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Fuzzy Logic Technique to Evaluation of Material Hardness, Specific Wear Resistance of Aluminium

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***Abstract** The composite material consists combination of materials which are having different physical and chemical properties. It consists of a base matrix which is the major component and reinforcements of different weight percentages. In this work a study on wear properties of Aluminium matrix which is reinforced with TiB2 and Cr2O3 is carried out. The Aluminium 7071 matrix is reinforced with 8% TiB2 and 4%, 6% of Cr2O3. The method used for manufacturing composite is stirr casting. The investigation of specific wear rate for the composite of different combinations is done using pin on disc method at various loads and velocity. The wear pattern is studied using scanning electron microscope image of worned surfaces. The wear rate is predicted using fuzzy model and compared with experimental values.*

***Keywords** :Fuzzy,Annova,Analysis..*

I. INTRODUCTION

Composite materials are an area where lot of studies have been conducted. Comparing to conventional materials it shows improved performance in material properties. Aluminium based composite material is a popular composite especially in automobile and aerospace field. The reason behind this is its availability, low manufacturing cost and ease of manufacturing. Among many of manfucturing methods stirr casting is the most popular manufacturing method for making composites.

Day to day mechanical parts in the machines are subject to wear and tear. In order to increase the reliability of the machine, the materials used in the machine should be wear resistant. Lot of study has been conducted on wear of aluminium composites. Aswin N (T. Kumar, Swamy, & Chandrashekar, 2013) reported that graphite content will increase the wear resistance of the Aluminium 6063 compoasites. Dora (Prasad & Shoba, 2014) made a study of the effect of SiC and Rice Husk Ash on Aluminium and found that those reinforcements will decrese the wear rate of Alumnium composites. Kanthavel (Kanthavel, Sumesh, &Saravanakumar, 2016) reported that the incoperation of MoS2 improves the wear resistance and reduce friction. Dinahara (Dinaharan, Murugan, &Thangarasu, 2016) mad an observation that the presence of TiC lowers the wear rate for Aluminium 6082 composites. The incoperation of Si3N2, AlN and ZrB2 (N. M. Kumar, Kumaran, &Kumaraswamidhas, 2016) improves wear rate and coefficient of friction for Aluminium 2618 alloy.Harane (Rana, Badheka, & Kumar, 2016) observed that better dispersion of B4C particle in Aluminium 7015 improves wear rate. Alwynkingsly (Ochieze, Nwobi-Okoye, &Atamuo, 2017) improves the wear rate of Aluminium by incoperatingcowhorn ash. M adlan (Abdulwahab, Dodo, Suleiman, Gebi, & Umar, 2017) improves the wear resitance of Aluminium by incoperating melon shell ash. A study made by pradeepsharma (P. Sharma, Paliwal, Garg, Sharma, &Khanduja, 2017) found that the presence of graphite will improve the wear rate for aluminium 6061 composites. Vipin K sharma (V. K. Sharma, Singh, & Chaudhary, 2017) reported an increase in wear resistance by incoperating fly ash in pure Aluminium. (Kundu, Roy, & Mishra, 2013) made a regression model for predicting wear rate for Aluminium SiC, Al2O3 composites. A decrease in wear rate for Aluminium composites was observed by (Satyanarayana, Naidu, &Babu, 2016) with the presence of Red mud as reinforcement. He also made a regression model and ANN model for predicting wear rate and found to be satisfactory with experimental results. Not much literature is available for the dry and wet wear rate of TiB2, Cr2O3 Aluminium 7071 composites.

Only little study has been carried out for developing models for predicting dry and wet wear rate. In this work an attempt has been made to study the wear rate of Aluminium 7071-TiB2, Cr2O3 hybrid composite. A fuzzy model has been developed for predicting wear rate. This model will help to have better understanding of wear rate on this composite.[1-10]

II. EXPERIMENTAL PROCEDURE

A. *Material Selection and ManufacturingProcess*

The technique used in this work for preparing composite is liquid metallurgy technique. In this work Aluminium 7071 was selected as base matrix. TiB_2 and Cr_2O_3 were selected as reinforcements for improving mechanical properites. Stirr casting was selected for preparing composite moulds. Aluminium ingot was melted by using 3 phase electric furnace. During melting there is a chance of atmospheric gases especially hydrogen to get absorbed to the liquid metal.

