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ORIGINAL PAPER

Experimental Investigation and Prediction Analysis on Granite/SiC Reinforced Al7050 and Al7075 Using Hybrid Deep Neural Network Based Salp Swarm Optimization

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Abstract

At present, industries require tremendous new technologies to solve the challenges faced in the production process. In the existing researches, Al7075 is frequently used but Al7050 is rare hence, in this study the effort has been made on the development of Al7050 and Al7075 alloys reinforced with Granite and Silicon carbide particles using stir casting technique. The nine different reinforcing mix ratios are fixed by using the Taguchi method performed in Minitab. Morphology of the reinforced particle is examined under optical microscopy and the mechanical properties such as hardness, impact, and wear of both Al7050 and Al7075 composites are studied. The Brinell hardness test is carried out to assess the hardness of both composites. Besides, Hybrid Deep Neural Network-based Salp Swarm Optimization (DNN-SSO) is performed to forecast and validate the experimented mechanical properties and compared with related neural networks. In which, the proposed DNN-SSO shows better outcomes by providing closer results to the experimented characteristics than the predicted DNN and ANN. From the overall study, in both Al7050 and Al7075 composites, hardness and wear rates are optimal when using 12% of granite and 6% of SiC particles. The optimal impact strength is achieved from 8% of granite and 4% of SiC particles. Besides, the reinforced composite of Al7050 possesses favorable impact energy and Al7075 possesses better hardness and wear rate. The superior mechanical characteristics observed for hardness is 141.22 BHN, wear rate is 0.00125 mm^3/m and impact energy is 13.35 J. The predicted characteristics obtained using the proposed hybrid DNN-SSO achieve closer values to the experimented outcomes.

Keywords Al7075 · Al7050 · Salp swarm optimization (SSO) · Deep neural network (DNN) · Hardness · Stir casting · Impact strength

1 Introduction

In the modern world, the application of material science plays a significant aspect in the improvement of industries and Nanotechnology. From the overall materials, Aluminium possesses significant convenient factors such as light metal, cheaper, high strength behaviors, etc. [1]. Aluminium is one of the most commonly used alloy materials and it plays a vital role in the zones of Aerospace, Automobile, and Defence industry [2]. Instead of several series of Aluminium, the most conveniently available exploring alloys are Al7050 and Al7075, which possess good corrosion resistance, better ductility, more microhardness, and high mechanical strength [3]. Such alloys are commonly used in the manufacturing of automotive and aircraft components. Normally, Reinforcement technology tends to be more beneficial in the current technology and it helps to improve the entire mechanical properties of the Aluminium alloy and prevent the shortage of the lifespan of equipment in the industry [4] [5]. The different reinforcing additive materials added to aluminium alloys are SiC, MgC, BC, Granite particles, and several earth oxides, etc. [6]. The hardness property of the base material is to be increased when utilizing SiC as a reinforcing agent [7]. The granite particles are easily available in the market cheaply with excellent mechanical properties such as high strength, inflexible, impervious, etc. It consists of chemical compounds of both SiO_2 and Al_2O_3 with a variety of usages in the domain of aerospace and chemical engineering. In addition to this, it possesses better hardness and greater wear and corrosion resistance.

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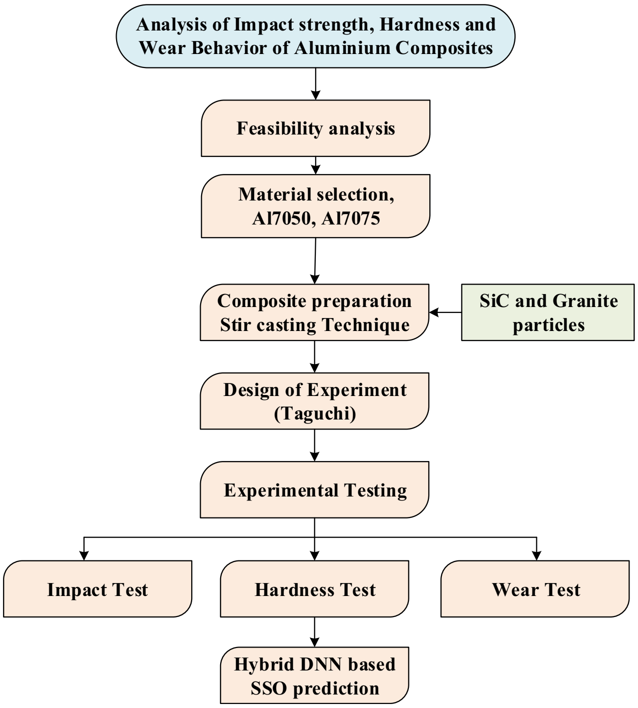


Fig. 1 Flow of the proposed Model

Satyanarayana et al. [8] have been utilized the graphite/granite nano particles to reinforce the A356 Aluminium alloy and better wear resistance was observed. In the case of several fabrication methods, a constant dispensation of particles is achieved by the method of stir casting [9]. Stir casting is a liquid metallurgical technique to fabricate aluminium composite, in which a dispersed zone (ceramic, nanoparticles) is blended with a matrix of molten metal utilizing a mechanical stirrer [10]. Ramadoss et al. [11] developed stir cast aluminium composites using B_4C and BN nanoparticles. In the stir cast specimen, the nanoparticles are homogeneously distributed, such distribution was viewed using optical microscopy.

Yuki and Otani. [12] have been investigated the mechanical properties of SiC reinforced 7075 Al composites. The fabrication of composites is performed by selective laser melting technique. The 7075 alloys cause severe crack during the Selective Laser Melting (SLM) process. Hence they added silicon which allows the fabrication process without any defects. By the addition of silicon content, the Vickers microhardness was increased and 0.2% of proof strength was increased. However, the addition of SiC also promotes certain disadvantages due to its less interfacing and porosity. So, the additional reinforced particles are to be added with SiC to enhance the interfacing ability. Besides, such blended behavior of nanoparticles helps to enhance the mechanical characteristics of Aluminium alloy. This is proved by the existing research, where aluminium material is to be reinforced with Al_2O_3 + SiC, its tensile strength and the hardness increases with the decrease of ductility [13]. Sharma and Vinodh kumar [14] have been used three different nanoparticles such as SiC, CeO_2, and Al_2O_3 to enhance the mechanical behaviors of Al6061. In which, the Rockwell hardness of the base alloy was enhanced by 33.80%.

