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Research Article

Investigation on Wear Behaviour of Al6061-Al_2o_3-Graphite Hybrid Metal Matrix Composites using Artificial Neural Network

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Abstract

Aluminum metal matrix composites are widely used in engineering applications, specially automobile, aerospace, marine and mineral processing industries owing to their improved wear properties compared to conventional monolithic aluminum alloys.Nowadays hybrid composites plays vital role in engineering application. In this present work Alumina and Graphite are added as reinforcement particle into Aluminum 6061 alloy for preparing hybrid composites. The hybrid composite is produced by liquid metallurgy route. This method is less expensive and very effective. The objective of this work is to predict the wear behavior of Al_2O_3- Graphite reinforced with Al6061 hybrid metal matrix composites by using feed forward back propagation algorithm. The design of experiment is planned based on taguchi (L_9) orthogonal array and it is performed by various control factors such as sliding speed, sliding distance, applied load and percentage of reinforcement. Artificial neural network is very accurate compare to other prediction techniques genetic algorithm, taguchi method

Keywords: *MMCs, Al_2O_3, Graphite, Stir Casting, Pin on Disc Tester.*

1. Introduction

Metal Matrix Composites (MMCs) have a high potential application in cylinder liners, brake drums, crankshafts etc. In aluminium metal matrix composite have been well recognized and steadily improve the engineering properties such as improved wear rate, low density, specific strength and stiffness. However they suffer from poor wear resistance, then overcomes the hard reinforcement phases such as particulates, fiber and whiskers which are having high specific strength, have been uniformly distributed. Composite material which are adding two or more reinforcement, it will differ the physical and mechanical properties of the materials.

In most cases, hard reinforcement particles such as Zirconia, alumina (Al_2O_3), and silicon carbide(SiC) have been introduced in aluminium metal matrix composites to increase the strength, stiffness, wear resistance, corrosion resistance, fatigue resistance and elevated temperature resistance. Among the reinforcement of alumina is chemically compatible with aluminium (Al) and forms a adequate bonding with the matrix material without developing inter-metallic phase. The demand for lightweight, inexpensive and energy sufficient materials used in Al alloy matrix composites. The results from previous studies indicate the wear increases the applied load. The composite failed under the certain load and speed limits. Graphite particulates are well suited to this application and their addition improves the machinability as well as wear resistance of Al-Al2O3. Graphite is a soft solid lubricant material which is used to increase the wear resistance. Therefore further discussion of the influence of graphite on the wear properties of composites is necessary. The introduction of alumina particle into the aluminium alloy expert a greater effect on wear. The sliding distance is found to have a much lower effect. In addition of alumina reinforcement/applied load and alumina reinforcement/sliding distance have a moderate influence on the abrasive wear. In this context, the present study aims to investigate the wear performance of Al-Al2O3-Gr hybrid metal matrix composites.

2. Experimental setup and procedure

2.1 Specimen preparation

The composites were fabricated by the powder metallurgy process. Aluminium 6061 is used as the matrix material in the present investigation and the details of its composition are given in Table 1. This matrix was chosen because it provides an excellent combination of strength and elevated temperature.

(i) Al/5 wt% of alumina composite
(ii) Al/10 wt% of alumina/2 wt% of Gr composite
(iii) Al/15 wt% of alumina/5 wt% of Gr composite

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Table 1 Chemical composition of Al6061 alloy

Element	Percentage
Si	0.43
Fe	0.7
Cu	0.24
Mn	0.139
Ni	0.05
Pb	0.24
Zn	0.25
Ti	0.15
Sn	0.001
Mg	0.802
Cr	0.25
Al	Balance

Table 2 provides the details of the Aluminum, alumina and graphite particulates, which are used as the matrix and reinforcements. The aluminium stir casting furnace is Mfd by SWAMEQUIP, Chennai-64. The stir casting method is the simplest and least expensive process for manufacturing of the particle reinforced MMCs. In this process, the hybrid metal matrix composite is used to achieve the optimal properties, the distribution of the particle reinforcement material in the matrix is uniform and wettability between the reinforcement particles and molten metal. The porosity level of the metal matrix composites should be minimized.

