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Investigate Wear Resistance of $TiAl_2O_3$ Coating by Detonation Gun Process On AISI 8620

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ABSTRACT: Lubricated sliding components such as gears and cams sometimes fail catastrophically and without any warning, due to Sliding wear. This sudden mode of failure is often called scuffing. Carbon steel such as AISI 8620 which has been principally used in the gears & cams. Thus after a certain time periods these are needed to be replaced. It results in wastage of time, money and material. To minimize this problem, Detonation Gun technique is utilized to develop wear resistant coatings for AISI 8620. It has been found out that $TiAl_2O_3$ coatings can be very useful to minimize the wear problem of AISI 8620. Therefore Detonation Gun Sprayed coatings has been recommended as a better choice to reduce the wear of AISI 8620.Therefore $TiAl_2O_3$ coatings are useful in order to enhance the wear resistance of the base metal steel. The coating powder namely $TiAl_2O_3$ was coated on the substrate AISI 8620 steel specimen. This coating was characterized by the SEM analysis. Subsequently the wear behaviour of the uncoated and coated AISI 8620 steel was investigated. Cumulative wear rate and Cumulative wear volume were calculated for the coated, as well as, the uncoated specimens for 10 N, 20 N and 40 N normal loads. The worn out surfaces were examined by SEM analysis. There are no signs of deformation of splats for the coated AISI 8620 steel case whereas very marginal deformation is indicated in the case of uncoated AISI 8620 steel. This shows that the coated samples have been significantly higher wear resistance in comparison to their uncoated counterparts..It has been concluded that $TiAl_2O_3$ coating has been recommended as a better choice to reduce the wear of AISI 8620 steel.

I. INTRODUCTION

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear may be defined as “the progressive loss of material from contacting surfaces in relative motion”. These wear related problems can be minimized mostly by following two methods:-

(i) By using high cost wear resistant alloys/ metals better than the existing low cost alloys.

(ii) By improving the wear and corrosion resistance of the existing metals and alloys by surface modifications.

In this presented thesis on wear study, the use of Detonation Gun spraying has been made to improve the wear and corrosion resistant properties of AISI 8620 steel. To reduce this wear problem, $TiAl_2O_3$ Coating has been deposited on the AISI 8620 steel with the help of Detonation Gun spray process and was investigated with respect to their wear characteristics. Dry sliding wear tests for the uncoated and Detonation Gun Sprayed AISI 8620 were conducted using a pin-on-disc machine. [Model: Wear and Friction Monitor Tester TR-20], supplied by M/S, Bangalore (INDIA).

II. PROBLEM FORMULATIONS

Wear problem of AISI 8620 steel selected as a case study in this thesis. Lubricated sliding components such as gears and cams sometimes fail catastrophically and without any warning, due to Sliding wear. We have already discussed that AISI 8620 steel has been principally used in the gears & cams. Thus after a certain time periods these are needed to be replaced. It result in wastage of time, money and material. To minimize this problem, Detonation Gun technique is utilized to develop wear resistant coatings for AISI 8620. Therefore Detonation Gun Sprayed coating has been recommended as a better choice to reduce the wear of AISI 8620. Therefore $TiAl_2O_3$ coatings are useful in order to enhance the wear resistance of the base metal steel. Subsequently the wear studies were planned to be conducted on the uncoated as well as Detonation Gun Sprayed coated AISI 8620 steel specimens with the help of Pin- On- Disk Test Rig. Wear data was planned to be collected for different load conditions of 10N, 20N and 40N while keeping a sliding velocity of 1.5 m/s, 3 m/s and 6 m/s.

This wear data would be helpful to ascertain the wear kinetics for the uncoated as well as the coated AISI 8620 steel and to explain the role of the coatings to affect the wear phenomenon of AISI 8620 steel. It was decided to investigate the role of Detonation spray coatings to reduce the wear of AISI 8620 steel. The wear behaviour has been further study with the help of Scanning Electron Microscope (SEM) analysis. The worn out surfaces were examined by SEM analysis.