Table 2 Composition of Reinforced Particles

Reinforcement Ratio	4:2	4:4	4:6	8:2	8:4	8:6	12:2	12:4	12:6
Matrix volume (%)	94	92	90	90	88	86	86	84	82

The proposed research work is to investigate the impact, hardness, and wear behaviour of Aluminium alloys (Al7050 and Al7075) with the blended reinforcing agent of SiC and Granite particles by stir casting process [15]. Several researchers proved that the use of hybrid nanoparticles possesses superior mechanical characteristics than the single nanoparticle. Subramaniam et al. [16] reported the mechanical characteristics of hybrid aluminium matrix composite. Aluminium matrix composites were cast by stir casting method and they are made by blended with coconut shell fly ash and boron carbide. The hardness and tensile strength were increased up to 33% and 66% significantly. But the impact strength of the composites was decreased. Venkatesan and Anthony Xavior [17] was investigated the mechanical characteristics of Al7050 blended with graphene nanoparticles. In this, the design of experiments was performed by Taguchi and the composites are fabricated by squeeze and stir casting technique. They have been found that the 0.3% wt of graphene in Al7050 composites has highly improved the tensile strength for both the squeeze and stir cast specimens.

Further, the testing of the material properties like Hardness, wear, and impact test is performed as per the ASTM standard [18]. Hardness test being accomplished by the Brinell hardness equipment and impact test by an impact tester [19]. By using the sliding property of the pin on the disc method, the wear test is carried out and determines the wear rate [20]. Sardar et al. [21] have been investigated the wear and frictional behavior of Al7075 with Al_2O_3 composites. The

Table 1 Chemical Composition of Al7050 and Al7075

Chemical Composition (%)	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al7050	0.6	0.5	0.25	0.15	1	0.04	0.25	0.15	Bal
Al7075	0.40	0.5	1.5	0.3	2.5	0.23	5.6	0.2	Bal

Fig. 2 Fabrication process

composites were cast by the stir casting method and the test conditions are carried out by analysis of variance (ANOVA), Taguchi orthogonal array, and regression methods. They reported the wear and the friction rate was highly reduced, but the surface roughness is increased. Baradeswaran and Perumal [22] have been investigated the mechanical properties of Al7075 with added Al_2O_3 and 5% wt of graphite. In this, the reinforced alloy was fabricated by liquid metallurgy. They reported the addition of Al_2O_3 and graphite with Al7075 highly gain wear reduction. The flexural strength, compression strength, hardness, and tensile strength were increased.

Microstructure analysis proves the uniformity of the particles after the casting process. Such a type of analysis process is accomplished with the help of an etching of NaOH solution [23]. The surface of the aluminum composite tends to be an action of etching so that the silicon particles are exposed and it helps to improve the mechanical properties [24]. Finally, the selection of a better aluminium composite is to be accomplished after the testing methods [25]. The combined effect of reinforced aluminium provides a better improvement of mechanical properties than the individual effect. The optimization techniques are also applied in composite research to find the supreme outcomes of mechanical properties. Taguchi methods are widely used for such optimization purposes [26]. Sathish and Karthick [27] analyzed the wear behaviour of reinforcement aluminium alloy made of Al7050 as base material with silicon carbide of 0%, 4%, and 6%. The design of experiments was performed by Taguchi and they reported that the wear rate was highly reduced due to the addition of silicon carbide (SiC) particles. Several researchers have applied neural networks to validate and predict the experimented mechanical behaviours of Aluminium alloy. The hardness of SiC reinforced Aluminium was predicted with the help of Artificial Neural Network (ANN) and RSM. In which, the predicted values from ANN promote optimal accuracy and minimal error than RSM [28].

From the existing papers, the nanoparticle of SiC is majorly contributed to the Al7075 and Al7050. But, the contribution of granite particles as the reinforcement for aluminium alloy is very limited. In our work, the combination of both SiC and granite particles is reinforced with Al7075 and Al7050. In existing researches, certain works have utilized ANN to validate the experimental results. In some cases, more hidden layers are required to achieve better training. So, in our work, a Deep neural network (DNN) is used and it is constructed by modifying the layers of ANN. During training, the weight values are optimized and updated with the help of Salp swarm optimization (SSO). Such forecasting behavior of the mechanical properties using a hybrid neural network is rare in the existing researches.

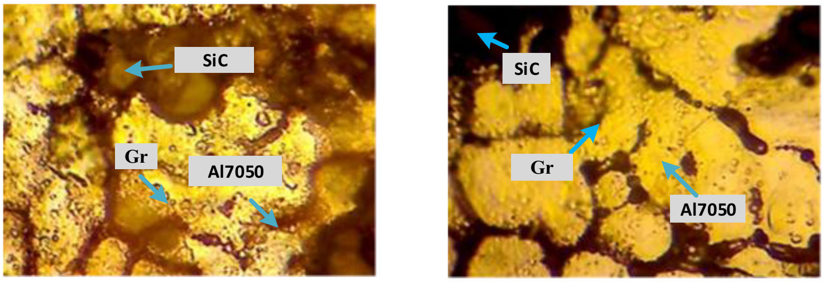
This research work will promote the guidance for the improvement of mechanical properties of the aluminium series of Al7050 and Al7075 with the help of reinforcing agents such as SiC and Granite particles. The Design of experiment is planned by using the Taguchi method. The test will be separately conducted to find out the microstructure analysis and the mechanical properties such as wear, hardness, and impact for the newly formed reinforced Aluminium composites as per the ASTM standard. In addition to this, the experimented outcomes are forecasted with the help of Hybrid DNN-SSO.

The rest of the sections are classified as follows: Section 2 briefly explains the existing researches related to the aluminium reinforcement. The proposed flow of work is discussed in section 3. The materials and prediction methods used in this research work are given in section 4. The outcomes revealed

(a) Al7075 (b) Al7050

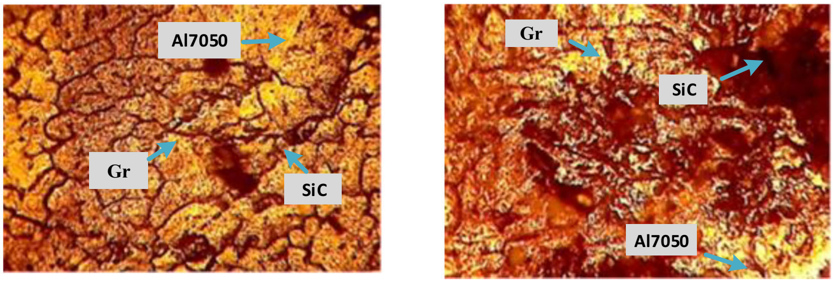
Fig. 3 Fabricated Reinforced specimens

Fig. 4 Microstructure Analysis of Al7050 Composite Alloy with Scope Ratio of 100X and 500X



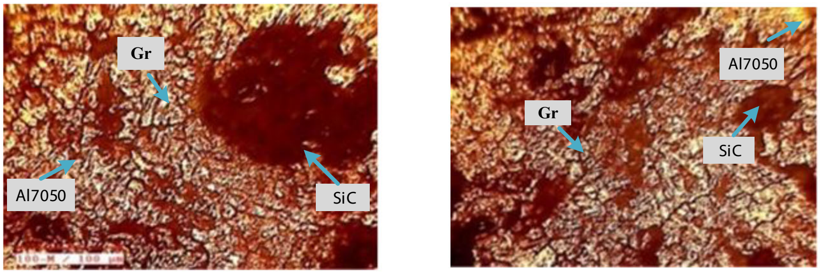
(a)Al7050-(4Gr+2SiC) - 100X

(b) Al7050-(4 Gr +2SiC)- 500X



(c) Al7050-(8Gr +4SiC) - 100X

(d) Al7050-(8 Gr+4SiC)- 500X



(e) Al7050-(12Gr+6SiC) - 100X)

(f) Al7050-(12Gr+6SiC) - 500X

from the Aluminium reinforcement are given in section 5 and section 6 concludes the research work.

