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Study on Sliding Wear Behavior of Plasma Sprayed TiO_2-15%Inconel718 Coatings on Al6061

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***Abstract* - In this paper, the tribological properties of plasma-sprayed coatings are studied. Plasma sprayed coating enhances the surface properties of the substrate material such as corrosion resistance and mechanical properties. Friction in rubbing surfaces causes wear and loss of energy. One way of improving surface resistance to wear is by applying coatings. Al 6061 alloy finds wide applications in the fields of automobile, aero-space, domestic etc.; however it is a soft material with poor wear resistance. To enhance the wear resistance of Al 6061, TiO_2-15%Inconel 718 is deposited on Al 6061 alloy substrate using plasma spray technique. Using pin-on-disc tribometer, the tribological behavior of Al6061coated sample was studied under dry sliding conditions. The objective is to establish a correlation between dry sliding wear behavior of Al6061 and Al 6061 as coated with same wear parameters. The effect of wear parameters like applied load, sliding distance and speed on the sliding wear were studied. The results showed that the extent of variation of wear of coated specimen was very minimal and lesser compared to uncoated Al 6061 with increase in load, speed and sliding d instance.**

Keywords: Al6061, Plasma Spray, TiO2-15%Inconel718, Wear.

1. INTRODUCTION

In the recent past, many studies have been reported in the literature on wear behavior of different coatings on varieties of substrates. Azzi M et al [1] in their study on tribological properties of CrSiNcoated 301 stainless steel under wet and dry conditions demonstrated that the corrosion reactions at the electrode/electrolyte interface were the reasons for the degradation of the tribological properties of these films and in the absence of corrosion reactions, CrSiN coatings resisted sliding wear much better. Cetinel H et al. [2] in their study on wear properties of functionally gradient layers on stainless steel substrates for high temperature applications have reported that the hardness values of FGCs initially increase up to 275 mm and wear resistance increases with depth. In their study on wear of plasma-sprayed nanostructured zirconia coatings when interacting with stainless steel under distilled water conditions, Huang Chen et al. [3] have reported that nanostructured zirconia coatings against stainless steel possessed better wear resistance when compared with traditional zirconia coating. InWoong Lyo et al. [4] in their study on microstructure and tribological properties of plasma-sprayed chromium oxide–molybdenum oxide composite coatings have concluded that composite coatings of Cr_2O_3–MoO_3 have lower friction coefficients for MoO_3-added coatings. Kai Yang et al [5] in their study on sliding wear performance of plasma sprayed Al_2O_3-Cr_2O_3 composite coatings against graphite under severe conditions inferred that 10wt%Al_2O_3-90wt%Cr_2O_3 (AC90) composite coating exhibited better anti-wear performance which was attributed to its higher thermal conductivity.

However, from the literature survey, it is evident that no work has been reported on TiO_2 – Inconel718 composite coatings although this system is very interesting and effective to combat both friction & wear. Hence, the present work focuses on tribological behavior of plasma sprayed TiO_2 – Inconel718 composite coatings on Al6061 substrates.

2. EXPERIMENTAL DETAILS

3.1. Materials:

Al 6061 which finds wide applications in automobile and aerospace industries by virtue of its light weight is used as substrate material. TiO_2-15% Inconel 718 is used as the coating material. Inconel 718 is a nickel chromium alloy consisting of niobium, tantalum, molybdenum, Iron and cobalt in significant quantities and carbon, manganese, copper, boron, Sulphur, silicon, aluminium and phosphorous in smaller quantities. Inconel718 possess excellent corrosion and creep resistance. TiO_2 is a ceramic material possessing high hardness and superior wear resistance.

3.2 Procedure of Coating:

TiO_2-15%Inconel718 alloy powder was plasma sprayed on Al6061 substrate. Alumina particles of 20 mesh size were used for grit blasting the substrate before coating. Hydrogen and argon gases were used as inert gases during the coating process with constant standoff distance of 5‖, flow rate of 40 lpm and 0.4 lpm of Argon and hydrogen gas respectively, 32 KW power, and 100gm/min of flow rate of coating powder. A voltage of 40V and current of 800A, were adopted to develop 100 µm thick coatings.

3.3 Wear Testing:


Fig1: Wear disc high carbon

Fig2: wear apparatus EN31 steel

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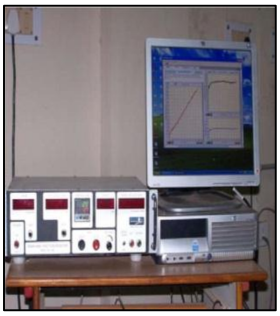


Fig 3: pin-on disc (DUCOM Instruments Ltd.