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So a little amount of Hexachloroethane (C2Cl6) was added into the mould for absorbing dissolved gases. Reinforcement were also subjeted for preheating before mixing with the base material. Once Aluminium alloy was melted it was constantly stirredbyaironstirrat500rpm.Around760^{o}C thepreheated reinforcements were added to molten material and the mixture was agian stirred constantly at 500 rpm for promoting uniform ditribution of reinforcements. Then the molt was poured to previously prepared metallic mould and was allowed for cooling. Later mould was removed for obtaining workpece of required dimension. The specimen were cut and machined to desired dimensions for hardness testing and weartesting.[11][12]

Table I: Weight Percentage in Samples

Samples	TiB_2 Weight %	Cr_2O_3 Weight %
Sample 1	8%	4%
Sample 2	8%	6%

B. Vickers hardnesstest

The hardness of the composites was evaluated Brinell hardness tester. Prior to testing, test specimens cut out from each composite composition were polished to obtain a flat and smooth surface finish. Brinell hardness is determined by forcing a specified diameter hard steel or carbide sphere at specified load into the surface of a material for a time period. The hardness number can be calculated by dividing the load with area of indentation made on the surface. In this work a 500 kg load is applied to the specimen for 30 seconds. The test was repeated on each sample and average of the reading was taken as measure of hardness for thespecimen.[13-16]

C.WearTesting

The Pin-on-Disc apparatus (DUCOM) is used for wear testing. ASTM G99 G95a standard is followed for conducting wear test. Aluminium 7071 composite specimen of different weight perentage of reinforcements with dimension 10 mm diameter and 25 mm length were used for wear testing. The specimen and disc was throughly cleaned by using acetone before the test. The weight of the specimen before and after the test were noted. The load applied were 20,30,40,50 kg, the velocity were 0.5,1,1.5 and 2 m/s. The distance taken were 500, 1000, 1500 and 2000 m. After each test the weight loss for the specimen were noted for calculating volume loss. The specific wear rate was calculated from the volume loss.[17-19]

D.ANOVAAnalysis

A taguchi table of L32 was selected as DOE. ANOVA analysis was done to find most influencing factor in the wear rate. The signal to noise ratio was also calculated for finding most optimized input parameters for minimum wearrate

Table 2

Run	Cr_2O_3 wt %	Load (N)	Vel. (m/s)	Dist. (m)
1	4	20	0.5	500
2	4	20	1	1000
3	4	20	1.5	1500
4	4	20	2	2000
5	4	30	0.5	500
6	4	30	1	1000
7	4	30	1.5	1500
8	4	30	2	2000
9	4	40	0.5	1000
10	4	40	1	500
11	4	40	1.5	2000
12	4	40	2	1500
13	4	50	0.5	1000
14	4	50	1	500
15	4	50	1.5	2000
16	4	50	2	1500
17	6	20	0.5	2000
18	6	20	1	1500
19	6	20	1.5	1000
20	6	20	2	500
21	6	30	0.5	2000
22	6	30	1	1500
23	6	30	1.5	1000
24	6	30	2	500
25	6	40	0.5	1500
26	6	40	1	2000
27	6	40	1.5	500
28	6	40	2	1000
29	6	50	0.5	1500
30	6	50	1	2000
31	6	50	1.5	500

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E. Fuzzy Modelling

The input values load,velocity and distance were used in this model for predicting ouput specific wear rate.