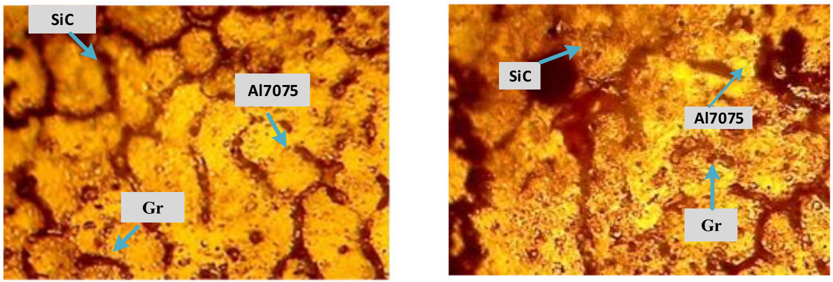
2 Proposed Methodology

The mechanical and microstructural characteristics of Granite and SiC particles added to Aluminium alloys are determined and optimized in this work.

The architectural flow for the proposed work of two aluminium alloys is demonstrated in fig. 1. Before starting the research work, the feasibility test was conducted to determine the best parameter fits in our work. The feasibility analysis is conducted by separate utilization of nanoparticles based on existing papers and setting the initial reinforcement ratio as 2%. By this input ratio, the output of granite reinforcement is worse than the SiC. So, 4% of granite particles and 2% of SiC is used as initial reinforcement level.

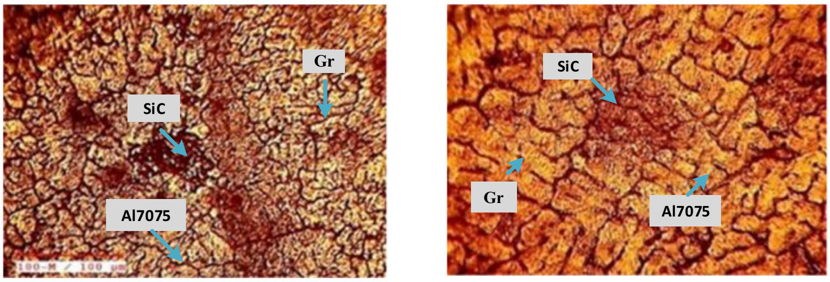
The proposed methodology of this research work makes use of two reinforcement agents such as Granite particles and SiC applied on the Aluminium series Al7050 and Al7075 for improvement of mechanical properties of the base aluminium series. The proposed research work is done in three phases. In the first phase, the fabrication of reinforced aluminium composite takes place by the use of a stir casting technique. In this phase, both the aluminium series of Al7050 and Al7075 are to be separately reinforced by adding reinforcing agents like SiC and Granite particles. In the second phase, experimental testing is carried out on the fabricated reinforced aluminium composites for finding out the behavior of impact, wear, hardness, and microstructural analysis. The tests are carried out under

Fig. 5 Microstructure Illustration of Al7075 Composite Alloy with Scope Ratio of 100X and 500X



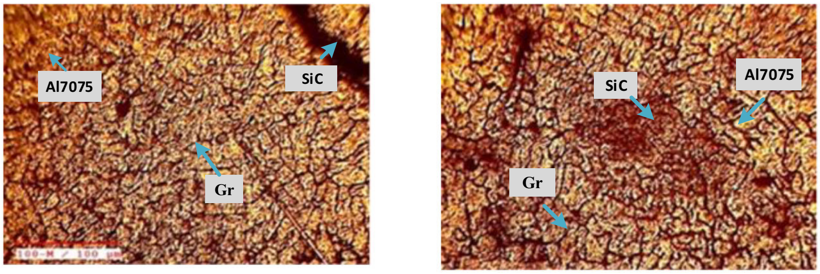
(a) Al7075-(4Gr+2SiC) - 100X

(b) Al7075-(4Gr+ 2SiC) - 500X



(c) Al7075-(8Gr +4SiC)-100X

(d) Al7075-(8Gr +4SiC)-500X

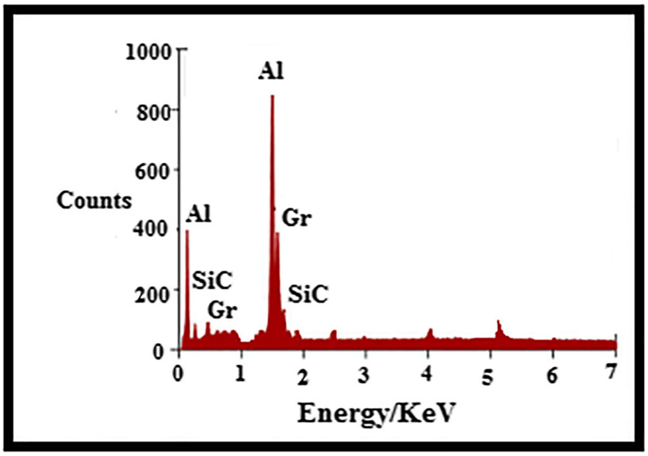


(e) Al7075-(12Gr+6SiC) 100X

(f) Al7075-(12Gr+6SiC)-500X

9 different reinforcement ratios of SiC and Granite particles. The microstructure analysis is done on the reinforced aluminium composite with the scope ratio of 100X and 500X. Further, Taguchi optimization is used to perform the design of the experiment and to find the better one based on the contribution of hardness, Impact, and Wear tests. Finally, Hybrid deep neural network-based SSO optimization is used to predict the supreme effects of Aluminium alloys and the results are compared with DNN and ANN.

Fig. 6 EDAX Analysis of Al7075 (12Gr + 4SiC)



3 Experimental Procedure

3.1 Material Selection

In this experiment, materials of aluminium in the series of Al7050 and Al7075 and the reinforcing agents of Granite and SiC particles are selected and their compositions are discussed in the following section. The particle size of the utilized granite and SiC was 60 and 40 μm. In Table 1, indicates the chemical composition of both the alloys of Al7050 and Al7075. In this, silicon and magnesium are the major content in the Al7050 alloy and zinc acts as a primary element in the Al7075 alloy. The proportion of fabricated nine different ratios for SiC and Granite particles are categorized in Table 2.