The stir casting method is used to create a uniform distribution of the reinforcement in the matrix. About one kg of Al6061 is melted in a ceramic crucible in an induction model electric resistance furnace. The temperature of the melting point is about 800^{o}C. Then the reinforcement particle is preheated about 500^{o}C in pre-heating furnace for an one hour before adding. For the period of stirring, the combination of preheated reinforcement particles of alumina and graphite in equivalent volume fraction is added inside the vortex formed during stirring. Once the complete addition of the particles to the molten metal, the liquid composite is still poured into the permanent steel mold is pre-heated about 200^{o}C and then allowed to cool in the atmosphere temperature. Then the billet is removed from the mould. A stir casting setup is shown in the figure 1.

Table 2 Properties of Matrix and Reinforcement

Material	Density (mg/m^3)	Melting temperature(^{o}C)
Al6061	2.7	620
Al_2O_3	3.95	2015
Gr	2.09-2.33	530

2.2 Wear test

Dry sliding wear tests were conducting on pin on disc machine (Model:TR 20-LE DHM250.Ducom Make, Bangalore, India). Pin on disc specimens is machined from powder metallurgy extruded billets. The contact surface is cleaned by acetone. All the experiment are conducted by atmospheric room temperature. The test were carried under the normal load is about 10, 20, and 30 N and

Figure 1 Stir Casting Set Up

run by different sliding distance 1000, 1500 and 2000 m at three different sliding velocity of 1.5, 3 and 4.5 m/s as constant for each test, were carefully cleaned with acetone. The pin was weighed before and after testing an accuracy of 0.1mg to determine the wear loss. The coefficient of friction was determined from the applied normal load. The pin on disc machine is shown in given figure 2

Figure 2 Pin on Disc Tester

2.3 Artificial neural networks (ANNs)

MATLAB version 2010a is used for the design, implementation and simulation of the networks with feed forward back propagation algorithm. Back propagation networks are multi layer networks with hidden layers of sigmoid transfer function and a linear output layer. The linear transfer function were used as the activation transfer function, the back propagation function is used to training algorithm, the back propagation algorithm was used as the linear rule and mean square error was used as the performance function. In each parameter model, the training and testing were normalized (-1,1) due to the use of hyperbolic tangent sigmoidal function in the model and network.

Table 3 Design of experiment

Sliding velocity	Normal load	Sliding distance	% of Reinforcement
1.5	10	1000	5
1.5	20	1500	12
1.5	30	2000	20
3	10	1500	20
3	20	2000	5
3	30	1000	12
4.5	10	2000	12
4.5	20	1000	20
4.5	30	1500	5

3. Results and Discussion

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and coefficient of friction. The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load, sliding distance and % of reinforcement. The results for various combinations of parameters were obtained by conducting the experiment as per the orthogonal array. The measured results were analysed using the commercial software MINITAB 14 and MATLAB specifically used for design of experiment. The experimental results average of two repetitions for wear rate and coefficient of friction

Modelling for predicting wear rate using Artificial Neural Network

Table 4 Prediction of wear rate using Taguchi and Artificial Neural Network

S.No	Sliding Velocity(v)	Normal Load(L)	Sliding Distance(D)	% of reinforcement	Wear rate	Prediction Taguchi	Prediction ANN
1	1.5	10	1000	5	0.00309	0.00309	0.003089
2	1.5	20	1500	12	0.00321	0.00321	0.00321
3	1.5	30	2000	20	0.00301	0.00301	0.002681
4	3	10	1000	20	0.00252	0.00252	0.00252
5	3	20	1500	5	0.00441	0.00441	0.004109
6	3	30	2000	12	0.0039	0.0039	0.003901
7	4.5	10	1000	12	0.0029	0.0029	0.002521
8	4.5	20	1500	20	0.0027	0.0027	0.00242
9	4.5	30	2000	5	0.0047	0.0047	0.003813

Modelling for Predicting wear rate using Artificial Neural Network was done by the following procedure

- Define the input and output(target)
- Import the input and target output
- Create the new network and select the network type, learning type,transfer function, and number of neurons
- Train the network and find out performance plot
- By changing the number of neurons many networks were created and also corresponding performance plot is noted

In this work 25 network is created by using the above procedures from that networks, network 5 with 9 neurons has minimum wear rate. Network 2 was selected as best network. By using that network the value of wear rate is predicted. The following figure shows the performance plot, regression plot and network for prediction

