World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:4, No:9, 2010

Open Science Index, Mechanical and Mechatronics Engineering Vol:4, No:9, 2010 publications.waset.org/13803.pdf

Application of HVOF Thermal Spraying in High Speed Gas Compressor Shafts

M.Jalali Azizpour, S.norouzi, H.mohammadi majd, H.Talebi and A.Ghamari

***Abstract*—**In this paper, the application of thermal spray coatings in high speed shafts by a revolution up to 23000 RPM has been studied. Gas compressor shafts are worn in contact zone with journal therefore will be undersized. Wear mechanisms of compressor shaft were identified. The predominant wear mechanism is abrasion wear. The worn surface was coated by hard WC-Co cermets using high velocity oxy fuel (HVOF) after preparation. The shafts were in satisfactory service in 8000h period. The metallurgical and Tribological studies has been made on the worn and coated shaft using optical microscopy, scanning electron microscopy (SEM) and X-ray diffraction.

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

I. INTRODUCTION

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 repairing of high speed compressor shafts (up to23000 rpm) using high velocity oxy fuel thermal spraying has been investigated. The metallurgical and Tribological studies was made on the worn and coated shaft using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction.

II. EXPERIMENTAL PROCIDURE

The coating was deposited industrially by employing a HVOF gun type Metjet III onto AISI 1045 steel substrate samples of 10×10×4 mm^3. 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}.

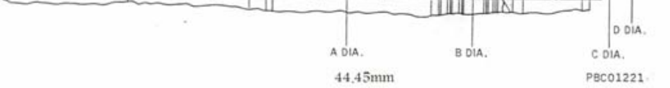

Fig. 1: Gas compressor shaft (subjected workpiece)

M.Jalali Azizpour is with the Islamic Azad University, Ahwaz branch. Iran.(corresponding author to provide phone: +986113358491; fax: +986113358490; e-mail: m_jpour@ yahoo.com).

S. Norouzi is with nushirvani Babol University of Technology.

H. Mohammadi majd is with the production technology research institute branch of ACECR

H.Talebi and A. Ghamari are with the SETESCO, Ahwaz, Iran.

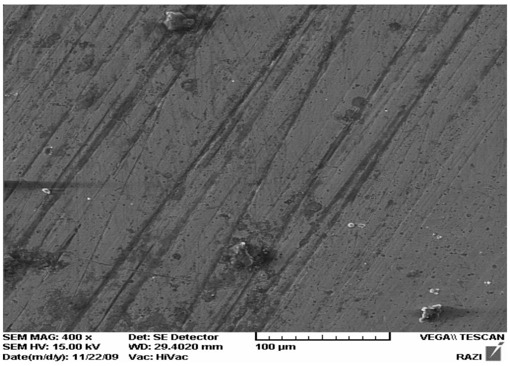

Fig. 2: SEM topography of worn shaft surface

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.

III. RESULT AND DISCUSSION

Fig. 1 and Fig. 2 show the gas compressor and SEM topography of the worn surface shaft – bearing contact zone. The wear mechanism is seamed to be abrasion wear. The abrasion wear resistance is enhanced by applying a hard coating such as WC-Co cermets. Fig.3 illustrates the result of the x-ray analysis. This figure presents a diffraction pattern of the WC-12% Co powder which clearly shows that phases present are C, Co and WC. The diffraction pattern of the coating, shown in Fig.4, illustrates that it has a complex composition involving multiple phases such as WC, W_2C and Co_6W_6C. It is believed that such phases arise as the result of the decomposition of WC into W_2C and Co_3W_3C, due to the complex interaction between the WC-Co elements and oxygen during deposition [7]. Also it is important to mention that decarburization of WC represents a key factor in the decrease of the coating hardness and wear resistance.

Fig. 5 shows the SEM micrograph of WC- 12Co powder to be used. The shape of powder particle is spherical in range of 12-40 µm. As mentioned in [8] the spherical particles require less kinetic energy for good adhesion on the substrate. The computational analysis of HVOF sprayed WC-Co particles shows that most particles are in solid state prior to impact for typical stand-off distance of 0.32m and only particles smaller than 5 µm are in liquid form[9]. Fig.6 shows the SEM topography of as sprayed coating in high magnification.

The porosity is intrinsic property in thermal sprat coating because of process nature but must be limited by controlling the process parameters. The rough surface must be grinded to achieve the desired roughness (~2 µm).