3.2 Specimen Preparation

Various fabrication techniques are available for the formation of reinforced composite, in this experiment, the stir casting method is utilized. The stir casting technique is processed by its corresponding operating parameters such as the speed of the stirrer, melting temperature, temperature to preheat the reinforcement, etc. It contains a furnace for preheating and a stirrer for colliding the particles. Initially, the aluminium alloys are melted in a single-phase electrical Muffle furnace (EIE Brand) at 850 °C. The operating frequency range of the furnace is 50 to 60 Hz. Later, Granite particles and silicon carbide reinforcement are added into the vortex of the melt with nine different ratios 4:2, 4:4, 4:6, 8:2. 8:4, 8:6, 12:2, 12:4 and 12:6. After adding the reinforcement stirring was continued for 5 min. A three-blade stainless steel stirrer is employed for stirring. Periodic care was taken to maintain casting pouring temperature (600 °C) and stirring time (15 min). The dimensions of the cylindrical-shaped specimens are about 15 mm radius and 150 mm in length. The Aluminium composites are cast by following the ASTM standard B686. The required samples are machined as per ASTM Standards.

Figure 2 represents the macroscopic picture view of the stir casting setup and melting action performed in the Aluminium alloy. The prepared reinforced aluminium alloys are shown in fig. 3.

3.3 Mechanical Characteristics

The mechanical characteristics such as impact energy and hardness of the aluminium composites are tested from Met Mech Engineers Pvt. Ltd., Chennai. The impact test is done under the utilization of the Charpy impact tester (Fine testing brand) with standard ASTM E-23. The test was estimated by total energy needs for shatter the sample and correlating it with cross-sectional dimensions of the samples. The impact energy of both Al7050 and Al7075 are most commonly depends upon particle dispersion in the composite matrix. For this current investigation, the Brinell hardness test (KRYSTAL EQUIPMENTS) is used according to the standard of ASTM E10. The Brinell hardness method consists of a ball-like structure that is made of steel material with a radius of 2.5 mm. The experiment is conducted by the load of 100 kg was subjected to each sample for about 10 s.

Table 3 Taguchi Design of Experiment

(a)Selected Levels and Factors

Levels	**Factors**	
	Granite particles	**SiC**
1	4	2
2	8	4
3	12	6

(b) DOE Array Format

Experiment number	**Granite particles**	**SiC**
1	4	2
2	4	4
3	4	6
4	8	2
5	8	4
6	8	6
7	12	2
8	12	4
9	12	6

3.3.1 Tribology Behaviour

The wear behaviour of the developed Aluminium composites is conducted using pin-on disc method (Met Mech Engineers Pvt. Ltd., Chennai). The wear test is to be conducted for about 10 mins with the load of 4 kg rotating at the speed of 500 rpm. For wear rate estimation of the composite alloys, the Pin-on-

```
Pseudocode- SSO
Initialization of weights, $x_i (i = 1,2,....,n)$
While (stopping criteria is not satisfied)
Fitness calculation for each weight
F-best weight values
Update $q_1$ using eqn. (9)
  for the weight ($x_i$)
    if (i=1)
        Updating leading weight position using eqn. (8)
    else
        Updating the follower weights position using eqn. (12)
    end
  end
    Update weight population using upper and lower variables limits
end
return F
```

Fig. 8 Pseudocode of Salp Swarm Optimization

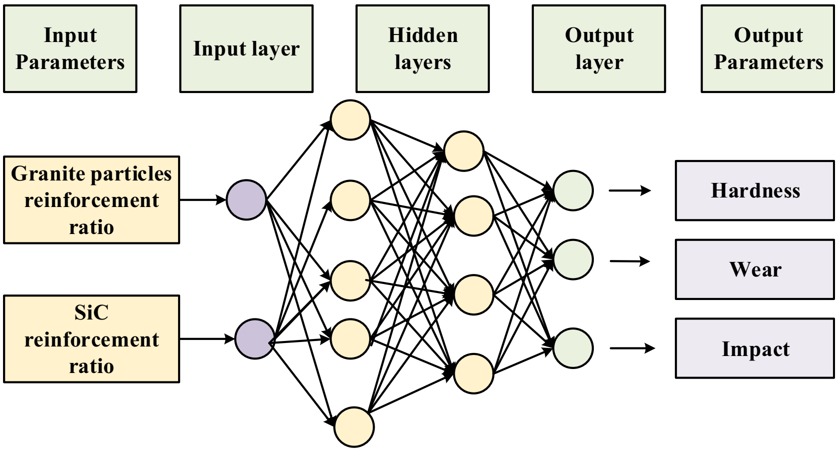


Fig. 7 Schematic Layout of DNN

disc test was considered and the pin sample with the length of 30 mm and diameter of 10 mm and all the preparations was as per the ASTM G-99-95 standard. For an estimation of the wear and frictional force between the sliding surfaces, Tribometer is used. The tested sample is placed in the holder and the load is suspended at the end of the specimen. A sliding disc made up of high carbon high chromium steel was connected across the holder of the Tribometer.

3.3.2 Microstructural Characterization of Al7050 and Al7075 Composite Alloy

The microstructural analysis has been performed by optical microscope (BS2082 model, Met Mech Engineers Pvt. Ltd., Chennai) with the microscopic ratio of 100X and 500X by varying weight percentages (4%,8%, and 12%) of granite and (2%,4%,6%) of SiC in the base alloy Al7050. In this, NaOH etchant solution is used to eliminate the burrs and foreign particles from the specimen. Figure 4(a – f) and Al7075 fig. 5(a-f). The figure shows the microstructure of the cast samples consists of pores, grain boundaries, and intermetallic compounds at etched conditions. In analysis it was observed, throughout the cross-section the particles are uniformly distributed and smaller size grains, granite, and SiC particles are located at the grain boundaries. The addition of granite and SiC particles in both the alloy of Al7050 and Al7075 shows a reduction in the composite grain size. In this, Al7050 (12Gr + 6SiC) and Al7075 (12Gr + 6SiC) composite show the smaller grain sizes with the highest granite and SiC particles. Besides, it shows an even dispersion of both the particles of Granite and SiC in the alloy matrices and from the above testing methods, it is concluded that the resistivity of an alloy get improves with the reinforcement of nanoparticles.

The distribution of nanoparticles such as SiC and granite particles is reported using EDAX and is represented in fig. 6. The result shows the distribution of granite particles is mostly occurs than the SiC particles. Thus, the strength of the Al matrix is enhanced due to the presence of both Gr and SiC particles.

3.4 Design of Experiment-Taguchi Approach

In the present study, the Taguchi method is used to investigate mechanical properties like impact energy, hardness, and wear.

