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Investigation of hot deformation behavior of Mg reinforced with BN nanocomposite using ANN

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***Abstract*---**The present study aims to study the hot deformation behavior of Mg reinforced with BN Nanocomposite. The hot deformation behavior of Mg reinforced with BN (1.5 wt.%) is reviewed by following ASTM standards E209, i.e., hot deformation on MTS-810 universal test apparatus. Three parameters, namely Tempertature, Strain rate and True strain, were considered in this study. The experiments for flow stress have been conducted as per ASTM standards E209. The flow stress obtained for Mg reinforced with BN (1.5 wt.%) is predicted by the ANN Toolbox of MATLAB R2021a using the Levenberg-Marquardt (trainlm) algorithm, which trains the feed-forward neural network having 3-5-1 (three input neurons, five hidden neurons in the single hidden layer and one output neuron). Experimental data sets obtained from the hot deformation test have been utilized to develop ANN. The results concluded that the error for flowstress of Mg reinforced with BN (1.5 wt.%) lies within 16%, with

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an average percentage error of 2.39% between experimental values and ANN predicted values.

***Keywords*---**Nanocomposite, Hot deformation, and (ANN) Artificial Neural Network.

1. Introduction

Mg is the lightest metal, making it very useful for the automobile, aerospace, and transportation sectors. Its potential is to dramatically reduce the weight of components that would otherwise be made from aluminum, which is 65% denser than magnesium [1,2]. The addition of reinforcement to magnesium and its alloys improves its strength and stiffness. In any case, at room temp. these materials have very low flexibility compared with other materials and limit their broad applications [3–5].

Magnesium will watch out of the overwhelming majority of the problems checked out by enterprises during which the strength to weight proportion is significant, as an example, the car, space, and telecommunication industries. The out there literature shows that Mg usage is continually increasing and may be expected to still grow within the future [6,7]. Metal matrix composites produced by adding ceramic materials for reinforcement exhibit improved mechanical properties, including structural, wear, and creep properties, among others, and thereby find many applications. An MMC's properties mainly depend upon matrix material, particle size, and materials used to reinforce and manufacture the composite [8]. The main drawbacks of magnesium and its alloys are wear and consumption protections. From all the problems, wear is the most predominant problem in mechanical segments, prompting a lessened lifetime for magnesium-based parts and making magnesium unsuitable for use in bearings, gears, pistons, and cylinders [9–11].

The reinforcement stage in MMC's can be a particle, continuous and tiny fiber. Among these, particle-reinforced MMC's are isotropic and easier to fabricate. Its high damping capability associate degreed stiffness Mg are fortified with an assortment of ceramic particulates, as an example, Al2O3, zinc oxide, TiC, SiC, B4C, TiB2. Among these ceramic particulates, Al2O3 and twitching have emerged as exceptional creative fortifications because of their distinguished mechanical, optical, and electrical properties and intensive type of uses. [12-14]. Magnesium could be a better metal than Al and Ti in terms of its physical properties, as well as process, machining, and exercise properties, which might staggeringly cut back continual prices. [17]. Even though friction and wear rate depend upon several factors, like applied load, sliding speed, material type, specimen geometry and surface roughness, it's ascertained that sliding speed and load had a considerable influence on the wear and tear rate [19-22]. In light-weight of this distinctive state of affairs, this analysis work aims to check the wear behavior of Mg reinforced with Boron Nitride Nanocomposite.

2. Materials and Methods

2.1 Nanocomposite Preparation

The Mg/BN (1.5 wt.%) Nanocomposite is synthesized by using the metallurgy technique. The process includes microwave aided two-directional sintering and a hot working process called hot extrusion. After extrusion, the required composite of diameter 8 mm is obtained.