III. PLANNING OF EXPERIMENT

This chapter presents the experimental techniques and procedures employed for applying the coatings and their characterization, sliding wear studies and analysis of worn out specimens. Specifications of the equipments and other instruments used for the present investigation are also included**.** A plan of experiment based on Taguchi technique was used to acquire the data in a controlled way. The experiments were conducted as per the standard orthogonal array. In the present work, an L_{27} orthogonal array was choosen, which has 27 rows. The Process parameters with their values at three levels are shown in the Table 1. Small 54 pins having cross-section of 8 mm and length 25.4 mm were prepared from AISI 8620 and after that 27 round pieces have been coated on one face with $TiAl_2O_3$ powder up to 200 micron thickness with the help of detonation gun spray process. These pins were required to perform pin-on disc experiment at room temperature. A pin-on-disc test apparatus as shown in the following figure.1 is used to investigate the dry sliding wear characteristics of the specimen**.** The initial weight of the specimen was measured in an electronic micro balance as shown in the following figure. The pin was held stationary against the counter face of a rotating disc made of EN-31 steel at 60, 80 and 100 mm wear track diameter. The weight changes were measured by an electronic micro balance to an accuracy of 10^{-3} g. Weight losses for pins have been measured at different intervals of time to determine the wear loss. We have determined weight loss and wear rate with respect to sliding distance. Following figure shows the variation of cumulative wear rate and cumulative wear volume with respect to sliding distance for the coated and uncoated specimens at normal load of 10, 20 and 40 N and sliding velocity of 1.5, 3 and 6 m/s. SEM Analysis of the coated and uncoated specimens and analysis of results.

Table 1 : Process parameters with their Values at Three Levels.

Levels	Sliding Speed (m/s)	Load (N)	Sliding Distance (m)
1	1.5	10	500
2	3	20	1000
3	6	40	2000

IV. ANALYSIS FOR SLIDING WEAR STUDY

All the specimens subjected to sliding wear were analyzed for the characterization of wear surface. The worn surfaces of the specimen have been examined under the scanning electron microscope using Scanning Electron Microscope

1. Wear Rate: The wear rate data for the coated as well as uncoated specimens were plotted with respect to sliding distance to establish the wear kinetics. The specific wear rate for the coated and the uncoated were obtained by

W = dw /L p F

Where, W = specific wear rate in mm^3/Nm, dw = loss of wt in grams, L = sliding distance, p = density of AISI 8620 in g / mm^3, F = applied load in N.

2. Wear Volume Loss: The wear volume loss was calculated from the weight loss and density of the material for all the investigated cases. These data were reported in the form of plot showing the cumulative wear volume loss v/s sliding distance for all the cases

Volume = mass /density

Wear volume loss = W/9.81/p

Where W = weight loss in gm, p = density of AISI 8620 in g / mm^3

V. WERA BEHAVIOUR OF UNCOATED AND COATED AISI 8620

In this chapter, wear behaviour of the bare, as well as, detonation gun sprayed coated AISI 8620 steel has been explained with the help of results obtained from the pin-on-disc wear testing. The worn out surfaces of the uncoated and coated steel have been analyzed with the help of scanning electron microscope (SEM) and the result of the same summarized in this chapter.

The variation of the cumulative wear rate with sliding distance for uncoated and coated steel has been plotted in Fig. 1.1 (a). It is evident from the plots that the uncoated steel has shown much higher wear rates as compared to its coated counterparts. It is evident from the Fig. 1.1 (a) that the uncoated AISI 8620 steel has undergone a highest wear rate, whereas the coated samples have shown relatively very low wear rate.