Wear tests were carried out on a computerized pin-on-disc wear testing machine. The counter surface of high carbon EN31 steel having a hardness of HRC60 was used. The wear specimen (pin) of diameter 10 mm and height 20 mm were subjected to external load and pressed against the counter surface and the disc was rotated at a known speed. The difference in the height measured by LVDT indicates the wear of the specimen. The effect of applied load, speed and sliding distance on wear of the specimen was studied.
Time duration for each speed is calculated as follows,

$$\text{Distance travelled(S)} = \frac{\pi \times d \times N \times t}{1000} \qquad (1)$$

Take value of S =1500m

$$1500\text{m} = \frac{\pi \times d \times N \times t}{1000}$$

$$\text{Time (t)} = \frac{1500 \times 1000}{\pi \times d \times N}$$

on substituting π= 3.142, d=0.06m, N= 3.33 m/s,5 m/s,6.66 m/s and 8.33 m/s on above equation
We obtain time (t) = 16min, 20min, 27min, 40min

4. RESULTS AND DISCUSSIONS

4.1. SEM Photographs:

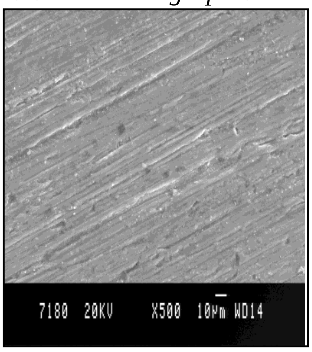


Fig 4: Uncoated Al6061 substrate

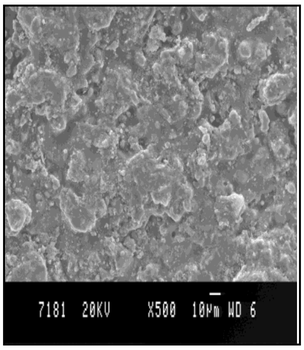


Fig 5: Coated Al6061 substrate

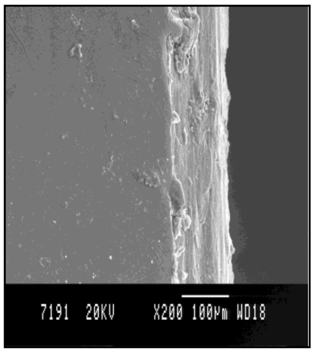
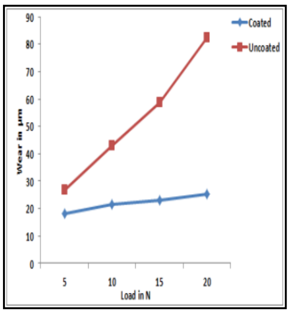


Fig 6: Coating thickness

The SEM photograph of uncoated Al6061 substrate in Fig.4 reveals the asperities which lock in with the rubbing surfaces resulting in higher friction and wear. Fig. 3 shows the SEM photograph of coated specimen exhibiting the formation of splats making the uneven surface of the substrates more uniform resulting in reduction of wear of the specimen. The coating thickness of 100 µm is evident from the Fig.6.

4.2. Tribological properties:

Effect of Load, Speed and Sliding distance



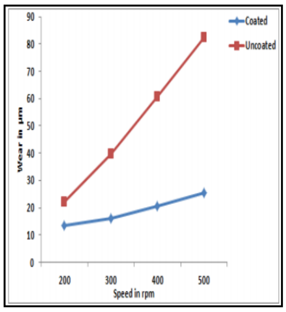


Fig 7: Wear v/s Load Fig 8: Wear v/s Speed

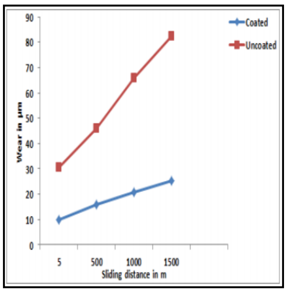


Fig 9: Wear v/s sliding distance

From Fig.5 it is evident that at 500 rpm, as load increases wear increases for a sliding distance of 1500m.It is evident that composite coatings do exhibit very high wear resistance even at high loads of 20N. The wear of substrate increases exponentially with load (especially at loads beyond 15 N) while for the composite coatings increased loads do result in a linear increase of wear. From Fig 6 it is observed that the wear increase is steeper with increase in speeds for the substrate Al6061 alloy when compared with the developed composite coatings for a sliding distance of 1500m. Fig.7 shows the effect of sliding distance (20 N load and 500 rpm speed) on wear of the substrate and the composite coatings. With increase in sliding distances, it

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is observed that wear increases for both the substrate and the coating. In all the cases, the amount of wear is considerably less for coated specimen when compared with uncoated Al6061 substrate. This can be attributed to the presence of titanium dioxide which is a hard ceramic and the alloying elements such as chromium, titanium and molybdenum which aid in increasing the surface hardness leading to superior wear resistance.

4.3: Weight loss plot:

The chat shows that the extent of variation of wear of coated specimen was very minimal and lesser compared to uncoated Al6061 with increase in load, speed and sliding distance. As the hardness of the base material increases by coating the surface wear rate reduces to the maximum extent hence weight loss we will get minimum value.