2.2 Method of Testing

Nanocomposite specimens were tested by sliding the samples against an OHNS steel disk with higher surface contact. The sample's weight is measured by an electronic balancing instrument with the least count of 0.0001 g. Tests were performed under sliding speeds of 0.6, 0.9, and 1.2m/s at normal weights of 5, 7, and 10N for a sliding separation of 500, 1000, and 1600 m [15, 16, 18].

$$\text{Friction coefficient } \mu = \frac{F}{P} \quad (1)$$

Where 'F' is the Force due to friction and 'P' is the load acting on pin.
The V_{loss} is determined with the help of a W_{loss} as per the formula given below [16]

$$V_{loss}(mm^3) = \frac{W_{loss}\,(gr)}{\rho\,(\frac{gr}{mm^3})} \quad (2)$$

Where V_{loss} is the Volume loss, W_{loss} is the Weight loss and ρ is the Density
The following formula is used to determine the wear loss

$$\text{Wear loss } (mm^3/m) = \frac{V_{loss}(mm^3)}{\text{Sliding distance (m)}} \quad (3)$$

3. Experimental Procedure

The operational condition under which the wear study of Mg/BN (1.5 wt.%) was carried out is given in Table 1 at room temperature. Three parameters, namely normal load, sliding distance, and sliding speed, were considered in this study.

Table 1: Input variables and their levels

Input variables	**Level**		
	I	**II**	**III**
Load (N)	5	7	10
Sliding speed (m/s)	0.6	0.9	1.2
Sliding distance (m)	500	1000	1600

3.1 Artificial Neural Network (ANN)

ANN is a modelling approach successfully applied in modeling many biological systems [23]. They can deal with multiple independent (input) and dependent (output) variables simultaneously without prior information about their functional relationship. The wear loss of Mg/BN(1.5 wt.%) is predicted by the NN Toolbox of MATLAB R2021a using a Levenberg-Marquardt (trainlm) algorithm [24-26], which trains the neural network having 3-5-1 (three input neurons, six hidden neurons in the single hidden layer, and one output neuron) shown in Fig.1. Experimental data consisting of 27 datasets has been utilized to develop ANN to understand the correlation between the input and output.

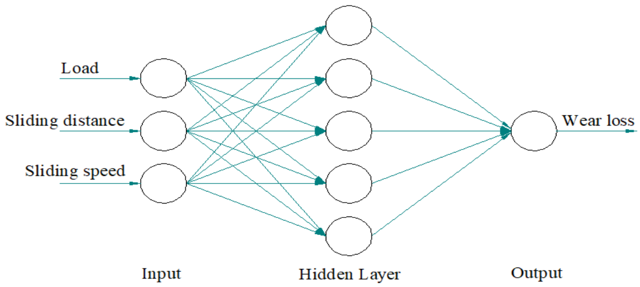


Fig.1. Neural network architecture

4. Results and Discussions

Table 2: Test conditions with output results for Mg/BN (1.5 wt.%) nanocomposite using pin on disc apparatus

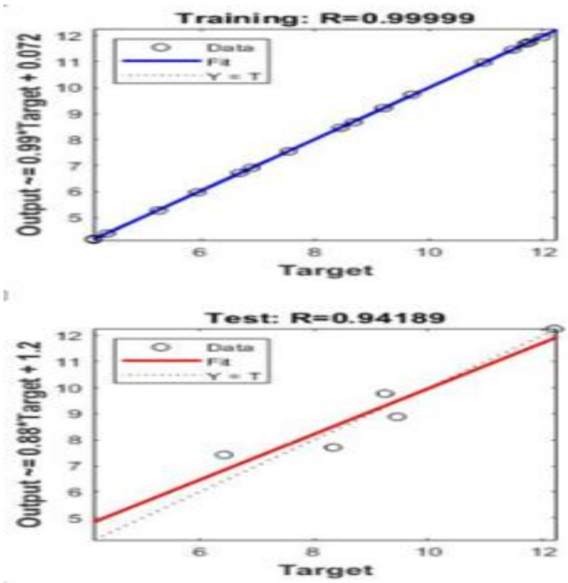
Sl. No.	Load (N)	Sliding Distance (m)	Sliding Velocity (m/s)	Wear loss (mm^3/m)
1	5	500	0.6	4.113
2	5	500	0.9	4.113
3	5	500	1.2	4.341
4	5	1000	0.6	5.712
5	5	1000	0.9	5.941
6	5	1000	1.2	6.569
7	5	1600	0.6	6.426
8	5	1600	0.9	6.676
9	5	1600	1.2	6.890
10	7	500	0.6	7.540
11	7	500	0.9	5.255
12	7	500	1.2	5.598
13	7	1000	0.6	8.340
14	7	1000	0.9	8.454
15	7	1000	1.2	8.683
16	7	1600	0.6	9.211