Table 4 Mechanical Characteristics of Both Al7050 and Al7075

Reinforcement Ratio	Al7050			Al7075		
	Hardness (BHN)	Impact energy (J)	Wear rate (*10^{-3}) mm^3/m	Hardness (BHN)	Impact energy (J)	Wear rate mm^3/m
4:2	87.56	7.93	0.00357	90.50	3.0	0.00300
4:4	91.48	8.4	0.00347	94.20	4.5	0.00250
4:6	96.67	9.3	0.00299	98.71	5.8	0.00228
8:2	102.60	10.1	0.00276	107.29	6.3	0.00215
8:4	115.78	13.35	0.00268	118.80	11.6	0.00181
8:6	117.75	7.2	0.00266	125.83	6.2	0.00172
12:2	121.85	6.3	0.00252	130.45	3.3	0.00150
12:4	124.26	5.2	0.00242	136.31	2.9	0.00138
12:6	129.20	4.1	0.00231	141.22	2.5	0.00125

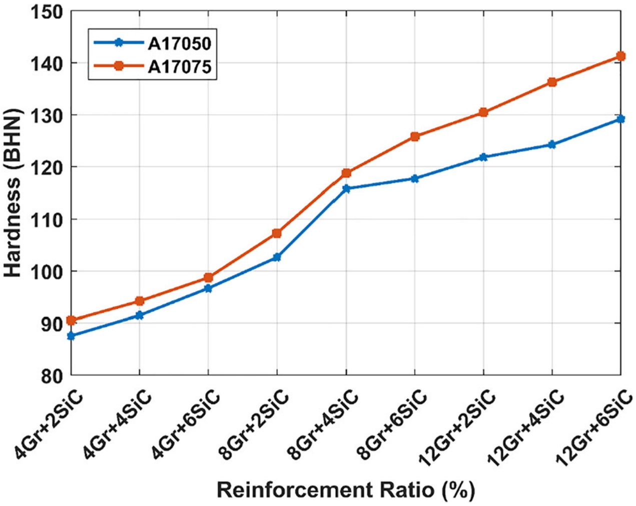


Fig. 9 Analysis of Hardness on Al7050 and Al7075 composites

This method reduced the experimental process with minimum experimental trials within a limited time at a low cost. The deviation in the optimal values and experimental values are performed by Taguchi's quality. Based on the S/N ratio the mechanical characteristics are investigated by three categories: the larger- the- better, nominal- the-best, and smaller-the-better. In this study, smaller-the-better is considered for the wear rate and the larger - the - better is considered for impact and hardness. In this work, the Taguchi method is used for both Al7050 and Al7075 reinforcements to find better reinforcements. The mechanical tests are carried with two parameters such as the ratios of SiC and Granite particles in columns 1 and 2 which varying them for three levels. In this, a total of 9 experiments are performed based on the Taguchi-based generated run order. The DOE based on Taguchi is given in Table 3.

Where, for smaller the better

$$S/N = -10\log\frac{1}{n}\left(\sum y^2\right) \tag{1}$$

For larger the better

$$S/N = -10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right) \tag{2}$$

3.5 Hybrid DNN-SSO

The deep neural network model is exploited for predicting the unknown mechanical properties of composite materials. The probability of overall mechanical properties of composite materials was predicted based on deep neural networks. In this model, the learning and training behaviours perform a major part in the prediction of mechanical behaviour of composite materials. In this network, three fully connected layers are used such as input, hidden, and output layer [29]. The input data are given to the input layer and transferred into the hidden layer. The output layer provides the needed output predicted data. The layout of a deep neural network is shown in fig. 7.

In a Deep neural network (DNN) the transmission of the input signal and generation of the output signal is performed by the neurons with the help of transfer or activation function. The input vector size is denoted as,

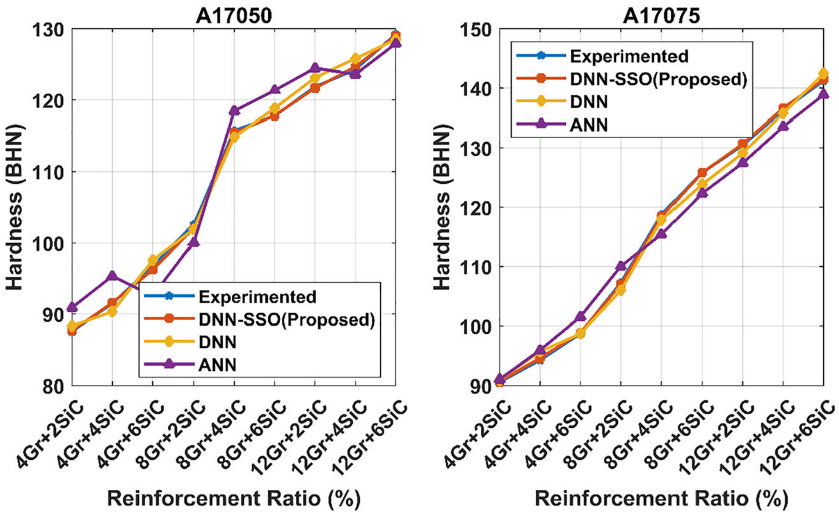
$$x = [x(k), x(k-1), \ldots x(k-m)] \tag{3}$$

Where the forecasting value is expressed as $x(k + 1)$.

The weighted sum is calculated among the hidden layer and is denoted as,

$$x_j = \sum_{i}^{m} x_i * w_{ij} + \theta_j \tag{4}$$

Fig. 10 Comparison of Hardness using different Prediction methods



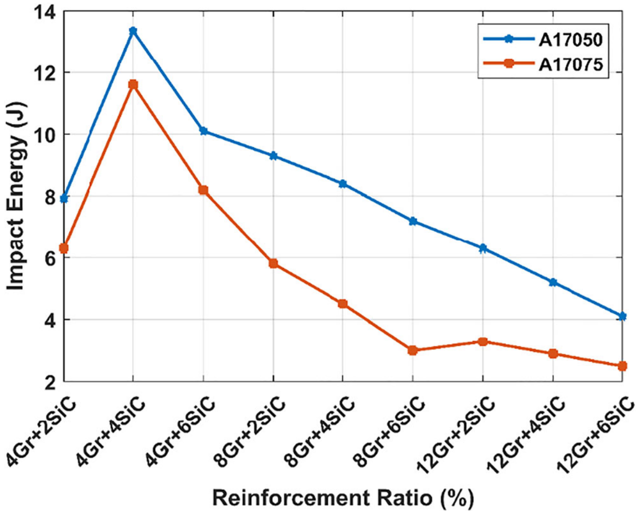


Fig. 11 Impact Energy Analysis on Al7050 and Al7075 composites

In which, the input data are represented as x_i and the bias is denoted as θ and the weighted links along the nodes are expressed as w_{ij}.

The activation function is denoted as,

$$\sigma_j(y) = \exp\left[-\left(x - \mu_j\right)\right] / \gamma_j^2 \quad (5)$$

In which, the input vector is denoted as y the center and the width of the network region is expressed as $\mu_j - \gamma_j$ the activation function of the jth neuron is represented as $\sigma_j(x)$.

In DNN, generally, after the termination of the training stage, the data are predicted. This stage is occurred for minimizing the error values obtained and this method is known as normalization. This process is repeated more times until the error values are reduced. Based on the attain error values the updating of weight is performed. Randomly the weights are updated and represented as,

$$\Delta w_{ij} = -n \frac{\theta_E}{\partial w_{ij}} \quad (6)$$

In which E represented the error values and n expressed the learning rate.

