ISSN (ONLINE) : 2395-695X
ISSN (PRINT) : 2395-695X
Available online at www.ijarbest.com

International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
Vol. 1, Issue 3, June 2015

An investigation of dry sliding wear behavior of hybrid (Al_2O_3 +TiO_2) coating on austenitic stainless steel

D.Sudhakar[a], D.Jeyasimman[a], M.Duraiselvam[b], R.Thiyagarajan[a]
[a]Department of Mechanical Engineering, Periyar Maniammai University, Thanjavur - 613403, Tamil Nadu, India.
[b]Department of Production Engineering, National Institute of Technology, Tiruchirappalli – 620015, Tamil Nadu, India.

***Abstract*— Thermal coating methods are a group of coating processes those available functional surfaces to prevent or improve the performance of a parent metal or component. However, there are various thermal spray coating processes, D-gun coating is one which considered being unique coating method. This method is used where the materials are subjected to wear, and tear, corrosion and erosion. This type covers coating of at most all engineering materials using metals, composite materials and cermets. The objective of the present study was to making of D-gun coating on alpha ferrite stainless steel (AISI 304) using hybrid (Al_2O_3+TiO_2) coating systems. Usually, AISI 304 stainless steel is used in high temperature applications caused by its less sensitive to heat because of low carbon content. In hybrid (Al_2O_3+TiO_2) coating of on this steel parent metal improves wear, corrosion and high temperature oxidation and erosion; since it can be used as reciprocating spindle, exhaust valve, screw conveyor etc. In the present work, the wear and tribological behavior of AISI 304 austenitic stainless steel and improving the wear resistance of hybrid (Al_2O_3+TiO_2) coating on it and estimating the wear performance and wear mechanisms have been discussed. In the present study, various experiments have been conducted at constant sliding distance (1500 m) and at constant sliding velocity of 1m/sec at two different temperatures (room temperature and 100^{0}C) with different loads of (10 N and 15 N).**

Key Words: Pin on disc method; Dry sliding wear; SS 304; Friction coefficient; hybrid coating

I. INTRODUCTION

Wear is an interaction between two mating surfaces and related to removal or deformation of material as result of mechanical action of the opposite surface [1]. It is the gradual removal of material obtained at contacting surfaces in relative motion. While friction results in important energy losses, wear is associated with increased maintenance costs and costly machine downtime. If solid surfaces in relative motion are not separated in some way, wear can be expected. Lubricants are used to separate contacting surfaces in relative motion and thus to reduce wear. Lubricants may completely separate the surfaces, as in fluid film lubrication or allow solid-solid contact only at a restricted number of locations (mitigated solid contact) as in boundary lubrication. Wear phenomena are heavily influenced by the fact that most engineering surfaces are rough and hence surfaces come in contact at single asperities and the real area of contact is

usually much smaller that the nominal contact area. The variations of the friction coefficient and wear rate with the sliding distances for different normal loads and sliding velocities for AA 6061 nanocomposites with various reinforcements prepared by mechanical alloying were plotted and analyzed in the previous study [2]. The spray methods can be classified into different categories one which is commonly used for D-gun method for all industries and defense sector now days. Dry sliding wear behavior of Cr_3C_2-NiCr coating on austenitic stainless steel was analyzed by another previous study [3]. Fig.1 shows thermal spray coating process.

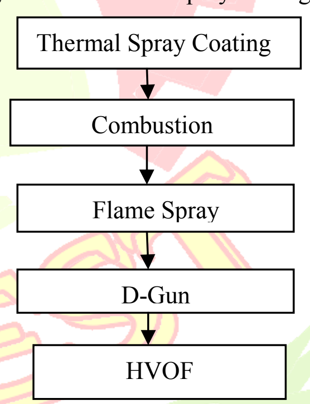


Fig.1 Thermal Spray coating Process

However, there are various authors [4-10] investigated the hybrid (Al_2O_3+TiO_2) spray coatings on metal substrate and tribological behavior of Al_2O_3/TiC composites [11-13] , the detailed investigation of dry sliding wear behavior of hybrid (Al_2O_3+TiO_2) spray coatings on AISI 304 stainless steel coating was not done. Because of the present study has been conducted for comparative study of surface coating analysis of coated and uncoated AISI stainless steel.