17	7	1600	0.9	9.247
18	7	1600	1.2	9.461
19	10	500	0.6	9.711
20	10	500	0.9	8.226
21	10	500	1.2	7.198
22	10	1000	0.6	10.968
23	10	1000	0.9	11.482
24	10	1000	1.2	11.767
25	10	1600	0.6	11.710
26	10	1600	0.9	11.996
27	10	1600	1.2	12.210

Table 3: Experimental test data and predicted ANN values for wear loss of Mg/BN(1.5 wt.%)

Sl. No.	Load (N)	Sliding Distance (m)	Sliding Velocity (m/s)	Wear loss (mm^3/m)		Error (%)	Absolute Error (%)
				Exp.	ANN		
1	5	500	0.6	4.113	4.172	-1.44	1.44
2	5	500	0.9	4.113	4.144	-0.76	0.76
3	5	500	1.2	4.341	4.384	-0.99	0.99
4	5	1000	0.6	5.712	5.560	2.66	2.66
5	5	1000	0.9	5.941	5.965	-0.41	0.41
6	5	1000	1.2	6.569	7.387	-12.45	12.45
7	5	1600	0.6	6.426	7.423	-15.51	15.51
8	5	1600	0.9	6.676	6.720	0.65	0.65
9	5	1600	1.2	6.890	6.919	-0.41	0.41
10	7	500	0.6	7.540	7.554	-0.19	0.19
11	7	500	0.9	5.255	5.272	-0.32	0.32
12	7	500	1.2	5.598	5.503	1.69	1.69
13	7	1000	0.6	8.340	7.707	7.59	7.59
14	7	1000	0.9	8.454	8.468	-0.16	0.16
15	7	1000	1.2	8.683	8.677	0.07	0.07
16	7	1600	0.6	9.211	9.220	-0.09	0.09
17	7	1600	0.9	9.247	9.780	-5.76	5.76
18	7	1600	1.2	9.461	8.887	6.07	6.07
19	10	500	0.6	9.711	9.732	-0.22	0.22
20	10	500	0.9	8.226	8.678	-5.50	5.50

21	10	500	1.2	7.198	7.245	-0.67	0.67
22	10	1000	0.6	10.968	10.978	-0.10	0.10
23	10	1000	0.9	11.482	11.475	0.06	0.06
24	10	1000	1.2	11.767	11.754	0.12	0.12
25	10	1600	0.6	11.710	11.705	0.05	0.05
26	10	1600	0.9	11.996	11.960	0.30	0.30
27	10	1600	1.2	12.210	12.259	-0.40	0.40



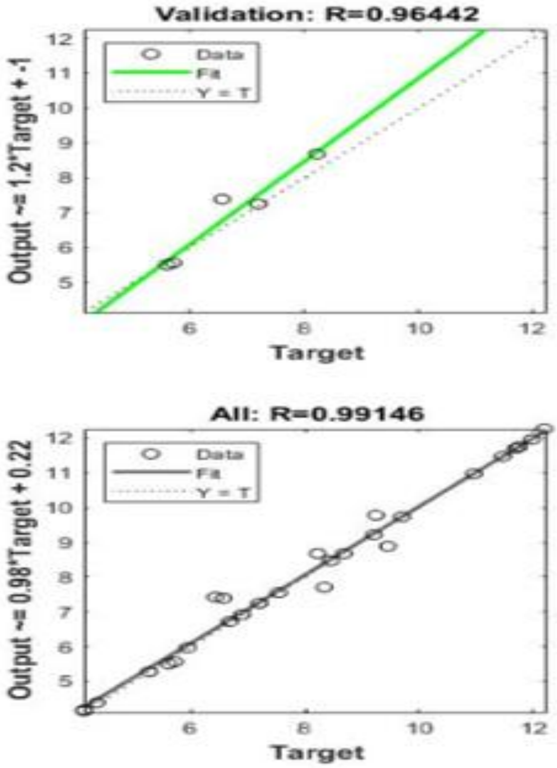


Fig.2 Regression plot using LM algorithm for wear test results of Mg/BN (1.5 wt.%)