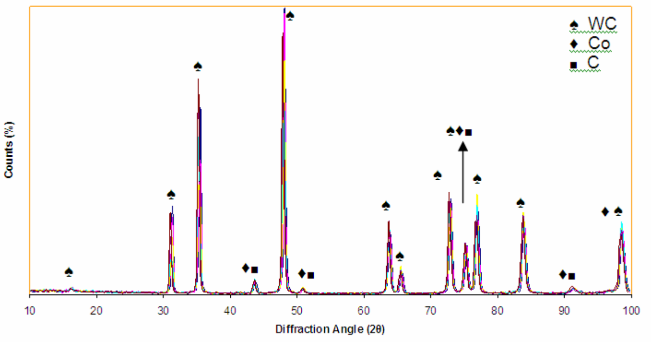

Fig3: X-ray diffraction pattern of powder

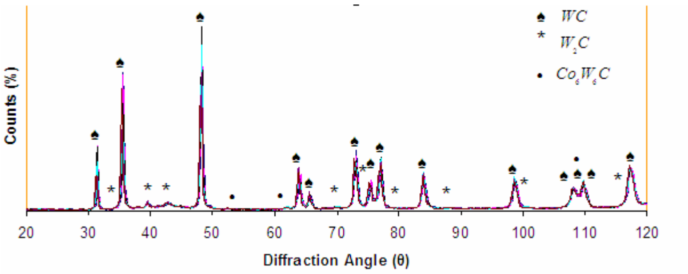

Fig. 4: X-ray diffraction pattern of coating

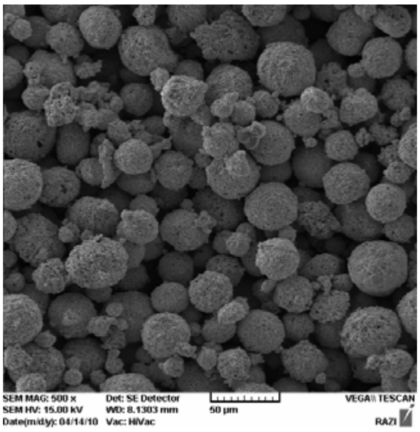

Fig. 5: powder Morphology by SEM micrograph

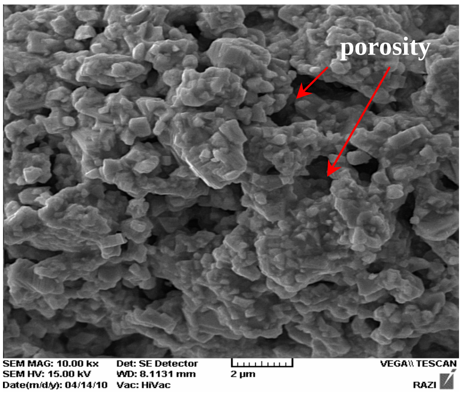

Fig. 6: SEM topography of as sprayed coating

Fig. 7 illustrates a general view of the coating after metallographic preparation. The WC-12Co HVOF thermally sprayed coating appear to be quiet dense. The presence of lamella boundaries, pores and equiaxial WC grain of different size embedded in the Co matrix is apparent. The cleaning of substrate surface after grit blasting is of great important. The Alumina inclusion that has reminded from sand blasting process is shown in Fig 8. Any failure that causes rebounding of coating can begin from this inclusion. Proper ultrasonic cleaning should be useful for cleaning the substrate surface from penetrated particle.

The compressor shaft was coated by HVOF thermal spray shaft at same condition after surface preparation. The coating was ground to desired roughness and dimensional tolerances. After electrically run out measurement the shaft assembled in the gas compressor. The shaft has an excellent operation in 23000 RPM after 8000 hours in service.

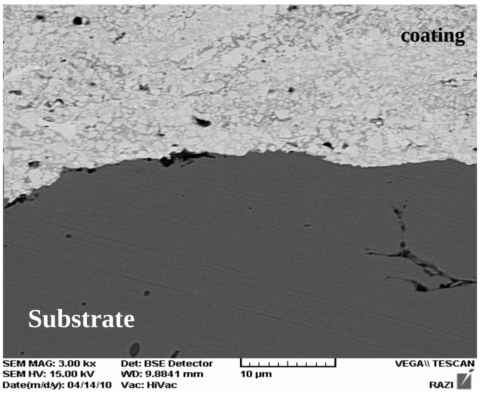

Fig. 7: General view of the coating-substrate cross section

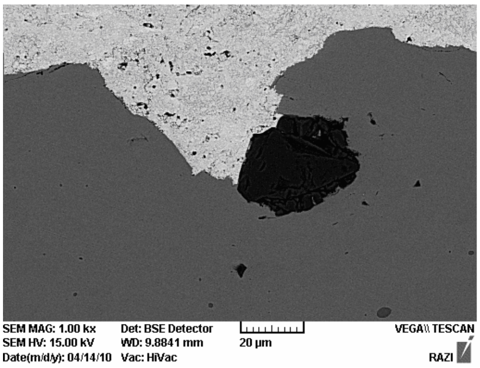

Fig. 8: The Alumina inclusion in substrate surface

IV. CONCLUSION

The repairing of high speed shafts has 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.
- Optimization of process parameter is essential to reduce the porosity and improve the mechanical and tribological property of coating-substrate system.

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] Q.Yang, T. Senda,A. Ohmori, Wear 254(2003)23.
[8] S.kamnis, S. Gu, Journal of thermal spray technology, vol. 19(1-2)2010, p31-41.
[9] S.Kamnis, S.Gu, T.J.Lu, comput. Mater.Sci.43(2008)1172-1182.