Performance Evaluation of Carbide Coated Titanium Alloy (Ti6Al4V) using Detonation Gun Process

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Abstract
Titanium alloy (Ti6Al4V) has an excellent combination of properties like high melting point ,low density and good corrosion resistance. However in many cases the application is limited because of their poor tribological properties. In this work a surface modification (Detonation Gun Spraying) is carried out to improve the tribological properties of Ti6Al4V. In this coating process tungsten carbide (WC-Co-Cr) coating powder is used to improve the properties of Ti6Al4V. This Detonation Gun spraying is done at different stand-off distance. The phase and microstructure of coated substrate were characterized by using XRD and SEM analysis. The surface roughness and microhardness were determined using Talysurf profilimeter and microhardness tester respectively. Result that obtained showed the WC-10Co-4Cr coated Ti6Al4V with 165 stand-off gave better wear resistance with their other coated material.

Keywords- Titanium alloy (Ti6Al4V) Carbide Powder , D-gun Coating, SEM, Microhardness, Image Analyzer

1. INTRODUCTION

Titanium and its alloys are widely used in Aerospace and mechanical application due to their good fatigue strength, fracture toughness and excellent corrosion resistant currently it is commonly used in Aerospace, Automobile and chemical process industry [1,2]. Use of titanium alloys in automotive application is gaining popularity [3,4] because due to light weight it has the potential to replace heavier steel components like connecting rods, pistons muffler and intake valves .

Apart from high cost the main reason of limited use titanium alloys are due to their poor tribological properties, because it is susceptible to failure by galling and high friction coefficient. when rubbing against common bearing material [5,6].

Therefore various coating and surface treatments method have been developed to improved the tribological properties of titanium and its alloys. For surface engineering of titanium alloy (Ti6Al4V) D-gun thermal spray coating with WC-Co-Cr coating powder is discussed in this paper. D-gun spraying process is one of the most promising thermal spraying techniques, variety of powders like cermets, ceramics, carbides metals and alloys can be used as coating powders, it was used to produce high quality wear resistance coating. Its gives and extremely good adhesive strength, low porosity and coating surface with compressive residual stresses. In D-gun spraying process, feed stock powder is strongly plasticized and accelerated to high velocities and then used to impinge the substrate the feedstock powder solidified rapidly to form flattened particles [7]. In this paper, WC-10Co-4Cr powder coating was prepared by D-gun spraying on Ti6Al4V titanium alloy substrate, and Vickers hardness and sliding wear behavior of the substrates were investigated at different spraying distance. Coating was performed with140mm, 165mm, 170mm, 190mm spray stand-off. Gritt blasting was done to get an optimum surface roughness and promote adhesion between coating and substrate.

2. EXPERIMENTAL PROCEDURE

2.1. Substrate

The substrate material used in present study was an Equiaxed alpha with intergranular beta titanium alloy(Ti6Al4V). The specimen were machined to a block of 25mm× 25mm × 10mm. Prior to testing they were polished and cleaned with acetone in an ultrasonic cleaner.

2.2. Materials and Coating Deposition

Titanium alloy (Ti6Al4V) was used as the substrate. WC-Co-Cr was used as coating materials. The chemical composition of coating powders WC-Co-Cr was presented in Table 1 with average particle size of 30 µm. In the present investigation 300µm thick WC-Co-Cr coating was performed by D-gun process. To get an optimum surface roughness and promotes the best attainable adhesion between coating and substrate grid blasting was performed. The process parameter for D-gun process is listed in Table 2.

Table. 1. Chemical composition of WC-Co-Cr

Constituents	%
WC	86
Co	10
Cr	4

Table. 2. Spraying parameter in this study

Parameters	Quantity
Oxygen flow rate (L/h)	4800
Acetylene flow rate(L/h)	1600
Nitrogen flow rate(L/h)	700
Spray distance(mm)	140,165,170,190
Spray angle(deg.)	90

2.3. Characterisation of Coatings

Microstructural characterization studies were conducted on WC-Co-Cr and Cr3C2NiCr samples. This is accomplished by using scanning electron microscope and metallurgical image analyzer. X ray diffraction pattern and EDS analysis were done for coating powder samples.

2.4. Microhardness

Microhardness tests were performed on coating cross section by Vickers hardness testing with load 5N and dwell period of 5s. Using microhardness tester model MHV2000. An average of four reading is reported.

2.5. Wear Testing

According to ASTM G99-04 standards The sliding wear test were conducted on a pin on disc testing machine (DucomTR201). The cylindrical pin (diameter 10mm and 30mm height)of coating were used for pin on disc operation. Wear test is carried out at 600rpm sliding speed at a load 50N and sliding distance 1500m. EN3 steel was used as a counter face material.

