Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 4; January-March, 2015, pp. 270-273

http://www.krishisanskriti.org/jbaer.html

To Study Sliding Wear Behavior Chromium OXIDE and Chromium Carbide-nickel Chromium Coating on 13Cr4Ni Stainless STEEL by HVOF Process

Arun Negi[1], Virendra Singh Rana[2] and Dashrath Singh Kathait[3]

[1,2,3]Department of Mechanical Engineering H.N.B.Garhwal University,(Uttarakhand)
E-mail: [1]negiarun73@gmail.com, [2]virurana91@gmail.com, [3]dskkathait@gmail.com

Abstract—*In the modern age of industrial development stainless steel plays a vital role in various fields such as petroleum industries, thermal, steam power plant and automobile sector .When the parts of stainless steel comes in mutual contact it result wear of the parts and at the same time the surrounding effect causes corrosion of the stainless steel .To improve the life of stainless steel some kind of coating is necessary. The present research work focuses on the study of chromium oxide and chromium carbide-nickel chromium coating as the top coat on metallic substrate without any intermediate bond coat. 13Cr4Ni stainless steel is chosen as the substrate material and the deposition of both coating is made by high velocity oxy fuel process. we investigate the sliding wear performance of coated and uncoated stainless steel samples at room temperature under a fix weight of 1000 gm is applied and loss in weight is noted after times 45 minute, 90 minute, and 120 minute for the specimen of uncoated stainless steel, Cr_2O_3 coated and Cr_3C_2-NiCr coated stainless steel. Sliding wear test machine under dry conditions using a pin- on-disc (ASTM G99) arrangement. Weight loss noted at varying time corresponds to weight loss varying sliding distance. High velocity oxyfuel sprayed Cr_2O_3 and Cr_3C_2-NiCr coated 13Cr4Ni stainless steel showed better sliding wear resistance in comparison with their uncoated counter parts.*

1. INTRODUCTION

Stainless steel are distinguished by their high resistance to corrosion in various aggressive media that is atmosphere of air and water vapor, sea water. Stainless steel used in food processing and handling machinery, kitchen equipment, some textile machinery, surgical and dental instrument. Stainless steel are also used in fuel element, reactor vessels, piping system, valves fitting. Various type of stainless steel can be used according to their application.

2. EXPERIMENTAL DETAILS

2.1. Substrate material and metalizing powder

Commercially available stainless steel was used as the substrate material and commercially available metalizing powders namely Cr_3C_2-NiCr and Cr_2O_3 were used for the purpose of coating whose chemical composition is given in table.

Table 1: Chemical composition (wt. %) of the substrate used [8]

Sr. No.	Element	Substrate
1.	C	0.05
2.	P	0.030
3.	Si	0.30-2.60
4.	Mn	0.050-1.0
5.	Ni	3.50-4.50
6.	Cr	12-14
7.	Fe	Balance

For the purpose of coating on the 13Cr4Ni stainless steel specimen High velocity oxy fuel spraying process is used.

High velocity oxy fuel spraying

In HVOF process the kinetic energy can be produced by efficient combustion of oxygen and gaseous or liquid fuel in controlled manner [1]. The powder of coating material is introduced to uniform heating by hot gas stream and transformed into semi or fully liquid form [2]. To propel the powder particles toward the substrate to be coated, the flame and powder are accelerated by a converging / diverging nozzle (air cap) to produce supersonic gas and particle velocities [3]. Due to high velocity and impulse, the powder particles flatten plastically upon the substrate and after cooling and solidifying it form the coating [4]. High particle velocities, uniform heating and low dwell time in combination produces coatings very dense and tightly bonded to the substrate [5]. The chemistry of Coating is more predictable with, homogeneous microstructures slightly bonded to the substrate [6].

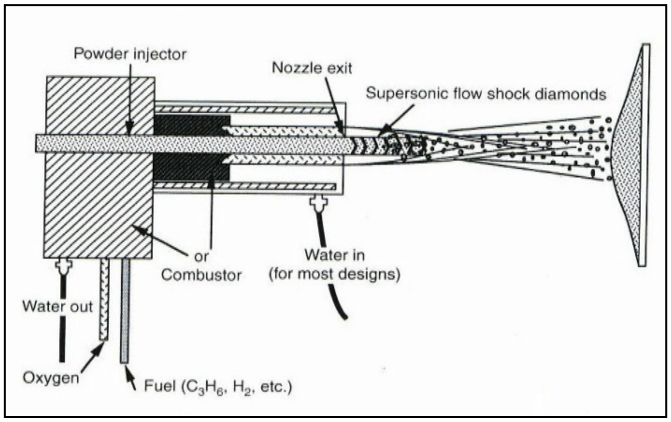

Fig. 1: Typical HVOF process diagram [7].”

