Artificial Neural Networks for the Prediction of Wear Properties of Al6061-TiO₂ Composites

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Abstract. The exceptional performance of composite materials in comparison with the monolithic materials have been extensively studied by researchers. Among the metal matrix composites Aluminium matrix based composites have displayed superior mechanical properties. The aluminium 6061 alloy has been used in aeronautical and automotive components, but their resistance against the wear is poor. To enhance the wear properties, Titanium dioxide (TiO₂) particulates have been used as reinforcements. In the present investigation Back propagation (BP) technique has been adopted for Artificial Neural Network [ANN] modelling. The wear experimentations were carried out on a pin-on-disc wear monitoring apparatus. For conduction of wear tests ASTM G99 was adopted. Experimental design was carried out using Taguchi L27 orthogonal array. The sliding distance, weight percentage of the reinforcement material and applied load have a substantial influence on the height damage due to wear of the Al6061 and Al6061-TiO₂ filled composites. The Al6061 with 3 wt% TiO₂ composite displayed an excellent wear resistance in comparison with other composites investigated. A non-linear relationship between density, applied load, weight percentage of reinforcement, sliding distance and height decrease due to wear has been established using an artificial neural network. A good agreement has been observed between experimental and ANN model predicted results.

1. Introduction

The expanding interest for lessening in weight, saving energy and to reduce pollution in auto vehicles has prompt to the improvement of novel, lightweight vehicle materials amid the most recent decade. Metal Matrix Composites (MMCs) are a class of materials that try to consolidate the high solidness, stiffness with the sturdiness and damage resistance gave by a metal matrix [1]. Veeresh et al [2] classified the uses of composite materials in military and airplanes, clarified in insight about composite materials and structures in airframes. The earthenware particulate filled composites display enhanced resistance to scratch [3] and they discover applications in car motor segments as blocks of cylinders, pistons, cylinder embed rings, calipers [4], microwave channels, vibrator segment,
contactors, impellers and space structures [5-8]. S Kumar et. al., [10] while developing a numerical model for dry-sliding states of wear direct in Al7075-Silicon Carbide composites nitty gritty that extended Silicon Carbide in mix decreases the measure of wear in the composites by restricting the stream or contorting of the grid material against associated stack. RupaDasgupta et. al., [11] communicated that the adjustment in the material hardness, resistance against wear and mechanical property are expert by warmth treating the composites. [12] in their survey contemplated that the 5 and 13 µm particle evaluate SiC strengthened Al7075 indicates upgraded inflexibility and lower pliability. [13] reported the overwhelming mechanical attributes of Al7075-Silicon Carbide composites. [14] found the more prominent wear rate of with composites containing SiCw, in contrast with SiCp [15] induced that Al6061–TiO$_2$ composite showed more noteworthy hardness, bring down coefficient of wear, when differentiatied and the combination framework and Al6061–8 wt% TiO$_2$ had minimal coefficient of wear. [16] inspected wear lead of hot ousted Al6061 based composites with Silicon Carbide, Al$_2$O$_3$-Cerium oxide fortifications, and assumed that rate of wear of Al6061-cerium oxide had the most insignificant rate of wear under unclear examination conditions.Expansive examination has been performed on the examination of wear direct of aluminum based MMCs [17]. The most basic reason behind the harm and following disaster of segments of machine is wear. [22]. ANN help in decrease of the experimentation cost when executed with legitimate care and adequate data [18-24].

2. Materials Details and Wear Tests

The ingots of Al6061 was procured from FenfeeMetallurgicals, Bengaluru. Titanium dioxide was chosen as the reinforcement material with a particle size of 100 µm from Sadan Abrasives, Bengaluru. The particles was preheated and introduced in to the vortex and the metal matrix composites was manufactured through liquid metallurgy. 500 rpm in the impeller made of steel was maintained and a driving temperature of 720 °C was maintained. The degree of reinforcement variation in Al6061 matrix was 0-3 wt%.The specimens were prepared according to G99 standards with 10mm breadth. The wear tests were executed on a pin on disc machine of DUCOM make. A LVDT was used to measure wear on terms of loss of height with an exactitude of 1.0 µm. The wear machine had a HRC60 disc of high carbon steel EN31. The metal matrix composite surface roughness was sustained at Ra 0.1 µm. A sliding speed of 2.62 m/s, loading of 10N-60N, sliding distance 6000m and a track radius of 120mm was maintained. The wear height loss from 0-3% TiO$_2$ has been shown in figure 1.