1.1 Detonation-Gun Spraying (D-Gun)

The detonation gun is considered the first high-velocity thermal spray process. It gives an extremely good adhesive strength, low porosity and coating surface with compressive

ISSN (ONLINE) : 2395-695X
ISSN (PRINT) : 2395-695X
Available online at www.ijarbest.com

International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
Vol. 1, Issue 3, June 2015

residual stresses. The detonation gun consists of a long water-cooled barrel with inlet valves for gases and powder. Oxygen and fuel (acetylene most common) is fed into the barrel along with a charge of powder. A spark is used to ignite the gas mixture, and the resulting detonation heats and accelerates the powder to supersonic velocity through the barrel. A pulse of nitrogen is used to purge the barrel after each detonation. This process is repeated many times a second. The D-gun method for thermal spray coating was shown in Fig.2.

1.2 Experimental setup and Theoretical Formulation

Wear experiments has been carried out by dry sliding contact Austenitic stainless steel 304 disc as counterpart on a pin-on-disk tribotester (TR-20M106) DUCOM. The pin-on-disk tribometer serves for the investigation and simulation of friction and wear processes under sliding conditions. It can be operated for solid friction without lubrication and for boundary lubrication with liquid lubricants. Thus both material and lubricant tests can be executed. According to the standard test [14] principle a stationary test specimen (pin or ball) with a defined normal force is pressed against the surface of another test specimen placed on the rotary disk.

Fig.2. D-Gun method for thermal spray coating.

The normal force is applied over the pin or ball by means of a set of dead weights 10 N and 15 N (other ranges under demand). This way of application allows a stable force during the test. The friction coefficient (μ) is determined during the test by measuring the friction force by means of the deflection of the elastic arm (strain gauges bonded on the elastic body of the arm convert it in a force sensor and allow the direct measurement of the frictional force. This option adds capacitive displacement sensor attached at the tribometer's arm carrier, for group specimen and ball or pin wears evaluation (as far as arm carrier's inclination is increased). To study the dry sliding wear behavior of the Cr coated and uncoated AISI 304 Austenitic stainless steel, wear test were carried out by using DUCOM TR-20M-106 Pin-on-disc wear testing machine (Fig. 3). The test was performed as per ASTM: G99.

The mass losses were calculated at every interval of sliding distance for different normal loads with respect to various sliding velocities. An X-Y plotter attached to the tester continuously recorded the coefficient of friction [14].

The coefficient of friction is

$$\mu = \left(\frac{F}{P}\right) \quad (1)$$

where F is the frictional force measured by the tester and P is the normal load on the specimen. The volume loss due to the wear test was calculated from the weight loss according to the following equation [14]:

$$Volume\ loss\,(mm^3) = \left(\frac{Weight\ loss\,(g)}{Density\,(g/mm^3)}\right) \times 1000$$

The wear tests were conducted five times for every pin and the obtained data were represented by the average value together with error bars. The wear rate was calculated from the following expression [14]:

$$Wear\ rate\ (mm^3/m) = \left(\frac{Volume\ loss\,(mm^3)}{Sliding\ disance\,(m)}\right) \times 1000$$

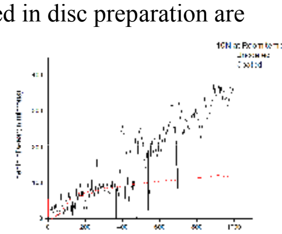
Fig. 3. Pin-on-disc apparatus for wear testing.

The pin material was 8 mm diameter and 30 mm length, pins were shaped from polished surface grinding machine shown in Fig. 4.

1.3 Preparation of counterpart material

The test specimens required to dry sliding wear test were in the form of pins and disc.

Steps involved in disc preparation are



1. The preparation of sample by cutting & machining

ISSN (ONLINE) : 2395-695X
ISSN (PRINT) : 2395-695X
Available online at www.ijarbest.com

International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
Vol. 1, Issue 3, June 2015

2. The samples were prepared to required dimensions and polishing.

Fig. 4. AISI 304 stainless steel Pin materials

AISI 304 stainless steel samples were made 3 mm thickness and finishing diameter to 90 mm the weighting 220 gm. The analytical instrument was used to measuring the weight balance and also for fixing the sample in tribotester for conducting the pin on disc wear test. Experimental parameters for coated and uncoated AISI 304 stainless steel were shown in Table 2.