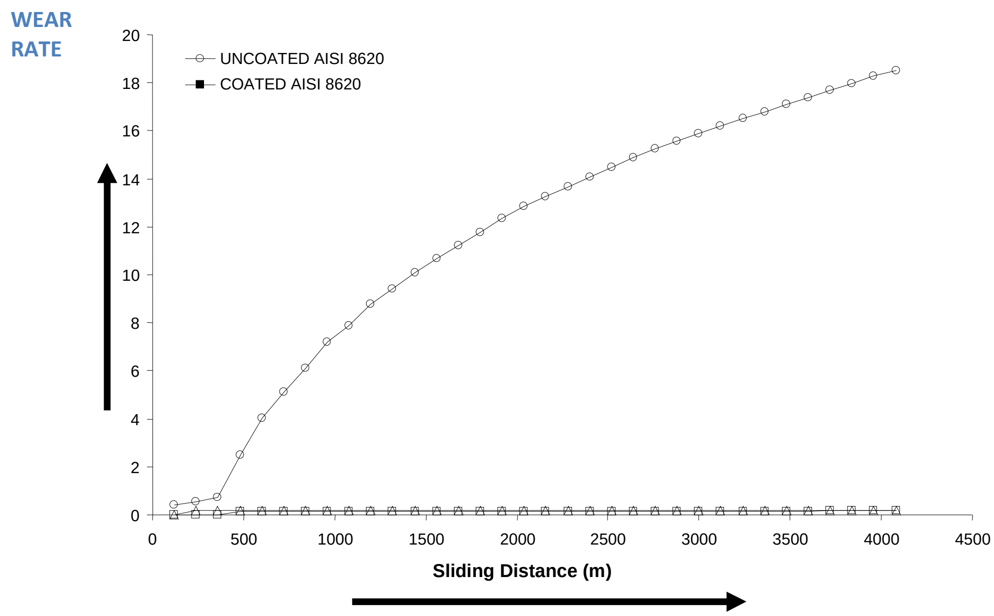

Fig.1 (a) Variation of Cumulative Wear Rate with Sliding Distance for the **Uncoated** AISI 8620 Steel AND **Coated** AISI 8620 SteeL

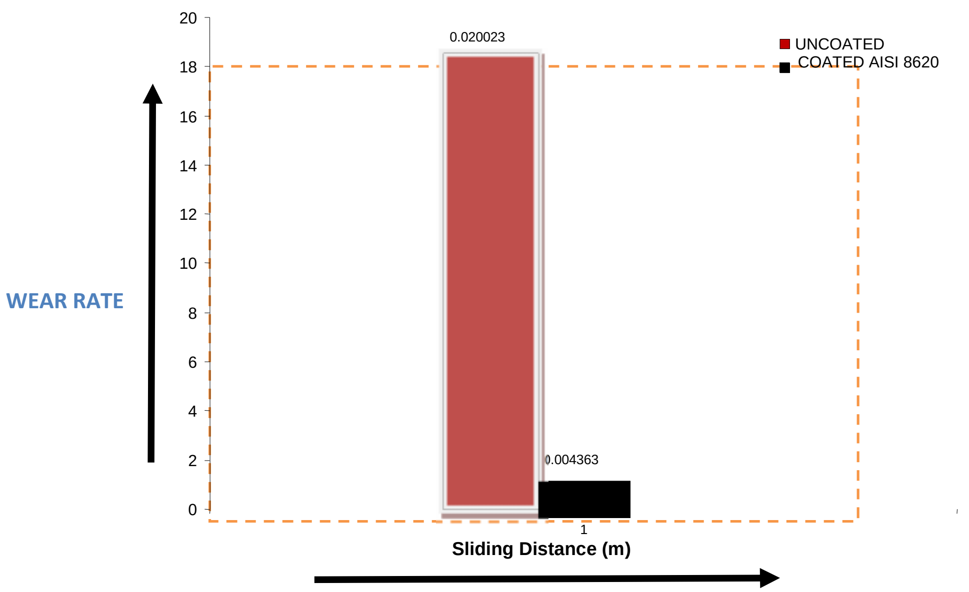

Fig.1 (b) Bar Chart Showing Variation of Cumulative Wear Rate with Sliding Distance for the **Uncoated** AISI 8620 Steel AND **Coated** AISI 8620 Steel