3. EXPERIMENT

3.1 DEVELOPMENT OF COATING

Substrate preparation

Prior to the coating, 30mmx7mm specimen dimension for sliding wear test were used. Cleaning was done with acetone and grit blasted at a pressure of 5 kg/cm^2 using aluminium oxide of grits size 30 grade on the coating face, and again cleaned and dried. The standoff distance in shot blasting was kept between 120 mm-170 mm.

Deposition of coating

The grit blasted substrate was held suitably in a fixture and the coating deposition was carried out within the samples in the stationary condition with gun traversing to and fro to obtain the desired coating thickness. The coatings of samples were carried out at METALLIZING EQUIPMENT CO.PVT.LTD Jodhpur Rajasthan, as shown in Fig 4.1. The spraying conditions adopted for the coatings are given in Table.

Table 3: Spraying condition adopted for High Velocity Oxyfuel spray process

Sr. No.	Parameters	Cr2O3	Cr3C2-NiCr
1.	O2 flow rate (SLPM)	250	270
2.	fuel flow rate (SLPM)	55	60
3.	Carrier gas(Nitrogen) flow rate (m3/h)	650	650
4.	Spray distance(mm)	165	165

4. TEST APPARATUS

4.1 Dry Sliding Wear Test Machine

The machine used for the purpose of calculating wear rate as shown in figure. Sliding wear test equipment shown in Fig. is manufactured by Ducom Instrument Pvt. Ltd. By the help of this machine we calculate the sliding wear rate of materials.

Fig. 2: Dry sliding wear machine used in present work.

Table 1, 2, 3 shows the weight loss of uncoated 13Cr4Ni stainless steel, Cr_3O_3 coated 13Cr4Ni stainless steel, Cr_3C_2-NiCr coated 13Cr4Ni stainless **steel** at varying sliding distance and time. Weight loss increases as the time increases. The tabular data shows that the weight loss in maximum in case of uncoated counterpart as compared to the Cr_3O_3 coated 13Cr4Ni stainless steel, Cr_3C_2-NiCr coated 13Cr4Ni stainless steel.

Table 4.1. Uncoated 13Cr4Ni stainless steel

S. No.	Initial Wt. of job(gm)	Final Wt. of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Total Distance (Km)	Total Time (min)	Load Applied (gm)
1.	9.3732	9.3548	0.0184	480	5.02	45	1000
2.	9.3732	9.3453	0.0279	480	10.04	90	1000
3.	9.3732	9.3276	0.0456	480	15.06	120	1000

Table 4.2. Cr3O3 coated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Total Distance (Km)	Total Time (min)	Load Applied (gm)
1.	10.0878	10.0870	0.0008	480	5.02	45	1000
2.	10.0878	10.0870	0.0021	480	10.04	90	1000
3.	10.0878	10.0870	0.0163	480	15.06	120	1000

Table 4.3 Cr3C2-NiCr coated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Total Distance (Km)	Total Time (min)	Load Applied (gm)
1.	10.1958	10.1853	0.0105	480	5.02	45	1000
2.	10.1958	10.1749	0.0209	480	10.04	90	1000
3.	10.1958	10.1610	0.0348	480	15.06	120	1000

4.2 CALCULATION

Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss. Mass loss in the specimen was obtained. Cares have been taken after each test to avoid entrapment of wear debris in the specimen. Wear rate which relates to the mass loss to sliding distance (L) was calculated using the expression.

$$W_r = \Delta m/L$$

The volumetric wear rate W_v of the specimen is related to density and the abrading time (t) was calculated using the expression,

$$W_v = \Delta m/_{\rho}.t$$

For characterization of abrasive wear behavior of specimen, the specific wear rate is employed. This is defined as the volume loss of specimen per unit sliding distance and per unit applied normal load. Often the inverse of specific wear rate expresses in terms of the volumetric wear rate as

$$W_s = W_v / V_{s.}F_n$$

Where V_s is the sliding velocity. Calculated results of the wear test of different test pieces at different test condition are tabulated and presented in table.