In a Deep Neural network, normally randomized weight values are updated. In such cases, the predicted output may lose its efficiency. So, in our work Salp Swarm Optimization (SSO) is used to select the optimized weight updating values and the procedures involved in the SSO method are discussed below.

The main objective of the SSO is the Salps searching for food sources by specifying the optimal position and creating the salp chain. In the present work, the salp is assumed as the weight value of the neural network and the food sources are assumed as a minimum error value.

In SSO generally, the different weight values are positioned in the form of a chain and split into leaders or followers [30]. The chain was initiated by the leader and the followers follow their movement from the leader. The pseudo-code of the SSO algorithm is illustrated in fig. 8.

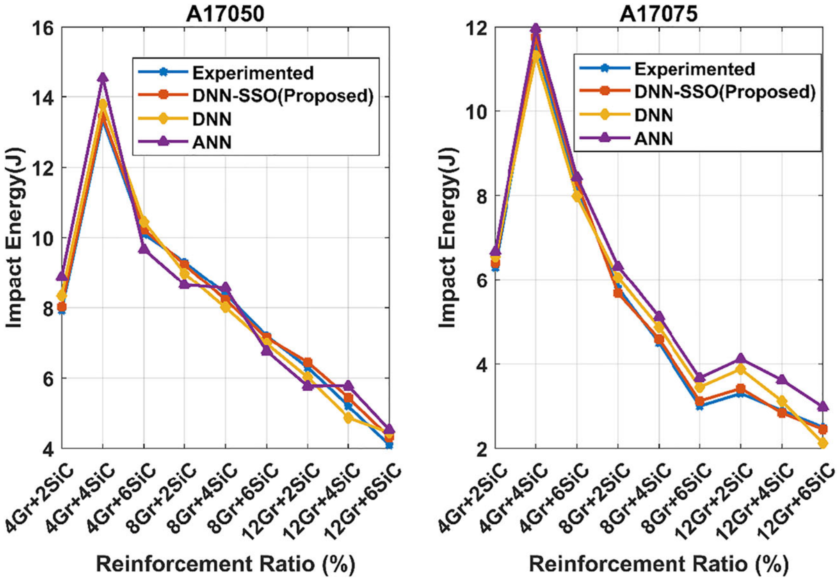
By using the following expression, the populations are initiated

$$X_i = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_d^1 \\ x_1^2 & x_2^2 & \cdots & x_d^2 \\ \cdot & \cdot & \cdots & \\ x_1^n & x_2^n & \cdots & x_d^n \end{bmatrix} \quad (7)$$

In which, the total error values are expressed as n, and the population X denote as a solution. The position of the leading weight is expressed as follows,

$$X_i = \begin{Bmatrix} y_i + q_1((av_i - lv_i)q_2 + lv_i) \\ y_i + q_1((av_i - lv_i)q_2 + lv_i) \end{Bmatrix} q_3 \geq 0, q_3 < 0 \quad (8)$$

Fig. 12 Prediction Analysis of impact energy on reinforced Al



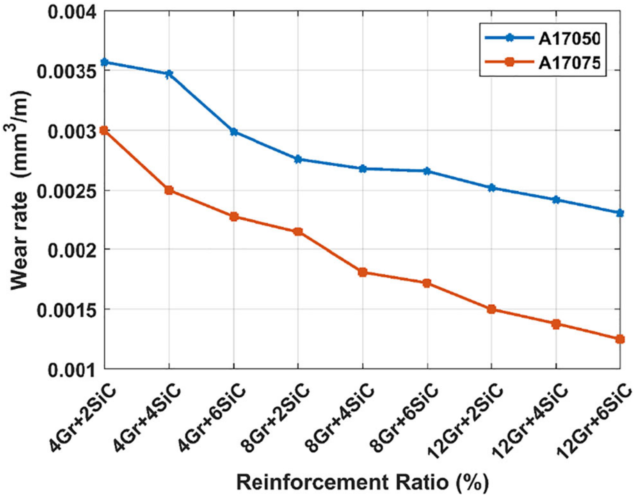


Fig. 13 Analysis of Wear rate on Al7050 and Al7075 composites

In which, in the ith dimension the first weight value is expressed as x_i^1 and the target minimized error value are expressed as y_i. The upper bound and the lower bound are expressed as $av_i lv_i$ and. The random numbers are expressed as q_2 and q_3

$$q_1 = 2e^{-\left(\frac{4l}{L}\right)^2} \tag{9}$$

In which, the current iteration and the maximum iteration are denoted as l L and. The objective of this optimization is to select the best weights by considering the minimum Root mean square error (RMSE), and is expressed below,

$$F = Min(RMSE) \tag{10}$$

The exploitation and the exploration are balanced by the coefficient q_1

$$x_i^j = \frac{1}{2}\lambda t^2 + \delta_0 t \tag{11}$$

In which, δ_0 denoted as the initial speed in the ith dimension and t is denoted as time.

Whereas $\delta = \frac{x-x_0}{t}$ and $\lambda = \frac{\delta_{final}}{}\ \delta_0$. The variations among the iterations are equal to 1 because the iteration indicates by time. Hence assume $\delta_0 = 0$ for this issue.

$$x_i^j = \frac{1}{2i}\left(x_i^j + x_i^{j+1}\right) \quad j \geq 2 \tag{12}$$

In which, some cases the error values move outwards to the search space. In such cases, the following equation is used to bring them into the search space.

$$x_i^j = \left\{ \begin{array}{cc} l^j & if x_i^j \leq l^j \\ v^j & if x_i^j \leq v^j \\ x_i^j & otherwise \end{array} \right\} \tag{13}$$

4 Result and Discussion

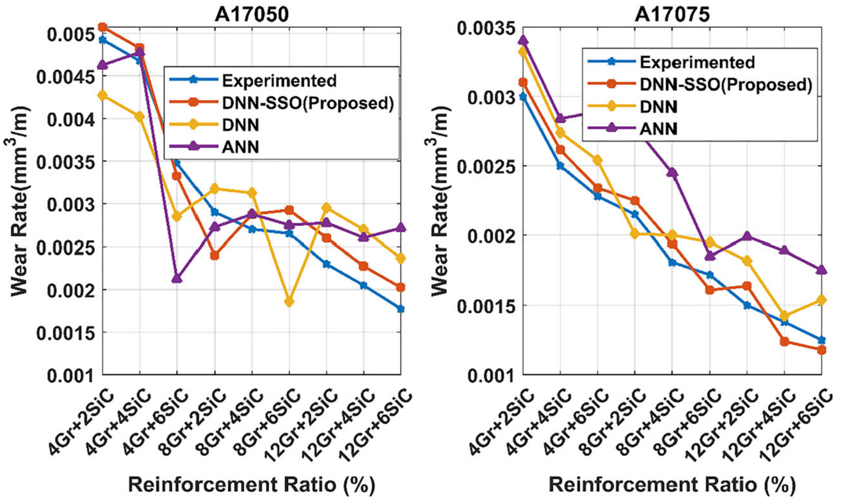
The mechanical characteristics such as impact, hardness, and the wear rate, analyzed from both the reinforced Al7050 and Al7075 are discussed in this section. Table 4 represents the mechanical characteristics of both Al7050 and Al7075 composites.

