. It means that the bond strength of thermally sprayed coatings by high velocity oxy fuel have adhesive and cohesive strength more than 75 MPa. This is because of high supersonic velocity impact of hard particles to the substrate in this process. The compressive stress induced in coating and substrate surface enhance the mechanical property of coatings.

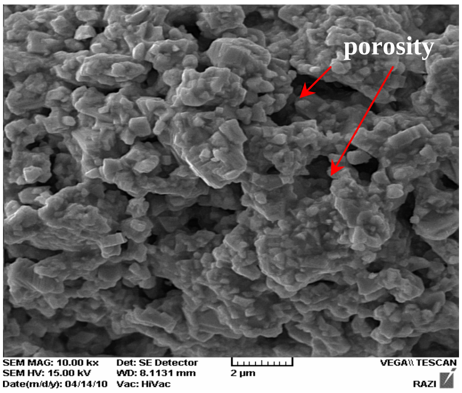

Fig. 5 SEM topography of as sprayed coating

Fig. 6 bonding strength test sample after bond test

The turbine components were coated by HVOF thermal spray shaft at same condition after surface preparation. The coating was ground to desired roughness and dimensional tolerances. The shafts have an excellent performance in their service.

IV. Conclusion

The repairing and bond strength of turbine component have been investigated. High velocity oxy fuel thermally spraying process and metallurgical analyses are employed for this purpose. A summery of conclusions is as follow:

- The WC-12Co coating can be used for resistance against abrasion wear mechanisms.
- High velocity oxy fuel thermal spray is a excellent choice for renewing the worn high speed shafts because of good adhesion and cohesion strength as well as compressive residual stress.
- WC-12Co cermet coatings have bonding strength more than 75 MPa conditions that used in repairing of turbine and compressor components.
- Developing A new approach – binder independent- for testing of adhesive and cohesive strength is an important necessity.

References

[1] U. Erning, M. Nestler, Proceedings of United Thermal Spray Conference (UTSC 99). Düsseldorf, March 1999, p. 462.
[2] T. Sahraoui, S. Guessasma, N.E. Fenineche, G. Montavon, C. Coddet,Materials Letters 58 (2004) 654.
[3] Y. Qiao, Y.R. Liu, T.E. Fischer, Sliding and abrasive wear resistance of thermalsprayed WC–Co coatings, Journal of Thermal Spray Technology 10 (2001) 118– 125.
[4] T. Sahraoui, S. Guessasma, N.E. Fenineche, G. Montavon, C. Coddet, Materials Letters 58 (2004) 654–660.
[5] R.J.K. Wood, B.G. Mellor, M.L. Binfield, Wear 211 (1997) 70–83.
[6] T.W. Clyne and S.C. Gill, Residual Stresses in Thermal Spray Coatings and Their Effect on Interfacial Adhesion: a Review of Recent Work, J. Therm. Spray Tech., 1996, 4, p 401-409.
[7] S.kamnis, S. Gu, Journal of thermal spray technology, vol. 19(1-2)2010, p31-41
[8] S.Kamnis, S.Gu, T.J.Lu, comput. Mater.sci43(2008)1172-1182