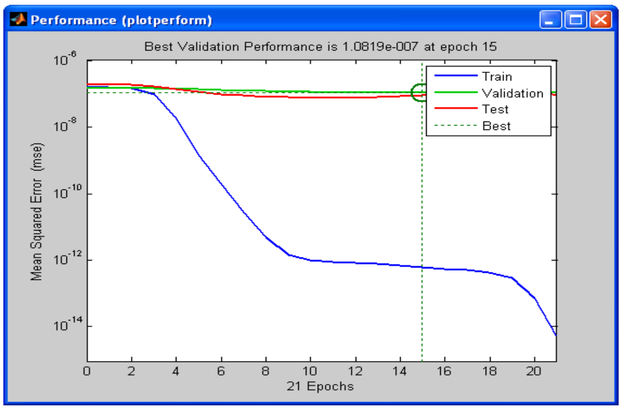

Figure 3 Performance plot for wear rate

Plot perform (TR) plots the training, validation and test performance given the training record TR returned by the function train. From the above figure Best validation performance is 1.0819e-007 at epoch 15

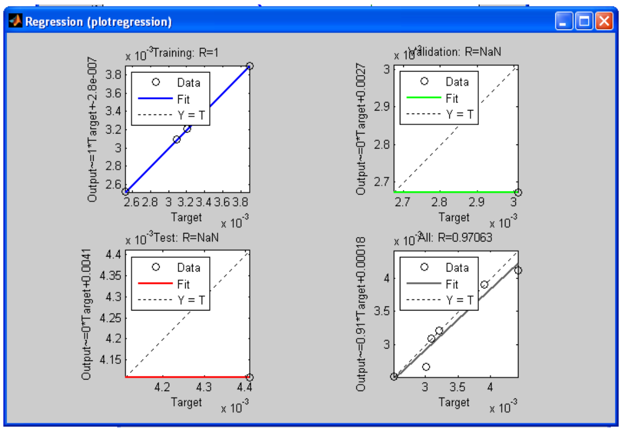

Figure 4 Regression plot for wear rate

Regression analysis of wear rate

Wear rate = 0.00279+0.000110 v +0.000052 L+0.000000 D-0.000080% of reinforcement

Plot regression (target, outputs) plots the linear regression of target relative to output. From the above figure R=0.97063

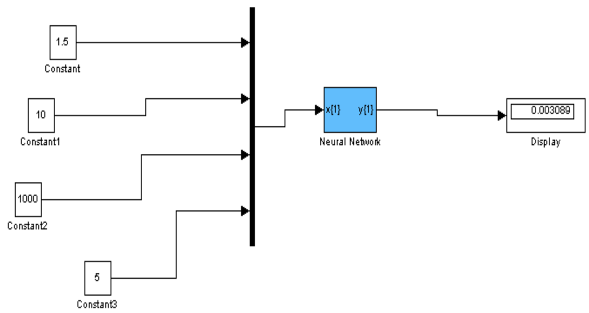

Figure 5 Network for prediction of wear rate

Modelling for predicting coefficient of friction using Artificial Neural Network

In this work 25 network is created by using the above procedures from that networks, network 10 with 15 neurons has minimum wear rate. Network 5 was selected as best network. By using that network the value of wear rate is predicted. The following figure shows the performance plot, regression plot and network for prediction

Table 5 Prediction of coefficient of friction using Taguchi and Artificial Neural Network

S.No	Sliding Velocity	Normal Load	Sliding Distance	%of reinforcement	Coefficient of friction	Prediction Taguchi	Prediction ANN
1	1.5	10	1000	5	0.216	0.222525	0.2284
2	1.5	20	1500	12	0.326	0.320836	0.326
3	1.5	30	2000	20	0.414	0.42012	0.414
4	3	10	1000	20	0.252	0.23628	0.2338
5	3	20	1500	5	0.315	0.313185	0.315
6	3	30	2000	12	0.403	0.397996	0.403
7	4.5	10	1000	12	0.223	0.227656	0.3179
8	4.5	20	1500	20	0.305	0.31344	0.2575
9	4.5	30	2000	5	0.396	0.390345	0.3974