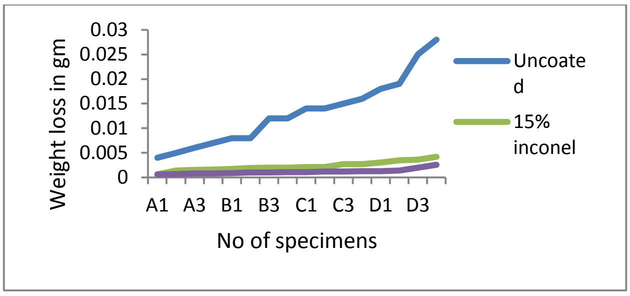


Fig 10: Weight loss plot for coated and uncoated specimen

4.4. Training the neural network:

Fig 1.7: The three layered ANN network for adhesive wear

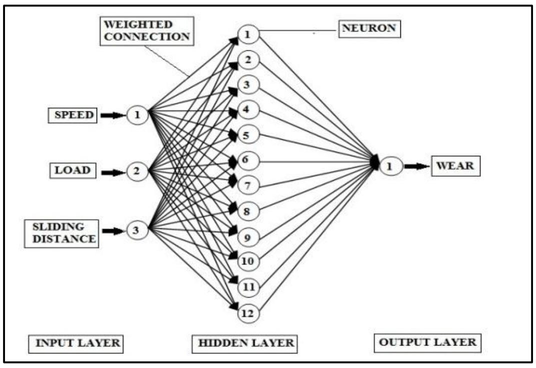


Table 1: Plot of error values obtained from difference in experimental and analytical values after training the network with 39 neurons in hidden layer.

Speed (rpm)	Load (N)	Sliding distance (m)	Wear(µm) (Experimental results)	39 Neurons (Analytical results)	% error
200	5	100	1.03	0.86201	0.16799
200	10	300	3.4	3.5535	0.1535
200	15	300	6.63	6.5745	0.0555
200	20	1150	12.06	12.2399	0.1799
300	5	150	12.37	12.3715	0.0015
300	10	800	12.75	12.7414	0.0086
300	15	1050	12.98	12.9199	0.0601
300	20	50	13.2	13.9737	0.7737
400	5	1350	15.1	14.9184	0.1816
400	10	650	17.3	17.3152	0.0152
400	15	400	18.4	18.3715	0.0285
400	20	700	18.93	18.7794	0.1506
500	5	200	20.7	20.7173	0.0173
500	10	1100	21.5	21.4831	0.0169
500	15	700	22.8	22.7981	0.0019
500	20	500	28.73	28.7795	0.0495

Fig.11: Performance plot showing best validation performance 0.2234

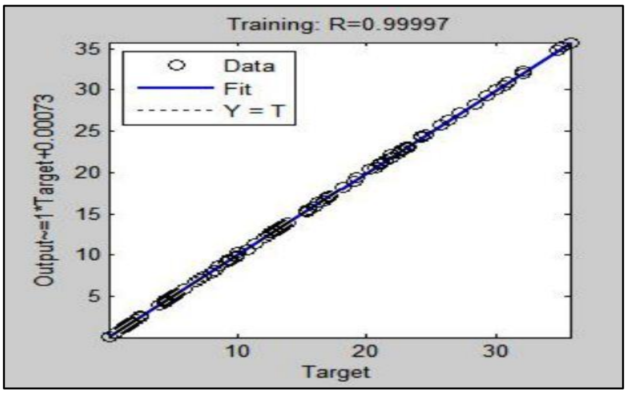
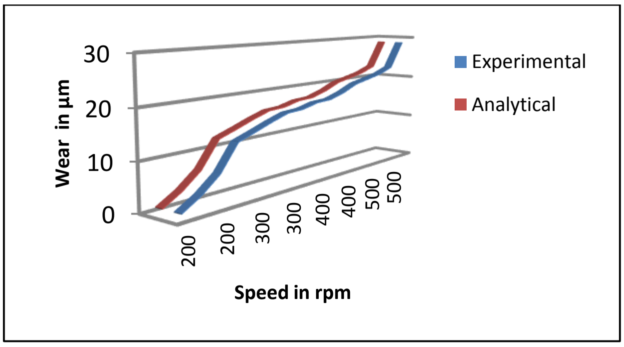


Fig4.12: Regression plot showing best data fit at 0.99997



The predicted values of response by the ANN model is compared with the experimental values for the validation set of experiments. This comparison has been depicted in terms of % error. In this case for 39 neurons in the hidden layer we get less than 4%error it is good indication of validation of experimental values.

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5. CONCLUSIONS

In this research it was intended to study the rate of adhesion wear for coated Al6061 with TiO_2 -15% inconel718 under the influence of different factors (speed, load and sliding distance); also conducted a MAT Lab analysis which can tell the rate of adhesion wear through the knowledge of time period, sliding speed, loads theses models are for experiments and applications.

- The coating cracks which are vertical in the direction of sliding will meet together with the lines of wear.
- The rate of wear is directly proportional to the speed, load & sliding distance
- It is concluded that the developed composite coatings of TiO_2–Inconel718 possess excellent wear resistance when compared with substrate Al6061.
- TiO_2 coatings are deposited on aluminium substrates with an intermediate bond coat of nickel and these bond coatings exhibit desirable coating characteristics viz. adhesion strength etc.
- The TiO_2 coatings developed has good compression strength hence much harder than substrate metals on which they are deposited.

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