Table 2 Experimental parameters for coated and uncoated AISI 304 stainless steel for 1m/s velocity, sliding distance 1500 m and track diameter 40 mm

Coated	Sl. No	Temp (°C)	Load (N)	Speed (RPM)	Time (Min)
	1	RT	10	477	16.40
	2	RT	15	477	16.40
	3	100	10	477	16.40
	4	100	15	477	16.40
Uncoated	1	RT	10	477	16.40
	2	RT	15	477	16.40
	3	100	10	477	16.40
	4	100	15	477	16.40

Fig. 7 shows the comparison between depth of wear and coefficient of friction (COF) of coated and uncoated AISI 304 stainless steel samples at 15 N in RT. Comparison between depth of wear and coefficient of friction coated and uncoated AISI 304 stainless steel samples at 15 N at 100°C was shown in Fig. 8. Depth of wear and coefficient of friction were less in uncoated AISI 304 stainless steel compared with coated AISI 304 stainless steel may be due to thermal expansion. Similar results were obtained in the previous study [3].

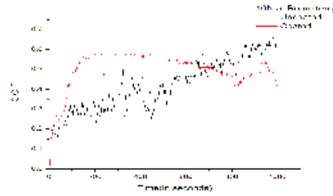


Fig. 5 Comparison between depth of wear and COF of coated and uncoated AISI 304 stainless steel samples at 10 N at room temperature.

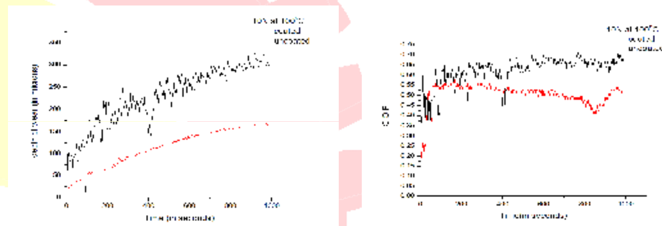


Fig. 6 Comparison between depth of wear and COF of coated and uncoated AISI 304 stainless steel samples at 10N at 100°C.

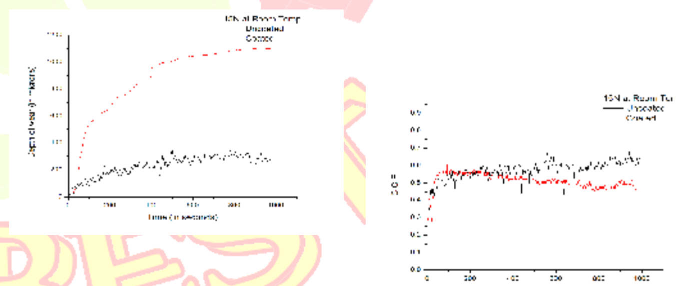


Fig. 7 Comparison between depth of wear and COF of coated and uncoated AISI 304 stainless steel samples at 15N RT.

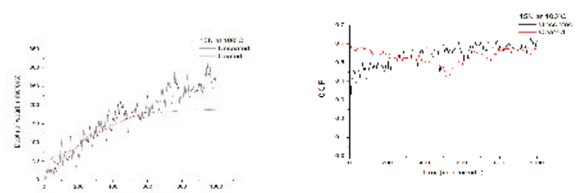


Fig. 8 Comparison between depth of wear and COF of coated and uncoated AISI 304 stainless steel samples at 15N with 100°C.

ISSN (ONLINE) : 2395-695X
ISSN (PRINT) : 2395-695X
Available online at www.ijarbest.com
International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
Vol. 1, Issue 3, June 2015

Pin volume loss with respect to temperature for coated and uncoated AISI 304 stainless steel was shown in Fig. 9. Wear resistance with respect to temperature for coated and uncoated AISI 304 stainless steel was shown in Fig. 10. Pin volume loss of uncoated sample was increased for both 100°C at 10 N, and 100°C at 15 N mean wear resistance of uncoated decreased for both 100°C at 10 N, and 100°C at 15 N. Pin volume loss of coated sample was decreased for both 100°C at 10N, and 100°C at 15N means wear resistance of uncoated sample was decreased for both 100°C at 10 N, and 100°C at 15 N. For 10 N at RT Uncoated sample volume more than of 15N at RT. when 10N at 100 °C first decreased for uncoated and then increased for coated sample 15N at 100 °C. Similar results were obtained in the previous study also [3].

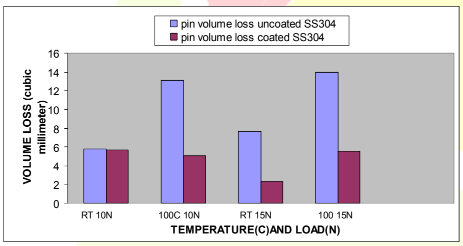


Fig. 9 Pin volume loss with respect to temp for coated and uncoated AISI 304 stainless steel.