Further the Fig. 1.1 (b) shows the bar chart of the cumulative wear rate after a sliding distance of 2000 m where it is clear that coated AISI 8620 steel has a minimum wear rate against the various investigated cases Therefore it can be concluded that the coatings are useful to enhance the wear resistance of the base steel. Similar observations can be made from the cumulative wear volume loss plots reported in the Fig. 1.2 (a) for the above said cases. It is evident from the Fig. 1.2 (a) that the uncoated AISI 8620 steel is continuously wearing out with the increase in sliding distance. However, the wear volume loss is marginal for the coated cases as compared to that for the uncoated steel. It is also clear the coating show a loss of volume in the initial period of the study only and subsequently became insignificant. Further the Fig. 1.2 (b) shows the bar chart of the cumulative wear volume loss after a sliding distance of 2000 m, where it is clear that coated AISI 8620 steel has lost a minimum volume against the various investigated cases. This shows that coatings are very useful to resist wear of AISI 8620 steel.

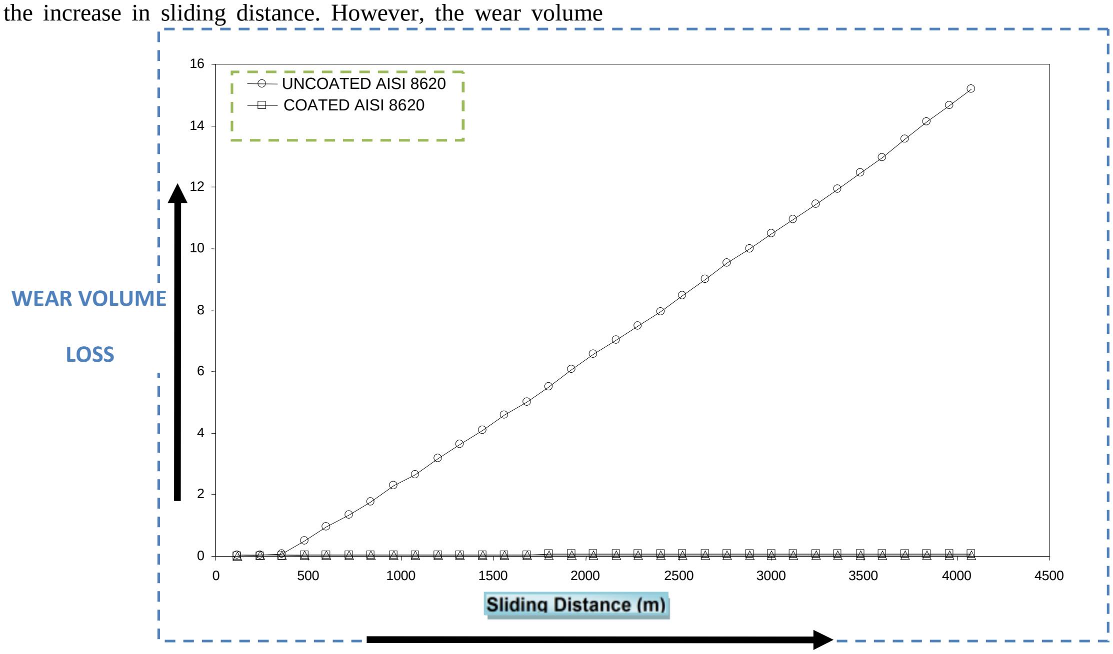

Fig.2 (a) Variation of Cumulative Wear Volume with Sliding Distance for the **Uncoated** AISI 8620 Steel and **Coated** AISI 8620 Steel.