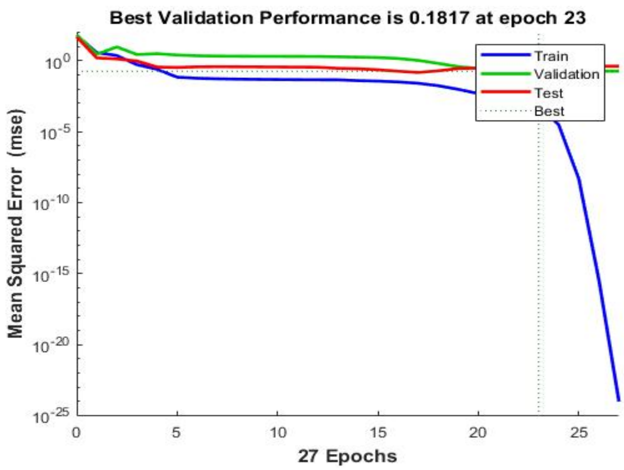


Fig.3. Performance plot using LM algorithm for Mg/BN (1.5 wt.%)

The experimental wear test results for Mg/BN (1.5 wt.%) nanocomposite were obtained using pin on disc apparatus under various test conditions [27] . The validation of wear loss was done by using the neural network tool in MATLAB R2021a. According to experimentation, the wear test results of Mg/BN (1.5 wt.%) nanocomposite are given in Table 2.

Experimental data consists of 27 datasets that are utilized to develop ANN to understand the correlation between input and output. The test and predicted values of wear loss for Mg/BN (1.5 wt.%) are depicted in Table 3. It must be noted that 60% of the experimental data was used for training the neural network model, and around 20% is used for validation and 20% is used for testing purposes [17]. The predicted ANN values and the experimental values of wear loss are compared, and the percentage error between them is calculated using Eq.4.

$$\%\text{Error} = \left|\frac{W_{Loss}(Exp) - W_{Loss}(ANN)}{W_{Loss}(Exp)}\right| \text{x } 100 \qquad (4)$$

Where W_{Loss} (Exp) = Experimental value of Wear loss, W_{Loss} (ANN) = ANN predicted value of Wear loss.

The error for wear loss of Mg/BN(1.5 wt.%) lies within 16% with an average error of 2.39% between experimental data and neural network prediction. Hence, we can conclude that neural network prediction has proceeded correctly. A regression plot is plotted between the network output, and the target is shown in Fig.2. The tracking of output values with the targets values holds good for the correlation coefficient (R^2-value) 0.99146. Also, it shows a better match with the experimental data. A performance plot showing the training, validation, and test errors are shown in Fig.3. At iteration nine, best validation performance occurs with a mean squared error value of 0.1817. After the 23rd iteration, the test set error and the validation set error will have similar characteristics, and there will be no over-fitting occurring. Therefore, validation stops at the 27th iteration

5. Conclusions

In the present work, analyzing wear properties of Mg/BN (1.5 wt%) have been analyzed using ANN. The wear test was conducted using pin-on-disc apparatus and determined experimental results for wear loss. Load, sliding distance, and sliding velocity were selected as input parameters. The comparison between experimental results and ANN results shows a good agreement having a correlation coefficient of R^2 = 0.99146. The prediction of wear loss using ANN was validated, and the accuracy of a result obtained was within 16% with an average error of 2.39%. Also, iteration 23rd proved to be the best validation performance for wear loss, as it had a mean squared error value of 0.1817.

References

1. Lim CYH, Leo DK, Ang JJS, Gupta M. Wear of magnesium composites reinforced with nano-sized alumina particulates. Wear 2005;259:620–5.
2. Goh CS, Wei J, Lee LC, Gupta M. Properties and deformation behaviour of Mg–Y2O3 nano-composites. Acta Mater 2007;55:5115–21.
3. Kainer, K.U.; Buch, F. *Magnesium Alloys and Technology*; Wiley-VCH: Weinheim, Germany, 2003; pp. 1–22.
4. Lloyd, D.J. Particle reinforced aluminium and magnesium matrix composites. *Int. Mater. Rev.*1994, *39*, 1–23.
5. Dieter, G.E. *Mechanical Metallurgy*; McGraw-Hill: New York, NY, USA, 1986.