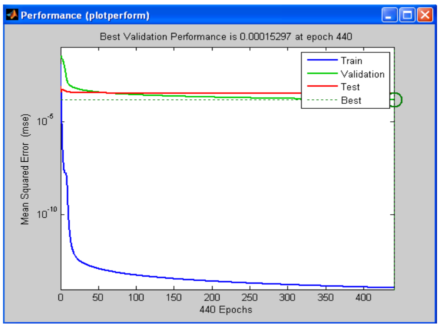

Figure 6 Prediction of Coefficient of Friction using Artificial Neural Network

Plot perform (TR) plots the training, validation and test performance given the training record TR returned by the function train. From the above figure Best validation performance is 0.00015297 at epoch 440

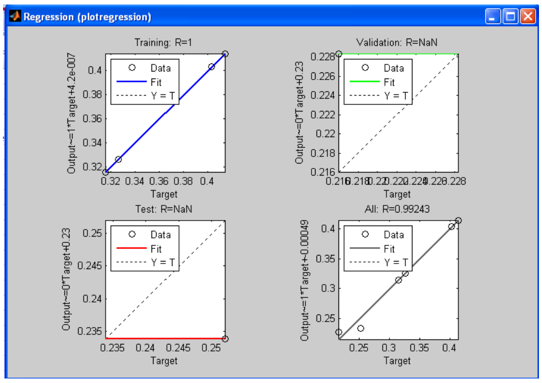

Figure 7 Regression plot for coefficient of friction

Regression analysis of coefficient of friction

Coefficient of friction = 0.127-0.00356 v +0.00870 L +0.0000009 D+0.000973% of reinforcement

Plot regression (target, outputs) plots the linear regression of target relative to output. From the above figure R=0.99243

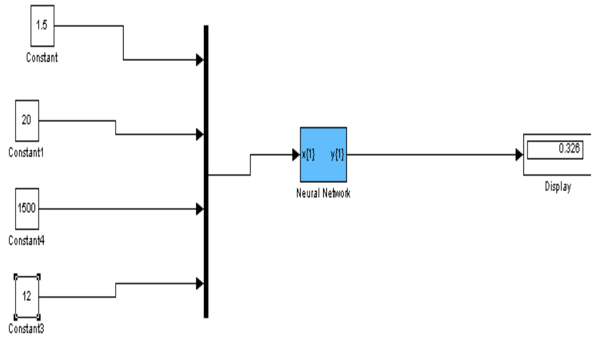

Figure 8 Network for prediction of coefficient of friction

Comparison of observed value with Artificial Neural Network

From the following table, the observed is predicted the target value with minimum percentage of error while compared with Artificial Neural Network

Table 6 comparison of observed value with Artificial Neural Network

Wear rate	Prediction Taguchi	Prediction ANN	Coefficient of Friction	Prediction Taguchi	Prediction ANN
0.00309	0.003035	0.003089	0.216	0.222525	0.2284
0.00321	0.002939	0.00321	0.326	0.320836	0.326
0.00301	0.002755	0.002681	0.414	0.42012	0.414
0.00252	0.00188	0.00252	0.252	0.23628	0.2338
0.00441	0.00372	0.004109	0.315	0.313185	0.35
0.0039	0.003624	0.003901	0.403	0.397996	0.403
0.0029	0.002749	0.002521	0.223	0.227656	0.3179
0.0027	0.002565	0.00252	0.305	0.31344	0.2575
0.0047	0.004405	0.003813	0.396	0.390345	0.3974