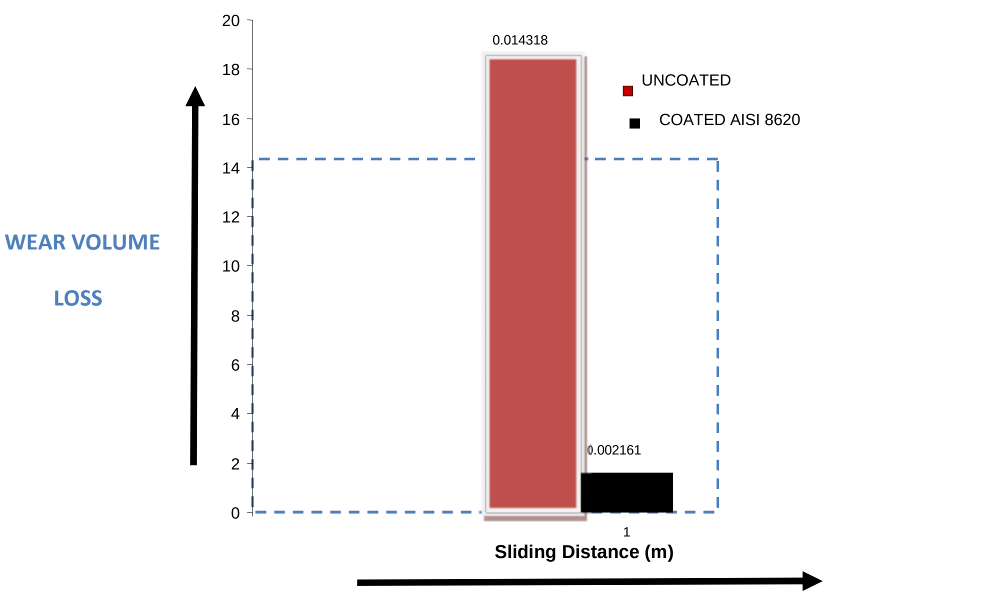

Fig. 2 (b) Bar Chart Showing Variation of Cumulative Wear Volume Loss With Sliding Distance for the **Uncoated** AISI 8620 Steel and **Coated** AISI 8620 Steel.

VI. SEM ANALYSIS

The SEM micrographs for the worn out surfaces for the coated AISI 8620 steel have been reported in the following figures. The SEM micrographs clearly show the presence of wear tracks on the surfaces. The surfaces have becomes rougher with unidirectional growth of the structure, probably along the direction of rotation. Further it looks as a surface has lost the material in the form of micro chips, probably due to ploughing of the surface by the wear debris between the contact surface of the pin and the disc. Following figure shows the surface morphology for the coated AISI 8620 steel. In Fig. 3 (b) and there are no signs of deformation of splats for the coated AISI 8620 steel case. It can be perceived that coatings have retained their original microstructure even after testing. This shows that the coated samples have been significantly higher wear resistance in comparison to their uncoated counterparts.

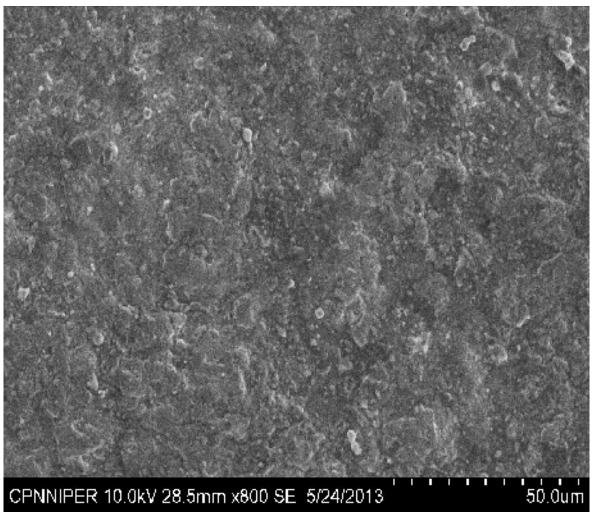

Fig. 3 (a) SEM of Coated sample before Wear Test.