4.2.1. Wear rate tables

Table 4.4 Wear rate of uncoated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Wear rate (gm/m) 10-6	Sliding distance (m)	Load Applied (gm)
1.	9.3732	9.3548	0.0184	480	3.66533	5020	1000
2.	9.3732	9.3453	0.0279	480	2.7788	10040	1000
3.	9.3732	9.3276	0.0456	480	3.02788	15060	1000

Table 4.5 Wear rate of Cr3O3 coated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Wear rate (gm/m) 10-7	Sliding distance (m)	Load Applied (gm)
1.	10.0878	10.0870	0.0008	480	1.59362	5020	1000
2.	10.0878	10.0870	0.0021	480	2.09163	10040	1000
3.	10.0878	10.0870	0.0163	480	0.10823	15060	1000

"Table 4.6 Wear rate of Cr3C2-NiCr coated 13Cr4Ni stainless steel."

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Disk Speed (R.P.M)	Wear rate (gm/m) 10-6	Sliding distance (m)	Load Applied (gm)
1.	10.1958	10.1853	0.0105	480	2.091633	5020	1000
2.	10.1958	10.1749	0.0209	480	2.081677	10040	1000
3.	10.1958	10.1610	0.0348	480	2.31075	15060	1000

From the table 4.4, 4.5 and 4.6 we can see that wear rate is maximum in case of uncoated 13Cr4Ni stainless steel and is minimum in case of chromium oxide coated and then for Nickel chromium coated 13Cr4Ni stainless steel.

4.2.2 Specific wear rate in terms of volumetric wear rate

Table 4.7 Specific wear rate of uncoated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/sec) 10-13	Specific wear rate (m3/N-m) 10-14	Load Applied (gm)
1.	9.3732	9.3548	0.0184	1.9	8.7369	4.59836	1000
2.	9.3732	9.3453	0.0279	1.9	6.6239	3.48626	1000
3.	9.3732	9.3276	0.0456	1.9	7.2170	3.79842	1000

Table 4.8 Specific wear rate of Cr3O3 coated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/sec) 10-13	Specific wear rate (m3/N-m) 10-15	Load Applied (gm)
1.	10.0878	10.0870	0.0008	1.9	3.7986	1.999	1000
2.	10.0878	10.0870	0.0021	1.9	4.9857	2.62	1000
3.	10.0878	10.0870	0.0163	1.9	2.90242	1.52852	1000

Table 4.9 Specific wear rate of Cr3C2-NiCr coated 13Cr4Ni stainless steel.

S. No.	Initial Wt.of job(gm)	Final Wt.of job(gm)	Loss of Wt. (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/sec) 10-13	Specific wear rate (m3/N-m) 10-14	Load Applied (gm)
1.	10.1958	10.1853	0.0105	1.9	4.9857	2.624	1000
2.	10.1958	10.1749	0.0209	1.9	4.9620	2.61	1000
3.	10.19	10.16	0.03	1.9	5.5000	2.894	1000

Table 4.9 shows specific wear rate of chromium oxide coated 13Cr4Ni stainless steel in terms of volumetric wear rate.

Volumetric wear rate is change with respect to sliding distance.

Table 4.7, 4.8 and 4.9 shows the specific wear rate in terms of volumetric wear rate. Here we can see that the value of volumetric wear rate is maximum in case of uncoated stainless steel and minimum in case of chromium oxide coated stainless steel and then for nickel chromium coated stainless steel.

5. RESULTS AND DISCUSSION

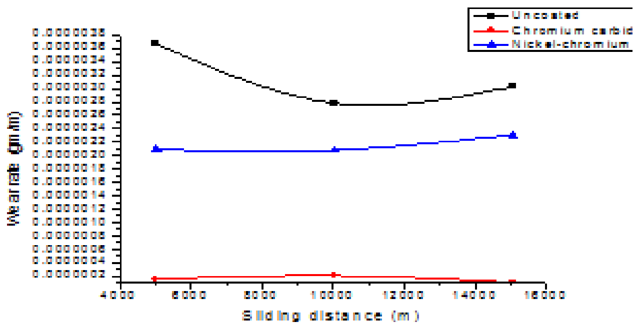

Fig. 3: Wear rate vs. sliding distance."