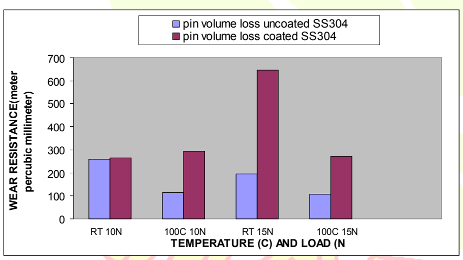


Fig. 10 Wear resistance with respect to temp for coated and uncoated AISI 304 stainless steel.

Fig. 11 shows the scanning electron microscope image and its corresponding EDAX analysis of uncoated AISI 304 stainless steel. From the micrograph, it can be concluded that white region represent NiCr as a major component. EDAX shows that the above Cr and Ni major components for the coatings.

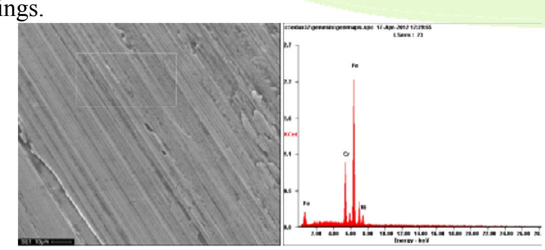


Fig. 11 SEM image and EDAX of uncoated AISI 304 stainless steel.

X-ray diffraction (XRD) analysis of the coated samples was performed with a D/Max Ultima III XRD machine (Rigaku Corporation, Japan). CuKα radiation (λ=1.5406 Å) at a scanning speed of 2° per minute operating at 30 mA and 40 kV was used. The scanning range was 20°-80° in steps of 0.02. Fig. 12 shows the XRD analysis of coated AISI 304 stainless steel sample. From the XRD analysis, we observed that the peak valley it shows that the coated area of Al_2O_3-TIO_2 and also found that alumina has high percentage of coated materials when compared to Titania.

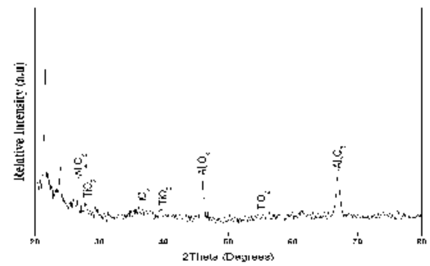


Fig. 12 XRD Analysis of coated AISI 304 stainless steel.

3. CONCLUSION

Dry sliding wear characteristics of Al_2O_3-TiO_2 coated & uncoated AISI 304 Austenitic stainless steel pin with AISI 304 disc were investigated using pin-on-disc tribotester at constant velocity 1m/s and constant sliding distance 1500 m, and load 10N and 15N at room temperature and 100°C. Volume loss, wear and wear resistance were calculated. Based on the experimentation and metallurgical and mechanical characterization the following conclusions were drawn

- Hybrid (Al_2O_3+TiO_2) coated specimen exhibited higher coefficient of friction for room temperature at 10 N, when compared to at 15 N by keeping the constant sliding distance which indicates that the uncoated specimens have higher wear resistance than coated samples.
- Wear resistance of hybrid (Al_2O_3+TiO_2) coated pin was very high, as the mass loss of disc material was more, (AISI 304) but there was heavy mass loss of the uncoated pin for same parameters, by keeping constant sliding distance disc wear resistance also very high in the case of coated RT, 100°C at 10N.
- At constant loads and 200°C (i.e.10 N and 15 N) hybrid (Al_2O_3+TiO_2) coated pin having good wear resistance than at RT for same loads, this was due to very low density of materials.
- Volume losses were less on Al_2O_3-TiO_2 coated sample when compared with uncoated AISI 304 stainless steel in all experiments, and at high temperatures hybrid (Al_2O_3-TiO_2) uncoated sample have more volume loss at RT 15N, when compared to 100°C at 15N.

References

[1]. E.Rabinowicz (1995) Friction and wear of materials, John Wiley and Sons, New York, USA.

ISSN (ONLINE) : 2395-695X
ISSN (PRINT) : 2395-695X
Available online at www.ijarbest.com

International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
Vol. 1, Issue 3, June 2015

[2]. D.Jeyasimman, R.Narayanasamy, R.Ponalagusamy, V.Anandakrishnan, M.Kamaraj. The effects of various reinforcements on dry sliding wear behaviour of AA 6061 nanocomposites, Materials & Design 64 (2014) 783-793.