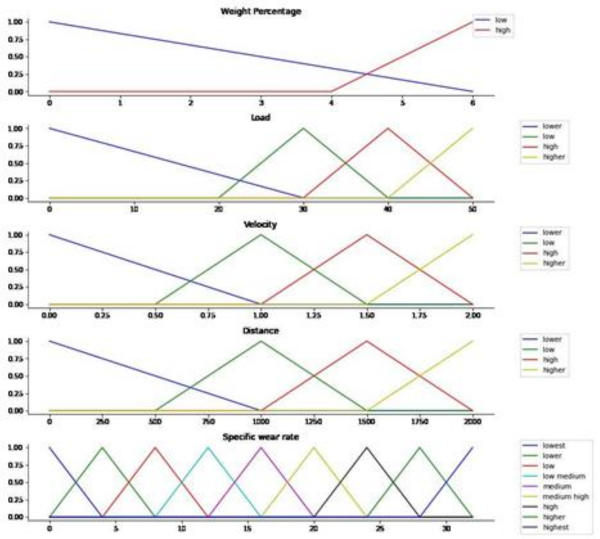

Fig 1. Membership Functions

The fuzzy linguistic variables used for expressing crisp input of these parameters are Low,Medium and High. The triangular memebership functions were used for converting crisp values to fuzzy values. A total of 32 rules were considered for the proposed mamdani fuzzy model interface system. These rules were used for predicting specific wear rate in the fuzzy model. The fuzzification and defuzzification was made using Python Scikit Fuzzy package. The rules are as follows

1. IF weight percentage is low AND load is lower AND velocity is lower AND distance is lower THEN specific dry wear rate is low
2. IF weight percentage is low AND load is lower AND velocity is low AND distance is low THEN specific dry wear rate is low.
3. IF weight percentage is low AND load is lower AND velocity is high AND distance is high THEN specific dry wear rate is medium.
4. IF weight percentage is low AND load is lower AND velocity is higher AND distance is higher THEN specific dry wear rate is high.
5. IF weight percentage is low AND load is lowAND velocity is lower AND distance is lower THEN specific dry wear rate is medium.
6. IF weight percentage is low AND load is low AND velocity is low AND distance is low THEN specific dry wear rate is medium high.
7. IF weight percentage is low AND load is lowAND velocity is high AND distance is high THEN specific dry wear rate ishigh.
8. IF weight percentage is low AND load is low AND velocity is higher AND distance is higher THEN specific dry wear rate is low.
9. IF weight percentage is low AND load is high AND velocity is lower AND distance is low THEN specific dry wear rate is medium high.
10. IF weight percentage is low AND load is high AND velocity is low AND distance is lower THEN specific dry wear rate is medium high.
11. IF weight percentage is low AND load is high AND velocity is high AND distance is higher THEN specific dry wear rate i slow.
12. IF weight percentage is low AND load is high AND velocity is higher AND distance is high THEN specific dry wear rate is low.
13. IF weight percentage is low AND load is higher AND velocity is lower AND distance is low THEN specific dry wear rate is mediumhigh.
14. IF weight percentage is low AND load is higher AND velocity is low AND distance is lower THEN specific dry wear rate is low.
15. IF weight percentage is low AND load is higher AND velocity is high AND distance is higher THEN specific dry wear rate is low.
16. IF weight percentage is low AND load is higher AND velocity is higher AND distance is high THEN specific dry wear rate is low.
17. IF weight percentage is high AND load is lower AND velocity is lower AND distance is higher THEN specific dry wear rate is low medium.
18. IF weight percentage is high AND load is lower AND velocity is low AND distance is high THEN specific dry wear rate is low medium.
19. IF weight percentage is high AND load is lower AND velocity is high AND distance is low THEN specific dry wear rate is low medium.
20. IF weight percentage is high AND load is lower AND velocity is higher AND distance is lower THEN specific dry wear rate is medium.
21. IF weight percentage is high AND load is low AND velocity is lower AND distance is higher THEN specific dry wear rate is medium.
22. IF weight percentage is high AND load is low AND velocity is low AND distance is high THEN specific dry wear rate is medium high.
23. IF weight percentage is high AND load is low AND velocity is high AND distance is low THEN specific dry wear rate is medium high.
24. IF weight percentage is high AND load is low AND velocity is higher AND distance is lower THEN specific dry wear rate is medium high.
25. IF weight percentage is high AND load is high AND velocity is lower AND distance is high THEN specific dry wear rate is medium high.
26. IF weight percentage is high AND load is high AND velocity is low AND distance is higher THEN specific dry wear rate is medium high.
27. IF weight percentage is high AND load is high AND velocity is high AND distance is lower THEN specific dry wear rate is medium high.
28. IF weight percentage is high AND load is high AND velocity is higher AND distance is low THEN specific dry wear rate is low.