3. RESULT AND DISCUSSION

3.1. Coating Characterization of WC-Co- Cr Coating powder

Fig. 1 shows the microstructure of powder sample and the average size of the particles was 30 µm. Fig. 2 show the EDS image of WC-Co-Cr coating powder. It gives the count per second value for powder molecules with respect to per electron volt.

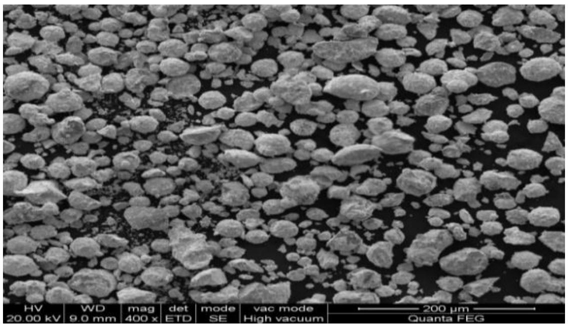

Fig. 1. SEM image of WC-Co-Cr coating powder

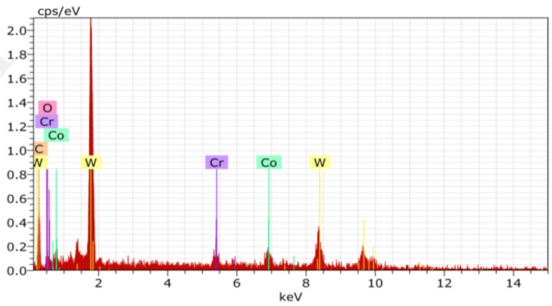

Fig.2. EDS analysis of WC-Co-Cr coating powder

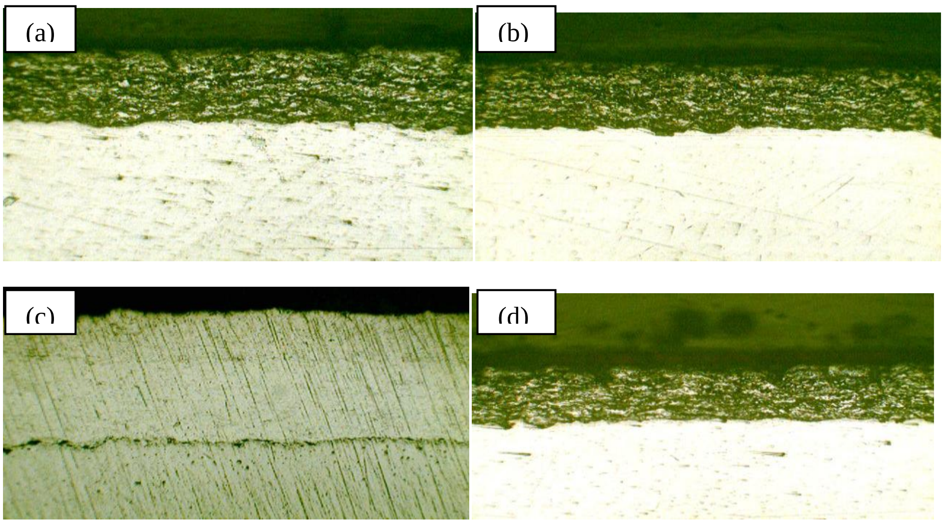

Fig. 3. Cross sectional microstructure of coating by image analyzer at different stand-off distance with 100X magnification (a)140mm (b)165mm (c) 170mm (d) 190mm.

Fig. 3a shows cross sectional microstructure of the WC-Co-Cr coating at 140mm spray stand-off.it provides uniform coating with less than 2% porosity and cracks observed on surface of coating. Fig. 3b shows cross-sectional microstructure of coating at 165mm spray stand-off, it provides coating with less than 2% porosity and no cracks observed. Fig. 3c shows microstructure of coated substrate at 170mm spray stand-off Fig. 3d shows microstructure of coating at 190mm spray stand-off, it provides uniform coating with less than 2% porosity, crack observed on surface of coating and interface between coated and base metal observed. Fig.4 shows the microstructure of coating surface by using SEM analysis at 4000x magnification.