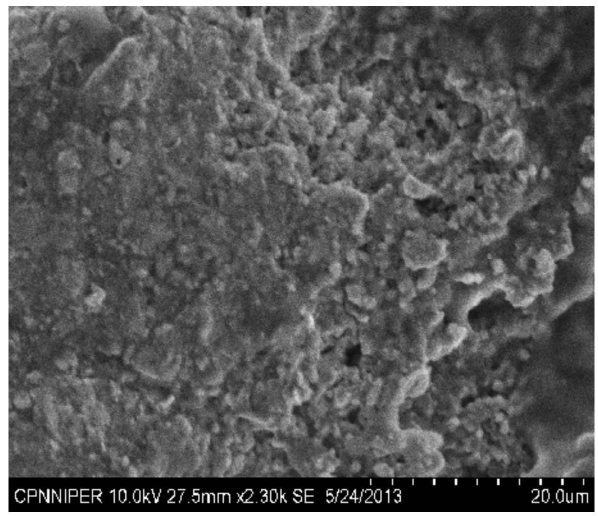

Fig. 3 (b) SEM of Coated Sample after Wear Test.

VII. DISCUSSIONS

A comparative discussion has been made on the results obtained from the current investigation in this chapter. The $TiAl_2O_3$ powders were successfully deposited on AISI 8620 steel by Detonation Gun process. The thickness of the coating was 200 µm. These coatings were characterized by SEM Analysis. SEM analysis for coated AISI 8620 steel has revealed typical splat-like morphology for the detonation Gun spray coatings with distinct splat boundaries. We have already discussed that there are no signs of deformation of splats for the coated AISI 8620 steel case.

This shows that the coated samples have been significantly higher wear resistance in comparison to their uncoated counterparts. We have already been stated that the uncoated AISI 8620 steel showed higher cumulative wear rate, as well as, cumulative wear volume loss under all the investigated loads variants. Moreover, this cumulative wear rate, as well as, cumulative wear volume went on increasing in sliding distance for the uncoated steel. It has been observed from the overall results of investigations that the coated 8620 AISI Steel has shown comparatively lower wear rate, as well as, the cumulative wear volume amongst the investigated cases this further indicates that the steel is able to sustain significantly higher normal loads after the deposition of coatings. Therefore, it may be concluded that the $TiAl_2O_3$ coating is more wear resistant. It has been observed from the overall investigation that $TiAl_2O_3$ coating has shown lower cumulative wear rate, as well as, the cumulative wear volume amongst the investigated cases.

We have already mentioned in the previous chapter that the uncoated AISI 8620 steel is continuously wearing out with the increase in sliding distance. However, the wear volume loss is marginal for the coated cases as compared to that for the uncoated steel. It is also clear the coating show a loss of volume in the initial period of the study only and subsequently became insignificant. It is cleared from the Fig. 1 (b) that coated AISI 8620 steel has lost a minimum volume against the various investigated cases. This shows that coatings are very useful to resist wear of AISI 8620 steel. From the ongoing discussion, it can be concluded that the wear

resistance of the AISI 8620 can significantly be improved with the applications of Detonation Gun Spray $TiAl_2O_3$ Coatings. The wear resistance for the uncoated AISI 8620 steel and coated AISI 8620 steel for a normal loads followed the trend given below:
Coated AISI 8620 steel > Uncoated AISI 8620 steel.

Similar observations regarding wear resistance can also be made from SEM analysis for the coated AISI 8620 steel. We have found that the surface structure of the coated steel has shown no significant changes. From the ongoing discussion, it can be concluded that the wear resistance of the AISI 8620 steel can significantly be improved with the application Detonation sprayed $TiAl_2O_3$ coatings.