6. Shanthi M, Nguyen QB, Gupta M. Sliding wear behaviour of calcium containingAZ31B/Al2O3 nanocomposites. Wear 2010;269:473–9.
7. Cicek Bunyamin, Ahlatc Hayrettin, Sun Yavuz. Wear behaviours of Pb added Mg–Al–Si composites reinforced with in situ Mg2Si particles. Mater Des 2013; 50:929–35.
8. Manoj Kumar BV, Bikramjit Basu, Murthy VSR, Manoj Gupta. The role of Tribochemistry on fretting wear of Mg–SiC particulate composite. Compos Part: A2005;36:13–23.
9. Ajith Kumar KK, Pillaia UTS, Pai BC, Chakraborty M. Dry sliding wear behaviour of Mg–Si alloys. Wear 2013;303:56–64.
10. Yang ZR, Wang SQ, Zhao YT, Wei MX. Evaluation of wear characteristics of Al3Tip/Mg composite. Mater Charact 2010;61:554–63.
11. Won Bae Lee, Chang Yong Lee, Myoung Kyun Kim, Jung I Yoon, Young Jig Kim, Yun Mo Yoen. Microstructures and wear property of friction stir welded AZ91 Mg/SiC particle reinforced composite. Compos Sci Technol 2006;66:1513–20.
12. Hassan S, Gupta M. Development of high performance magnesium nanocomposite using nano-Al_2O_3 as reinforcement. Mater Sci Eng A 2005;392:163–8.
13. Tun K, Jayaramanavar P, Nguyen Q, Chan J, Kwok R, Gupta M. Investigation into tensile and compressive responses of Mg–ZnO composites. Mater Sci Technol 2012;28:582–8.
14. Saravanan RA, Surappa MK. Fabrication and characterization of pure magnesium-30 vol.% SiCp particle composite. Mater Sci Eng A 2000;276:108–16.
15. Selvam B, Marimuthu P, Narayanasamy R, Anandakrishnan V, Tun KS, Gupta M. Dry sliding wear behaviour of zinc oxide reinforced magnesium matrix nano-composites. Mater Des 2014;58:475–81.
16. D. Jeyasimman, R. Narayanasamy, R. Ponalagusamy, V. Anandakrishnan, M. Kamaraj, The effects of various reinforcements on dry sliding wear behavior of AA 6061 nanocomposites. Mater Des 2014.
17. Thein Maung Aye, Lu L, Lai MO. Mechanical properties of nano-structured Mg–5 wt% Al–x wt% AlN composite synthesized from Mg chips. Compos Struct 2006;75:206–12.
18. Basavarajappa S, Chandramohan G, Paulo Davim J. Application of Taguchi techniques to study dry sliding wear behaviour of metal matrix composites. Mater Des 2007;28:1393–8.
19. Taltavull C, Rodrigo CP, Torres B, Lopez AJ, Rams J. Dry sliding wear behavior of AM50B magnesium alloy. Mater Des 2014;56:549–56.
20. Rao RN, Das S. Effect of sliding distance on the wear and friction behavior of as cast and heat-treated Al–SiCp composites. Mater Des 2011;32:3051–8.
21. Deuis RL, Subramanian C, Yellup JM. Dry sliding wear of aluminium composites-A review. Compos Sci Technol 1997;57:415–35.
22. Kwok JKM, Lim SC. High-speed tribiological properties of some Al/SiCp composites II wear mechanisms. Compos Sci Technol 1999;59:65–75.
23. Ramesh C S, Kumar R S. Mathematical and Neural Network models for prediction of wear of mild steel coated with Inconel 718 – A Comparative Study. International Journal of Scientific and Research Publications, 2012;2;1-8.

24. Montazer E, Yarmand H, Salami E, Muhamad, M R, Kazi S N, Badarudin A. A brief review study of flow phenomena over a backward-facing step and its optimization. Renewable and Sustainable Energy Reviews, 2018;82;994-1005
25. Vaishak NL, Prashanth T, Suhas. Investigation of wear behavior of as forged inconel 690 super alloy using Artificial Neural Networks. Journal of Manufacturing Engineering 2019;14; 129-133.
26. S. D. Saravanana, M. Senthilkumar. Prediction of Tribological Behaviour of Rice Husk Ash Reinforced Aluminum Alloy Matrix Composites Using Artificial Neural Network. Russian Journal of Non-Ferrous Metals; 2015;56;97–106.
27. R Vara Prasad Kaviti, D. Jeyasimman, Gururaj Parande, Manoj Gupta, R Narayanasamy. Investigation on dry sliding wear behaviour of Mg/BN nanocomposites. 2018;6;263-276