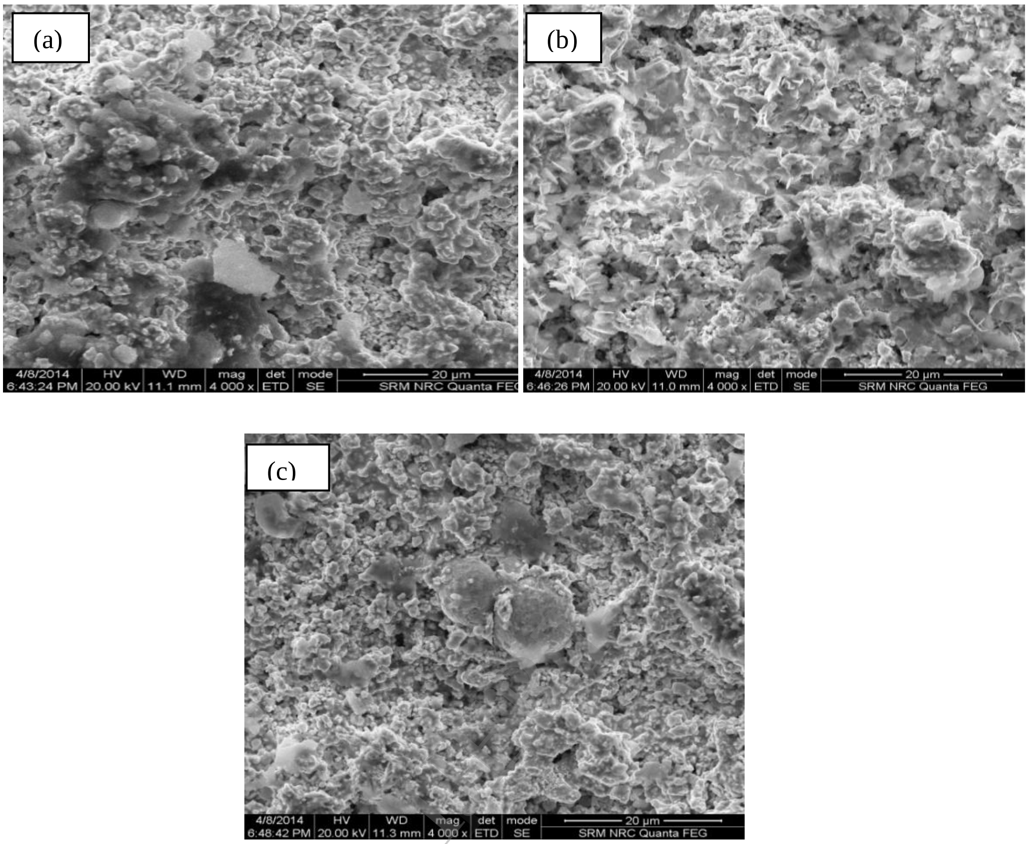

Fig.. 4. SEM image of coated surface at different stand-off distance (a)140mm (b) 165m (c) 190mm

3.2. Microhardness

Fig. 5 shows the Vickers microhardness values for different spray stand-off distance between 140mm to 190mm. it was observed that the hardness increases with the increasing spray stand-off. The hardness increases gradually and reaches the maximum hardness at 190mm spray stand-off.

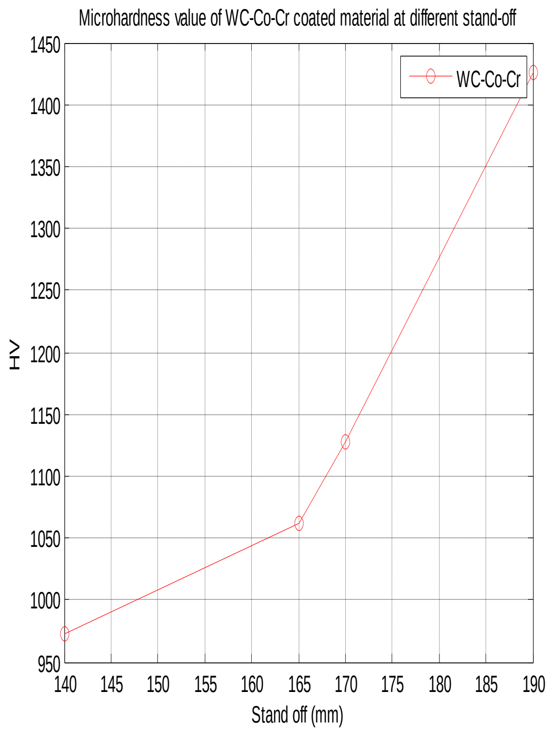

Fig. 5. Microhardness values of WC-10Co-4Cr coated samples at different stand-off distance

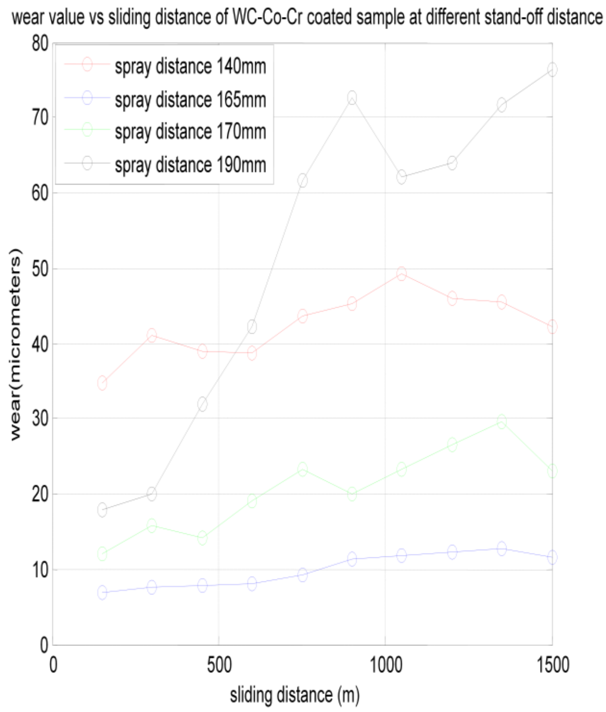

Fig. 6: Variation in wear during sliding for WC-10Co-4Cr coating at different stand-off distance.