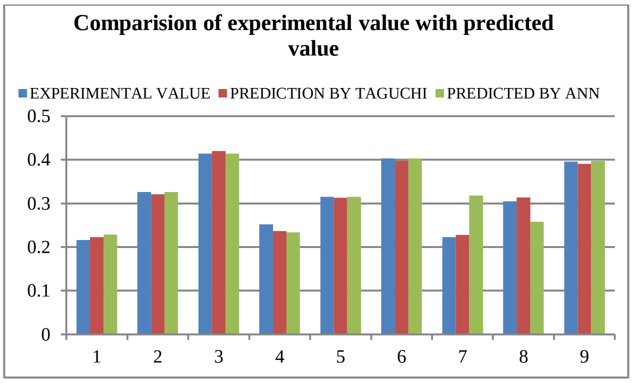

Figure 9 Comparison of Predicted value and experimental value of wear rate

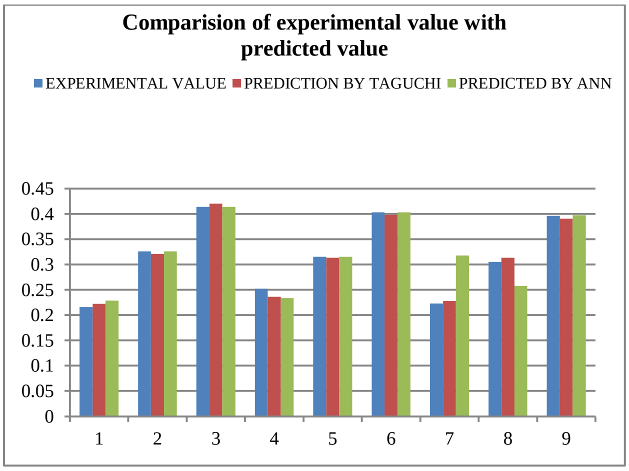

Figure 10 Comparison of Predicted value and experimental value of coefficient of friction

Conclusion

- Aluminium metal matrix composites have been successfully fabricated by stir casting Technique with fairly distribution of alumina and graphite particles
- The aluminium alloy metal matrix material with mixing of reinforcement of alumina and graphite is to improve the wear behaviour.
- Incorporation of alumina as a primary reinforcement also has a significant effect on the wear behaviour and of graphite as secondary reinforcement increases the wear resistance of composites by forming a protective layer between pin and counter face.
- Regression equation generated for the present model was used to predict the wear rate and coefficient of friction of HMMC for intermediate conditions with reasonable accuracy.

References

A A Adebisi, M.A Maleque, M.M. Rahman, Metal Matrix Composite Brake Rotor: Historical Development and Product Life Cycle Analysis. International Journal of Automotive and Mechanical Engineering ISSN: 1985-9325 Vol 4 PP471-480 July –Dec 2011.

B.D Miracle, Metal Matrix Composites-From Science to Technological Significance, Composites Science and Technology 65(2005) 2526-2540

S. Balasivanandha Prabu , L. Karunamoorthy , S. Kathiresan, B. Mohan, Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite, journals of materials processing technology 171(2006) 268-273

G.G Sozhamannan, S.Balasivanandha Prabu, V.S.K. Venkatagalapathy, Effect of Processing Parameters on Metal Matrix Composites : Stir Casting, Journal of Surface Engineered Materials and Advanxced Technology:2012 2 11-15

K. Umanath, K. Palanikumar, S.T. Selvamani Analysis of dry sliding wear behaviour of Al6061/SiC/Al_2O_3 hybrid metal matrix composites Composite: Part B 53(2013)159-168.

P. Ravindran, K. Manisekar, P. Narayanasamy, N. Selvakumar, R. Narayanasamy Application of factorial techniques to study the wear of Al hybrid composites with graphite addition Materials and Design 39(2012) 42-54.

R.N. Rao, S. Das Effect of SiC content and sliding speed on the wear behaviour of aluminium matrix composites Materials and Design 32 (2011) 1066-1071.

Sakip Koksal, Ferit Ficici, Ramazan Kayikci, Omer Savas Experimental optimization of dry sliding wear behavior of in situ AlB_2/Al composite based on Taguchi’s method Materials and Design 42 (2012) 124-130.

S.Basavarajappay, G.Chandramohan Wear Studies on Metal Matrix Composites: a Taguchi Approach Journal of Materials for Science and Technology., Volume.21 No.,2005

V.C. Uvaraja, N. Natarajan Optimization of Friction and Wear Behaviour in Hybrid Metal Matrix C0omposites Using Taguchi Technique Journal of Minerals and Materials Character ization and Engineering,2012,11,757-768

V.C.Uvaraja , N. Natrajan Optimization on Friction and Wear Process Parameters Using Taguchi Technique International Journal of Engineering and Technology Volume 2 No.4, April 2012.

J.Hashim, L.Looney, M.S.J.Hashim Metal Matrix Composites: production by the stir casting method Journal of Materials Processing Technology 92-93 (1990) 1-7.

N. Radhika, R. Subramanian, S.Venkat Prasat Tribological Behaviour of Aluminium/Alumina/Graphite Hybrid Metal Matrix Composite Using Taguchi’s Techniques Journal of Minerals & Materials Characterization and Engineering, Volumne 10,No.5 pp,427-443,2011.

S.C. Vettivel, N. Selvakumar, N. Leema Experimental and prediction of sintered Cu–W composite by using artificial neural networks Materials and Design 45 (2013) 323-335.