3. Implementation of Artificial Neural Network

In the current examination Back propagation (BP) algorithm was utilized for ANN modelling. An ANN with 4 – [4 – 3]2 – 1 setup was chosen similar to the network shown in figure 1 (with four info, one yield and two unseen layers with 7 unseen hubs, 4 and 3 neurons in the neurons first and second covered layers respectively), with material and testing (two parameters each) as information and wear tallness misfortune as yield. ANN model were demonstrated utilizing NN (Neural Network) tool kit of MATLAB 7.7. NN device is an acronym for neural network apparatus with realistic UI (GUI) module. The got trial wear information were supplementary partitioned into preparing and testing set. The information was gathered from leading 24 tests. An aggregate of 860 information were gathered out of which 716 were chosen as preparing information and the rest was utilized as verifying information for check. A tan-sigmoid transference function served among the layers (aside from the yield layer), and a direct linear transference function were utilized amongst the last unseen layer and the yield layer to abstain from constraining the yield an incentive to little range. This ANN model has been utilized to anticipate wear-tallness misfortune. Subsequently best design of ANN and algorithms for learning were obscure ahead of time, experimentation strategy was utilized amid preparing procedure to discover arrange attributes (number of shrouded layers, number of handling units i.e., neurons and estimations of association weights between neurons, learning algorithms) for coordinating a specific
information/yield work. The feedforward backpropagation (BP) system, utilizing LMBP algorithms with Mean Square Error (MSE) as the execution measuring parameter were prepared. The streamlining procedure were gotten by utilizing a TRAINLM work which was accessible inside the neural network tool compartment. TRAINLM is a system preparing capacity that overhauls weightiness and inclination standards in a BP algorithm as per Levenberg Marquardt improvement. Levenberg Marquardt algorithm is profoundly proficient strategy aimed at taking care of non-straight maximization issues. The ANN implementation has been represented from figure 2 to 6.

![Wear height loss for base alloy Al6061 with 0-3% TiO$_2$](image)

**Figure 1(a) to (d).** Wear height loss for base alloy Al6061 with 0-3% TiO$_2$
Figure 2 (a) to (f). Estimation of the relationship of loss of wear height vs sliding distance (m) and weight% of TiO$_2$ reinforcement at a constant load applied (10N to 60N).

Figure 3. ANN regression curve

Figure 4. Actual experimental wear values and predicted ANN values

Figure 5. ANN testing curve

Figure 6. ANN Validation curve

4. Conclusions

The subsequent inferences drawn from the present investigation of wear behaviour of Al7075-matrix base material and its Al2O3 reinforced MMC’s using ANN are as follows.

a) The loss in terms of wear height for Al6061 alloy and its TiO$_2$ reinforced MMC’s improved as the load applied and sliding distance improved, but it was witnessed to decline as the TiO$_2$ reinforcement content increased in the base matrix.
b) The Al6061-6 wt% TiO$_2$ composite exhibited an admirable resistance against wear resistance in comparison with other composites investigated.

c) A non-linear relationship was established using ANN between weight% of TiO$_2$ reinforcement, sliding distance, density, load applied and wear height loss.

d) The experimental results and the ANN trained model results are found to be in close agreement with each other.

e) An efficiently trained competent artificial neural network is capable of predicting the loss in terms of wear height of base Al6061 alloy and its TiO$_2$ reinforced MMC’s

Acknowledgments

Authors extend sincere gratitude towards the encouragement provided by the management of Amrita Vishwa Vidyapeetham University, Bengaluru Campus in carrying out the experimental work

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