[3]. D.Sudhakar, D.Jeyasimman, M.Duraiselvam, Dry sliding wear behavior of Cr_3C_2-NiCr coating on austenitic stainless steel, International Journal of Core Engineering & Management 1 (12) (2015) 215-225.

[4]. M.F.Morks, K.Akimoto - The role of nozzle diameter on the microstructure and abrasion wear resistance of plasma sprayed Al_2O_3/TiO_2 composite coatings, Journal of Manufacturing Processes 10 (2008) 1-5.

[5]. E. Sánchez. Moreno M. Vicent , M.D. Salvador V. Bonache E. Klyatskina I. Santacruz , R. Moreno, Preparation and spray drying of Al_2O_3/TiO_2 nanoparticle suspensions to obtain nanostructured coatings by APS, Surface & Coatings Technology 205 (2010) 987–992.

[6]. Eun Pil Song, Jee Hoon Ahn, Sung Hak Lee, Nack J. Kim -Effects of critical plasma spray parameter and spray distance on wear resistance Of Al_2O_3–8 wt.%TiO_2 coatings plasma-sprayed with Nano powders, Surface & Coatings Technology 202 (2008) 3625–3632.

[7]. Yo-Seung Song, In-Gyu Lee, Shin Nam Hong-Corrosion properties of plasma-sprayed Al_2O_3-TiO_2 coatings on Ti metal- j mater sci 41 (2006) 2059–2065.

[8]. R.S.Lima, C.Moreau, and B.R. Marble, HVOF-Sprayed Coatings Engineered from Mixtures of Nanostructured and Submicron Al_2O_3-TiO_2 Powders: An Enhanced Wear Performance-JTTEE5 16:866–872.

[9]. F.L.Toma, C.C.Stahr, L.-M.Berger, S.Saaro, M.Herrmann, D.Deska, and G.Michael, Corrosion Resistance of APS and HVOF Sprayed Coatings in the Al_2O_3-TiO_2 System- JTTEE5 19:137–147.

[10]. K. Jafarzadeh, Z.Valefi, B.Ghavidel, The effect of plasma spray parameters on the cavitation erosion of Al_2O_3-TiO_2 coatings-Surface & Coatings Technology 205 (2010) 1850–1855.

[11]. E.P.Song, J.Ahn, S.Lee, N.J.Kim, Microstructure and Wear Resistance of Nanostructured Al_2O_3-8wt.% TiO_2 Coatings Plasma-Sprayed with Nanopowders, Surface Coating Technology 201 (2006) 1309-1315.

[12]. J.H.Ouyang , S.Sasaki, Tribological characteristics of low-pressure plasma-sprayed Al_2O_3 coating from room temperature to 800°C-Tribology International 38 (2005) 49–57.

[13]. Deng Jianxin, Cao Tongkun, Ding Zeliang, Liu Jianhua, Sun Junlong, Zhao Jinlong- Tribological behaviors of hot-pressed Al_2O_3/TiC ceramic composites with the additions of CaF_2 solid lubricants-Journal of the European Ceramic Society 26 (2006) 1317–1323.

[14]. ASTM standard test method for wear testing with a Pin-on-Disc apparatus. ASTM 99-95 Philadelphia. PA: 1995.

The First Author is D. Sudhakar, working as a Asst.Professer in Periyar Maniammai University, Thanjavur, Tamil Nadu, India. He has 3 years teaching experience in the same University. He has completed his postgraduate degree in Manufacturing Technology in NIT-Trichirappalli, Tamil Nadu, India. He has obtained his undergraduate degree in Mechanical Engineering in Anna University, Chennai, India.

The second author is Dr. D. Jeyasimman, working as a Senior Asst.Professer in Periyar Maniammai University, Thanjavur, Tamil Nadu, India. He has completed his Full Time Ph.D. research work in nanocomposites area under Dr.R.Narayanasamy, Professor, NIT-Trichirappalli, Tamil Nadu, India. He has ten more good publications in international journals (with high impact factors) and Eight years teaching experience in various engineering colleges & Universities. He has obtained his postgraduate degree in Manufacturing Engineering in Anna University, Chennai, India. He has obtained his undergraduate degree in Mechanical Engineering in Bharathiyar University, Coimbatore, Tamil Nadu, India.