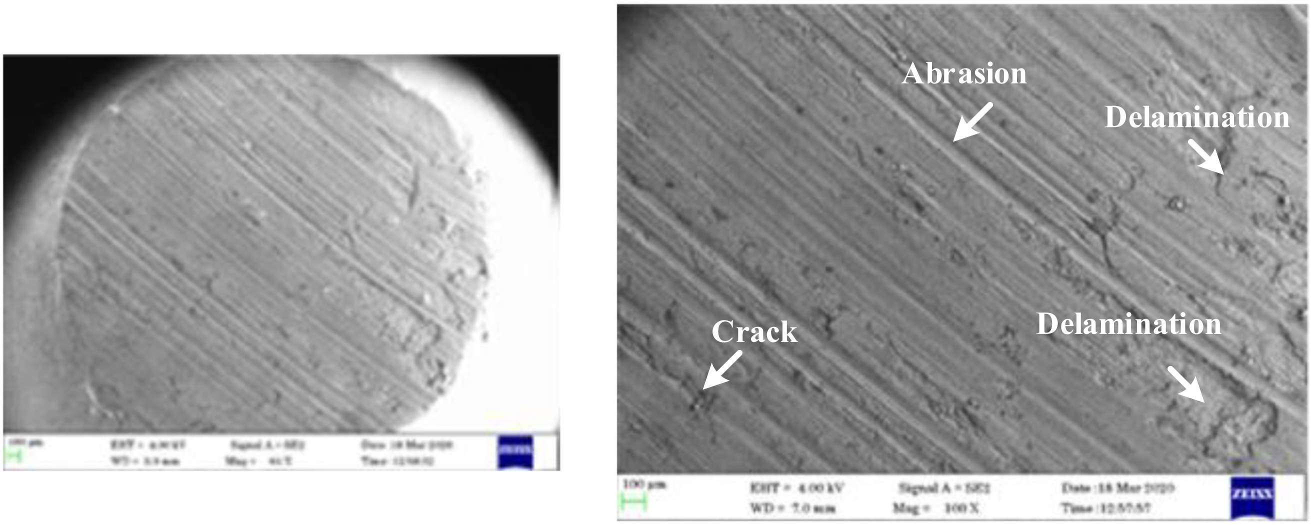
4.1 Hardness

Figure 9 shows the variations in the Brinell hardness of Al7050 and Al7075 with varying reinforcement percentages Granite and SiC.

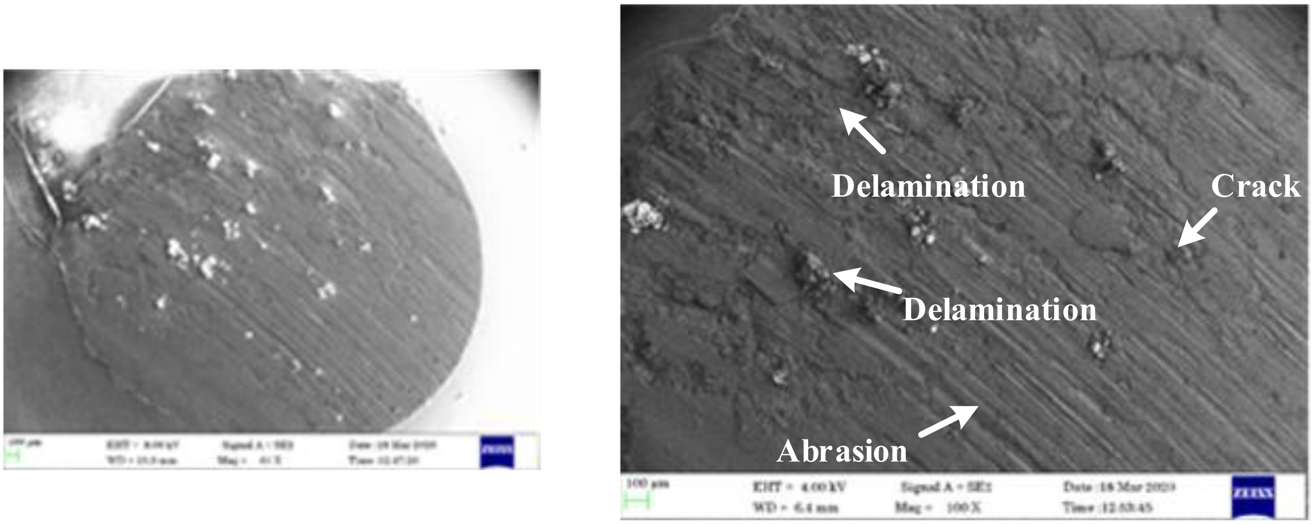
In both Aluminium alloys of Al7050 and Al7075, the addition of Granite and SiC particles gradually increases hardness. The hardness value increases with the increasing of reinforcement ratios and this is agreed with Raturi

Fig. 14 Comparison of Wear Rate using different Prediction methods





(a) Al7075 (4Gr+2Si)



(a) Al7050 (4Gr+2Si)

Fig. 15 Analysis of Maximum Wear

et al. [31]. The higher hardness values are obtained due to the addition of granite and SiC particles, this is because the voids are minimized due to the reinforced particles and tend to increase the hardness. Besides, the reinforcements highly contributed to minimizing the porosity and the formation of a finely grained structure which creates higher resistance to plastic deformation and enhances the hardness behavior. The contribution of

Table 5 Response ratio for the signal to noise ratio

Level	Impact(larger is better)		Hardness(larger is better)		Wear(Smaller is better)	
	Granite	Silicon Carbide	Granite	Silicon Carbide	Granite	Silicon Carbide
1	21.63	23.22	41.70	42.29	49.58	50.75
2	25.95	24.49	42.75	42.67	51.46	50.99
3	25.20	25.07	43.33	42.82	52.35	51.65
Delta	4.32	1.85	1.63	0.52	2.78	0.90
Rank	1	2	1	2	1	2

Table 6 S/N ratios Al7050

Level	Impact(larger is better)		Hardness(larger is better)		Wear(Smaller is better)	
	Granite	Silicon Carbide	Granite	Silicon Carbide	Granite	Silicon Carbide
1	43.09	43.49	43.09	43.49	51.80	53.55
2	43.71	43.63	43.71	43.63	54.46	54.53
3	44.17	43.85	44.17	43.85	57.03	55.20
Delta	1.09	0.36	1.09	0.36	5.23	1.65
Rank	1	2	1	2	1	2

hard reinforcement particles in Al alloy offers superior matrix strengthening behaviour. The hardness is to be enhanced by using the weight proportion of reinforced particles as 12% of granite and 6% of SiC particles. The maximum Brinell hardness is obtained by experimented for Al7050 (12Gr + 6SiC) is 129.20 BHN and Al7075 (12Gr + 6SiC) is 141.22 BHN. Thus, reinforced Al7075 promotes an enhanced level of hardness than the Al7050. The prediction behaviour for the hardness of both Al7050 and Al7075 composites is given in fig. 10. Also, by prediction method, the better results obtained from the hybrid DNN-SSO is 129.32 BHN for Al7050 (12Gr + 6SiC) and 141.29 BHN for Al7075 (12Gr + 6SiC). For Al7050, the DNN predicted value is 129.35 BHN and the predicted value from the ANN is 133.25 BHN. Besides, for Al7075 composites, the optimal predicted values from the DNN and ANN are 141.40 BHN and 137.21 BHN. Overall, our proposed predicted DNN-SSO model provides the Brinell hardness number closer to the experimental outcomes. The variation between the experimented and the Nonhybrid prediction outcomes are more. Thus, more amount of errors are attained in the non-hybrid prediction processes than in the proposed hybrid DNN-SSO.