VIII. CONCLUSIONS

A comparative discussion has been made on the results obtained from the current investigation in this chapter. Comparative wear behaviour of the uncoated and coated AISI 8620 steel have been discussed in light of existing literature. Detonation Gun Spray coatings were deposited on AISI 8620 steel in order to enhance its wear resistance. The coatings were characterized by the SEM Analysis. Subsequently their wear behaviour was investigated, on Pin-On-Disc machine. The cumulative wear rate and cumulative wear volume loss were calculated for all the cases. The worn out surfaces were analyzed by SEM analysis. Following conclusions have been drawn from the investigations:

(i) The Detonation Gun Spray process provides the possibility of $TiAl_2O_3$ powders on the AISI 8620 steel. A uniform coating thickness of 200 micrometer was achieved.

(ii) The SEM analysis revealed splat like morphology with distinct boundaries for sprayed coatings, which is a typical characteristics factors of Detonation Gun Spray coatings.

(iii) The wear resistance for the uncoated AISI 8620 steel and coated AISI 8620 steel for a normal loads followed the trend given below:
Coated AISI 8620 steel > Uncoated AISI 8620 steel

(iv) The coatings were found to be successful in keeping their surface contact with the substrate AISI 8620 steel when subjected to wear tests.

(v) From the current investigations $TiAl_2O_3$ coating may be recommended as a desired coating to reduce wear of AISI 8620 steel for the applications in gears & cams.

(vi) Therefore, a Detonation Gun Sprayed coating has been recommended as a better choice to reduce the wear of AISI 8620. $TiAl_2O_3$ coatings are useful in order to enhance the wear resistance of the base metal steel.

IX. SCOPE FOR FUTURE WORK

1. The said coatings should be characterized to more depth with transmission Electron Microscopy (TEM), Energy Dispersive Spectroscopy (EDS) and Electron Probe Micro Analysis (EPMA).
2. The surface roughness, micro hardness and bond strength of the said coatings should be investigated.
3. The effect of post coating treatment such as laser remelting on the wear behaviour of the said coatings should be studied
4. The effect of the cryogenic treatment on the wear performance of the said coatings should be investigated
5. These coatings should be deposited by other thermal spray processes such as HVOF and plasma spray techniques that a comparative wear performance of various thermal spray coatings should be evaluated.

ANNEXURE

Table 2: Wear Test data for coated AISI 8620.

Test No.	Sliding speed	Load	Sliding distance	Cumulative Wear Rate	Cumulative Wear Volume Loss
	(m/s)	(N)	(m)	(mm^3/Nm)	(mm^3)
1	1.5	10	500	0.5	0.2
2	1.5	10	1000	1.31	0.96
3	1.5	10	2000	1.5	0.6
4	1.5	20	500	1.41	0.98
5	1.5	20	1000	2.1	1.3
6	1.5	20	2000	2.5	1.6

7	1.5	40	500	1.2	0.4

8	1.5	40	1000	2.01	1.02
9	1.5	40	2000	3.38	1.24
10	3	10	500	0.3	0.1
11	3	10	1000	1.01	0.60
12	3	10	2000	1.3	0.2
13	3	20	500	0.88	0.42
14	3	20	1000	1.45	0.97
15	3	20	2000	1.5	0.6
16	3	40	500	1.00	0.29
17	3	40	1000	1.5	0.5
18	3	40	2000	2.2	1.3

Test No.	Sliding speed	Load	Sliding distance	Cumulative Wear Rate	Cumulative Wear Volume Loss
	(m/s)	(N)	(m)	(mm^3/Nm)	(mm^3)
19	5	10	500	0.3	0.1
20	5	10	1000	1.0	0.3
21	5	10	2000	2.03	1.03
22	5	20	500	1.31	0.86
23	5	20	1000	2.37	1.12
24	5	20	2000	3.2	1.6
25	5	40	500	1.07	0.62
26	5	40	1000	2.0	0.9
27	5	40	2000	3.3	1.8

Table 3: Wear Test data for uncoated AISI 8620.