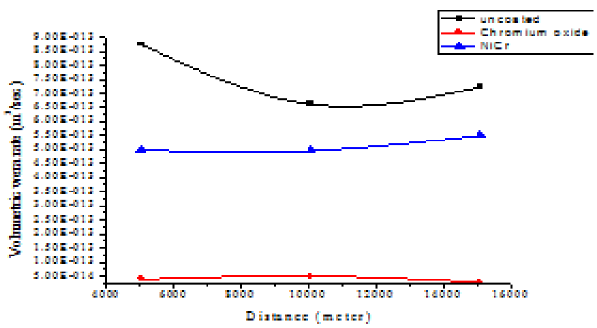

Fig. 4: Volumetric wear rate against sliding distance."

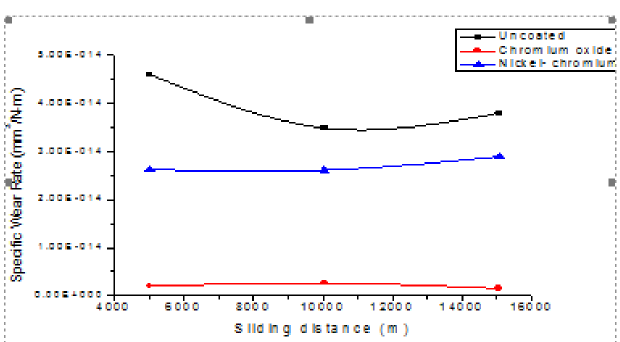

Fig. 5: Specific wear rate against sliding distance."

Fig. 5 shows graph for the wear rate, volumetric wear rate and specific wear rate with respect to sliding distance. Initially the value of wear rate for uncoated sample decrease with respect to sliding distance but then value of wear rate increases as sliding distance increases. Similarly the behavior of volumetric wear rate and specific wear rate can be shown in graphs. From the above graphs we observed that the value of volumetric wear rate and specific wear rate is maximum for uncoated sample and after that for NiCr coated sample. The value of volumetric wear rate, specific wear rate wear rate is minimum for chromium oxide coated sample.

6. CONCLUSION

In the present study we examined the wear behavior of uncoated and coated 13Cr4Ni stainless steel by HVOF process. From the sliding wear test it was found that the coating were successful in keeping their surface contact with the substrate 13Cr4Ni stainless steel when subjected to wear tests. The HVOF Spray process provides the possibility of Cr_2O_3 powders on the 13Cr4Ni stainless steel. Chromium oxide coating shows better wear resistance properties in case of sliding wear test. Therefore, a HVOF Sprayed coating has been recommended as a better choice to reduce the wear of 13Cr4Ni steel.

REFERENCES

[1] Wood RJK. Tribology of thermal sprayed WC–Co coatings. Int J Refract Met Hard Mater 2010; 28:82–94.
[2] Chivavibul P, Watanabe M, Kuroda S, Shinoda K. Effects of carbide size and Co content on the microstructure and mechanical properties of HVOF-sprayed WC–Co coatings. Surf Coat Technol 2007; 202:509–21.
[3] Stewart DA, Shipway PH, McCartney DG. Influence of heat treatment on the abrasive wear behaviour of HVOF sprayed WC–Co coatings. Surf Coat Technol 1998; 105:13–24.
[4] Sidhu, T. S., Prakash, S., Agarwal, R. D., 2007. A Comparative Study of Hot Corrosion Resistance of HVOF Sprayed NiCrBSi and Stellite-6 Coated Ni-Based Super alloy at 900ºC, Mat. Sci. and Engg. 445, p. 210.
[5] Toma, D., Brandl, W., Koster, U., 2000. The Characteristics of Alumina Scales Formed on HVOF-Sprayed MCrAlY Coatings, Oxidation of Metals 53 (1/2), p. 125.
[6] Thorpe, M. L., Richter, H. J., 1992. A Pragmatic Analysis and Comparison of HVOF processes, Journal of Thermal Spray Technology, ASM Intl., 1-2, p. 161.
[7] The Metals Handbook, Eighth Edition, Volume1, 1961, American Society for Metals, Metals Park, OH.
[8] Haihong International Trade 9(HK) CO. Limited 6-01-2014.