29. IF weight percentage is high AND load is higher AND velocity is lower AND distance is high THEN specific dry wear rate is medium high.

30. IF weight percentage is high AND load is higher AND velocity is low AND distance is higher THEN specific dry wear rate is high.

31. IF weight percentage is high AND load is higher AND velocity is high AND distance is lower THEN specific dry wear rate is high.

32. IF weight percentage is high AND load is higher AND velocity is higher AND distance is low THEN specific dry wear rate is high.

The output derived from the model has to be unified and for this max-min interference method was selected. The output will be in the form of fuzzy values and this has to be defuzzified. The centroid of gravity method was used for defuzzification. The expression for calculating centre of gravity in defuzzification is given as:[20]

$$x = \int \mu(x)xdx$$
$$\int \mu(x)dx$$

III. RESULT AND DISCUSSION

The figure 2 shows the comparison of hardness values of specimens. It was found that the hardness of the specimen 2 is higher. Reason for this increase in hardness is due addition of more Cr2O3 particles in Aluminium matrix.

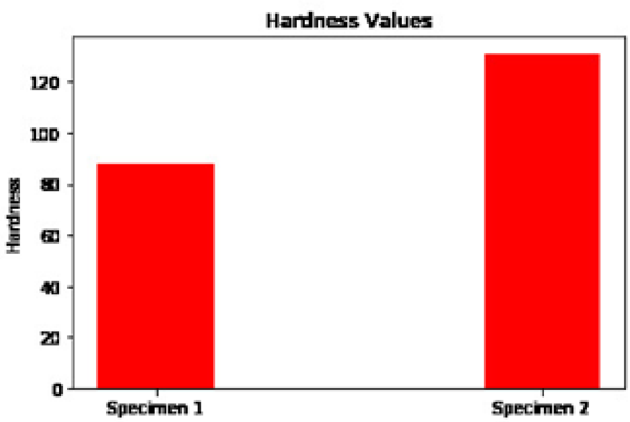

Table III: Specific Wear rate from experiment and fuzzy model

Run	Dry Sp Wear rate $\times 10^{-5}$ (mm^3/Nm)	S/N Ratio	Predicted Dry Sp Wear rate $\times 10^{-5}$ (mm^3/Nm)
1	11.41	-21.15	11.1818
2	14.53	-23.25	14.2394
3	17.64	-24.93	21.168
4	22.01	-26.85	26.412
5	17.41	-24.82	20.892
6	21.32	-26.58	25.584
7	24.99	-27.96	29.988
8	27.58	-28.81	33.096
9	20.93	-26.42	25.116
10	21.44	-26.62	21.0112
11	27.33	-28.73	26.7834
12	27.59	-28.82	27.0382
13	21.45	-26.63	1.021
14	26.24	-28.38	25.7152
15	30.62	-29.72	30.0076
16	30.64	-29.73	32.172
17	10.5	-20.42	11.025
18	12.65	-22.04	13.2825
19	12.93	-22.23	13.5765
20	15.8	-23.97	16.59
21	16.79	-24.5	17.6295
22	19.55	-25.82	20.5275
23	20.73	-26.33	21.7665
24	20.5	-26.24	21.525
25	18.15	-25.18	19.0575
26	20.38	-26.18	19.9724
27	20.7	-26.32	20.286
28	22.75	-27.14	22.295
29	19.01	-25.58	18.6298
30	25.42	-28.1	24.9116
31	23.48	-27.41	23.0104
32	25.79	-28.23	25.2742