3.3. Wear and Frictional Force Behavior

Wear and frictional force of the coated sample and sliding distance were shown in Fig. 6 and Fig. 7. It was observed that the wear and frictional force is minimum at 165mm spray stand–off, and wear is maximum at 190mm spray stand-off and frictional force is maximum at 170 mm spray stand-off.

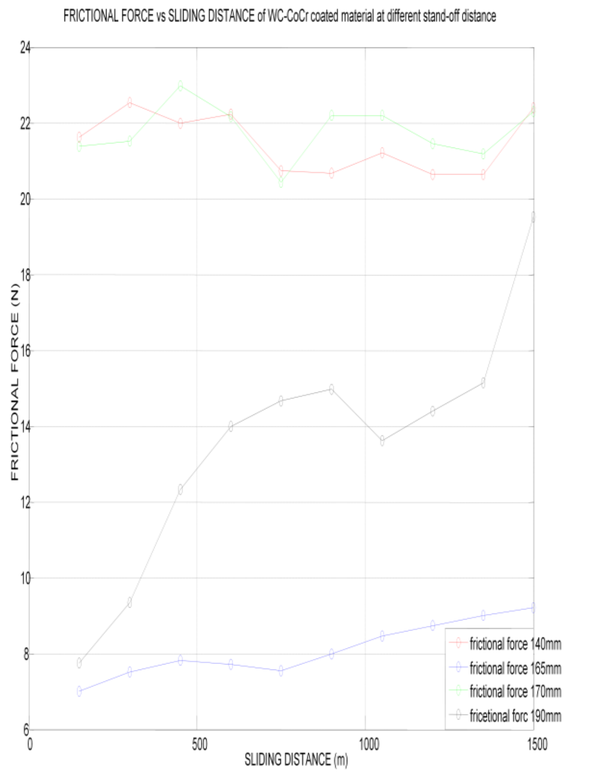

Fig. 7: Variation in frictional force during sliding for WC-Co-Cr coating at different Stand-off distance.

4. CONCLUSION

The present work was conducted to study the tribological behavior of detonation gun sprayed WC-10Co-4Cr coating at stand-off distance 140mm, 165mm, 170mm, 190mm.. The following conclusions can be drawn as follows.

Microhardness of WC-10Co-4Cr coating is maximum at a spraying distance of 190mm. It increases with the stand-off distance from 140mm to 190mm. Wear and frictional force are minimum for WC-10Co-4Cr coated sample at 165mm spraying distance. The microstructure of the coatings is also dependent on the physical characteristics such as porosity, phase transformations of the coating materials during spraying at different stand-off distance. Tungsten carbide coatings are more dense coating. Porosity is less than 2% for WC-10Co-4Cr coated sample. WC-10Co-4Cr Coating at 165 mm distance shows uniform coating with less than 2% of Porosity and no cracks.

REFRENCES

[1] K.W. Bird, Resista-clad titanium in the chemical process industries, in: Proceedings of the 1998 TMS Annual Meeting, Febrary 16, 1998–Febrary 19, 1998, Minerals, Metals and Materials Society (TMS), San Antonio, TX, USA, 1998, pp. 245–253.
[2] R.R. Boyer, Overview on the use of titanium in the aerospace industry, Materials Science and Engineering A A213 (1996) 103–114.
[3] Y. Yamashita, I. Takayama, H. Fujii, T. Yamazaki, Applications and Features of Titanium for Automotive Industry, Nippon Steel Technical Report, 2002 pp. 11–14.
[4] O. Schauerte, Titanium in automotive production, Advanced Engineering Materials 5 2003 411–418.
[5] K. Faller, F. Froes, The use of titanium in family automobiles: current trends, JOM Journal of the Minerals Metals and Materials Society 53 27–28 2001.
[6] K.G. Budinski, Tribological properties of titanium alloys, Wear 151 1991 203–217.
[7] Wang Tie-Gang, Zhao Sheng-Sheng, Hua Wei- gang, design of separation device used in D-gun spraying system and its effects on the performance of WC-Co coatings, Surface & Coating Technology 2009 203 1637-44.