Test No.	Sliding speed	Load	Sliding distance	Cumulative Wear Rate	Cumulative Wear Volume Loss
	(m/s)	(N)	(m)	(mm^3/Nm)	(mm^3)
1	1.5	10	500	6.3	4.2
2	1.5	10	1000	7.11	5.16
3	1.5	10	2000	7.3	4.8
4	1.5	20	500	7.21	5.15
5	1.5	20	1000	7.9	5.5
6	1.5	20	2000	8.3	5.8
7	1.5	40	500	7	4.6
8	1.5	40	1000	7.81	5.22
9	1.5	40	2000	9.18	5.44
10	3	10	500	6.1	4.7
11	3	10	1000	6.81	5.2
12	3	10	2000	7.1	4.8
13	3	20	500	6.68	5.02
14	3	20	1000	7.25	5.57
15	3	20	2000	7.3	5.2
16	3	40	500	6.8	4.89
17	3	40	1000	7.3	5.1
18	3	40	2000	8	5.9

Test No.	Sliding speed	Load	Sliding distance	Cumulative Wear Rate	Cumulative Wear Volume Loss
	(m/s)	(N)	(m)	(mm^3/Nm)	(mm^3)
19	5	10	500	6.1	4.9
20	5	10	1000	6.8	5.1
21	5	10	2000	7.83	5.83
22	5	20	500	7.11	5.06
23	5	20	1000	8.17	5.92
24	5	20	2000	9	6.4
25	5	40	500	6.87	5.42
26	5	40	1000	7.8	5.7
27	5	40	2000	9.1	6.6

REFERENCE

[1]. Bhushan B., and Gupta B.K., (1991), "Handbook of Tribology: Material Coating and Surface Treatments," McGraw-Hill, New York.

[2]. Booser, E.R. 91983), Handbook of Lubrication: Theory and Practice of Tribology, Vol. **1**: Application and Maintenance, CRC Press, Boca Raton, Fla.

[3]. Burwell, J.T. (1957), "Survey of Possible Wear mechanisms", *Wear*, Vol. **1**, pp. 119-141.

[4]. C. Martini, G. Palombarini, G. Poli, D. Prandstraller, "Sliding and abrasive wear behaviour of boride coatings", Wear 256 (2004) 608–613.

[5]. Cetegen B. M., Semenov S.Y., Goberman D., (2003), "Deposition of Multi- Layered Alumina-Titania Coatings by Detonation waves" Seripta Materialia, Vol. **48**(10), pp.1483-1488.

[6]. Gill, B.J. and Tucker, R. C. Jr., (1986), "Detonation Spray Coating processes" Mater, Sci. Technol., Vol. **2**, No. 3, pp, 207-213.

[7]. H. Bhushan, E. Gupta, "Handbook of Tribology: materials, coating and surface treatments", Ed. Mc Graw-Hill, (1991).

[8]. Knight R., Smith R. W., (1992), "Detonation Sprayed 80/20 NiCr Coatings: Process Influence Trends", Florida, pp. 159-164.

[9]. Knotek, O., (2001), "Chapter 3: Thermal Spraying and Detonation Spray Gun Processes", in Handbook of Hard Coatings: Deposition Technologies, Properties and Applications, Ed. Bunshah, R. F., Noyes Pub. Park Ridge, New Jersey, U.S.A/William Andrew publishing, LLC, Norwich, New York, U.S.A., pp, 77-107.

[10]. Tabur M, Izciler M, Gul F, Karacan I (2009). "Abrasive Wear Behaviour of Boronized AISI 8620 Steel", Wear, 266: 1106-1112.

[11]. Taguchi, G., "Taguchi on Robust Technology Development Methods", New York, NY: ASME press, 1993. P. 1-40.

[12]. Taguchi G, Konishi S, "Taguchi Methods, Orthogonal Arrays and Tool for Quality Engineering", Dearborn, MI: American Supplier Institute; 1987. P. 35-38.