Table III shows the experiment values of specific wear rate for the specimens. The wear values from the experiment shows that wear rate increases with the weight percentage of Cr2O3. This is due to increse in hadnesss of thematerial

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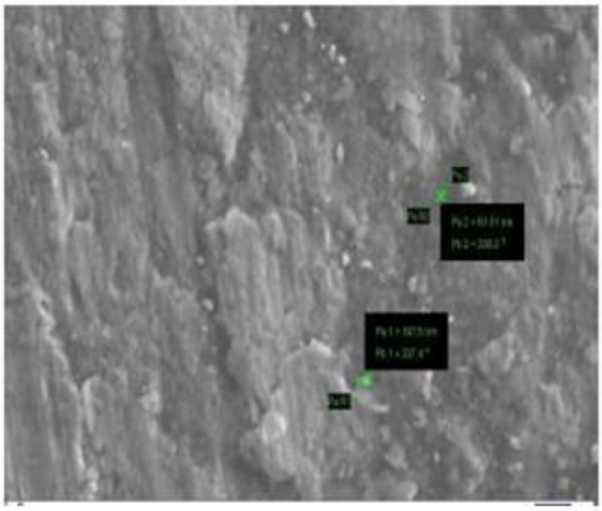

Fig 3. SEM image of Specimen 1

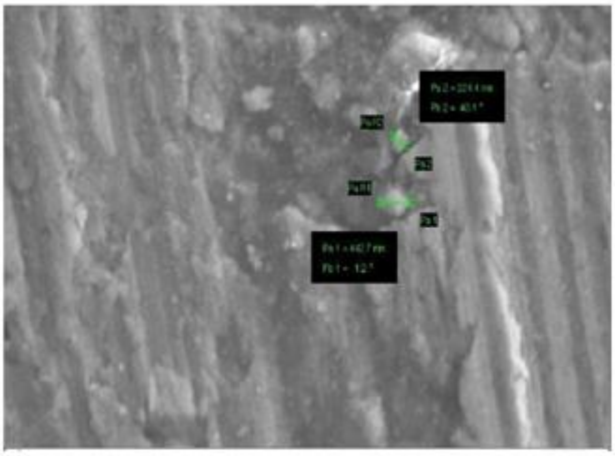

Figure 4. SEM image of Specimen 2

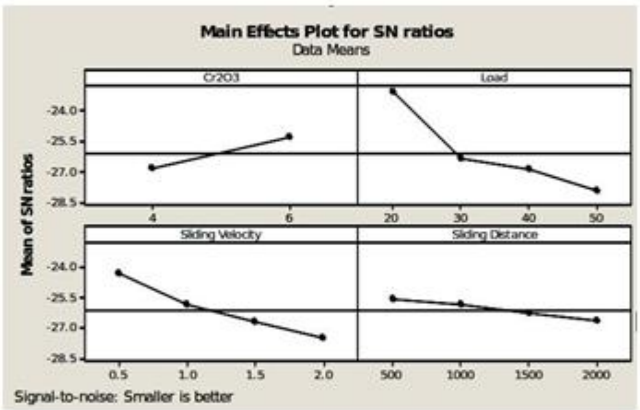

Fig 5. ANOVA Analysis

The anova analysis shows that most influencing factor in the experiment is weight percentage and less influencing factor is speed. The most optimized parameters are Cr2O3 8% weight percentage, Load is 20 N,Sliding Velocity is 0.5 m/s and Distance travelled is 500 m

The results obtained from fuzzy model is matching with the experimental values. The average error in the predicted values is less

IV. CONCLUSION

- Aluminium 7071-TiB2, Cr2O3 hybrid composite has been developed and characterization was carriedout.
- The investigation shows clearly that addition of Cr2O3 increases the hardness of metal matrix composite.
- The ANOVA analysis was made for the specific wear rate of the material.
- The fuzzy model for predicting specific wear rate was successfully made.

. The fuzzy model predicted values which are closer to the experimental values.

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