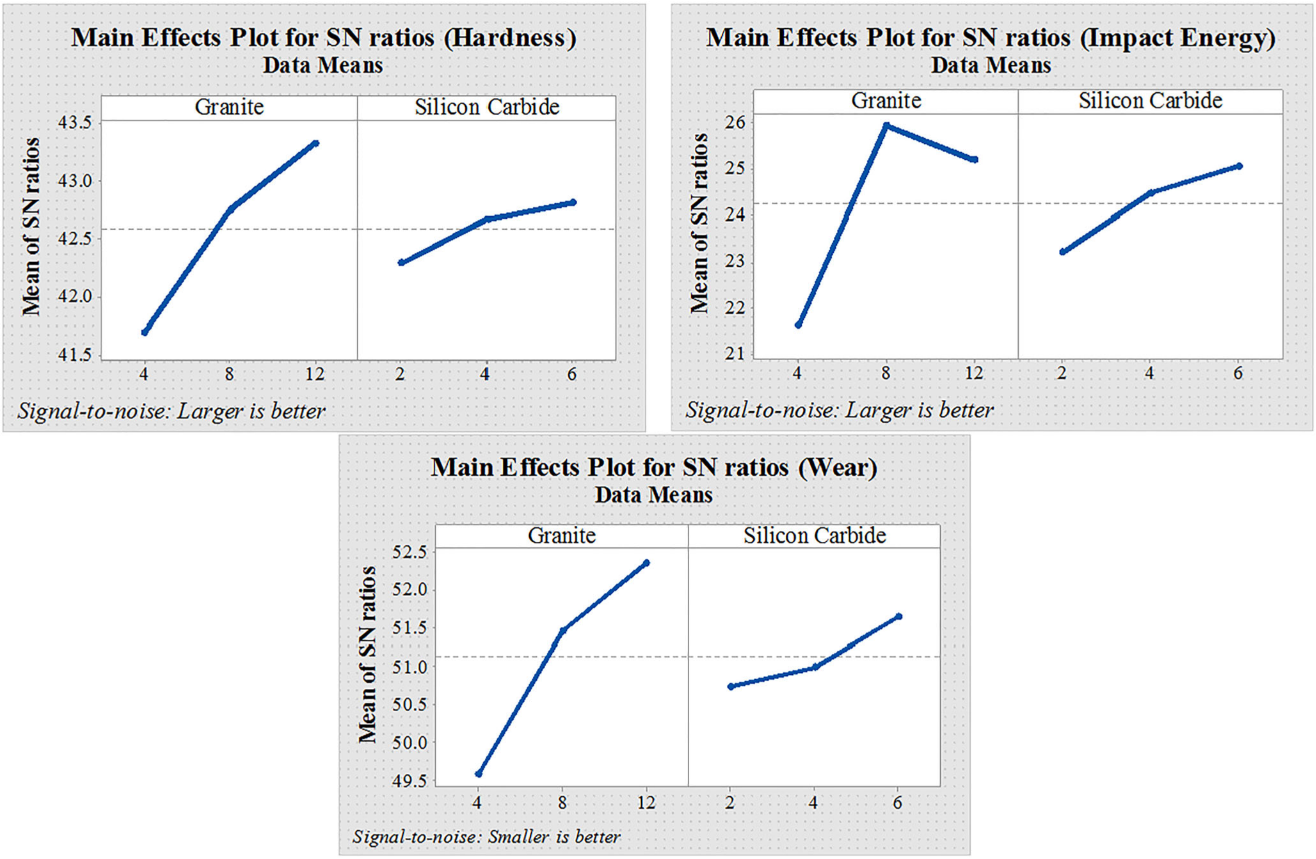


Fig. 16 SN plots for Al7050

4.2 Impact Energy

The variations of Impact energy on reinforcement alloys of Al7050 and Al7075 are plotted and shown in fig. 11.

In both Aluminium alloys, while the addition of reinforcements particles, the impact energy is gradually increased up to certain points and tends to decreases. This is due to while strengthening of material it will undergo deformation and lose its ability to withstand. Hence it cannot store more energy and impact strength is reduced. Figure 11, reveals that when adding 8%Gr and 4%SiC, the impact energy of both Al70750 and Al7075 to be enhanced. The maximum impact energy obtained from the Al7050 (8Gr + 4SiC) is 13.35 J and from the Al7075 (8Gr + 4SiC) is 11.6 J. So, the reinforced Al7050 offers better impact strength than the Al7075. Then, by improving the weight ratio up to 12% of granite particles and 6% of SiC, the minimum impact energy is observed. The addition of granite and SiC particles makes the Aluminium alloy more brittle and suppresses its ductile behavior. So, the minimum impact energy is observed when adding a higher percentage of reinforced particles. In certain cases, the impact energy becomes minimal due to the presence of intrinsic defects mainly cracks in the composite. Figure 12 represents the predicted values of impact energy. For Al7050 (8Gr + 4SiC), the predicted results from DNN-SSO, DNN, and ANN are 13.41 J, 13.87 J, and 14.5 J. Besides, the predicted results for Al7075 (8Gr + 4SiC) are 11.73 J, 11.87 J, and 12.23 J. By comparing with the experimented and the predicted values of impact energy, the prediction values gained from the proposed DNN-SSO is almost similar to the experimental outcomes. This is mainly due to, at the training stage of DNN, weight values are optimized with the help of Salp swarm optimization.

4.3 Wear Rate

The variation of wear behaviour of Al7050 and Al7075 reinforcement alloys is shown in Fig. 13. The wear behaviour of Al7050 and Al7075 are observed by the Pin-on-disc wear test.

The increase in the percentage of granite and SiC particles tends to reduce the wear. The wear rate which we determined is indirectly proportional to the Hardness values and this statement is agreed with Rana et al. [32]. In Al7050 and Al7075, the wear rate of reinforcement alloys decreases due to the formation of the mechanically mixed layer (MML) and due to the hardness by the addition of granite and SiC particles. By

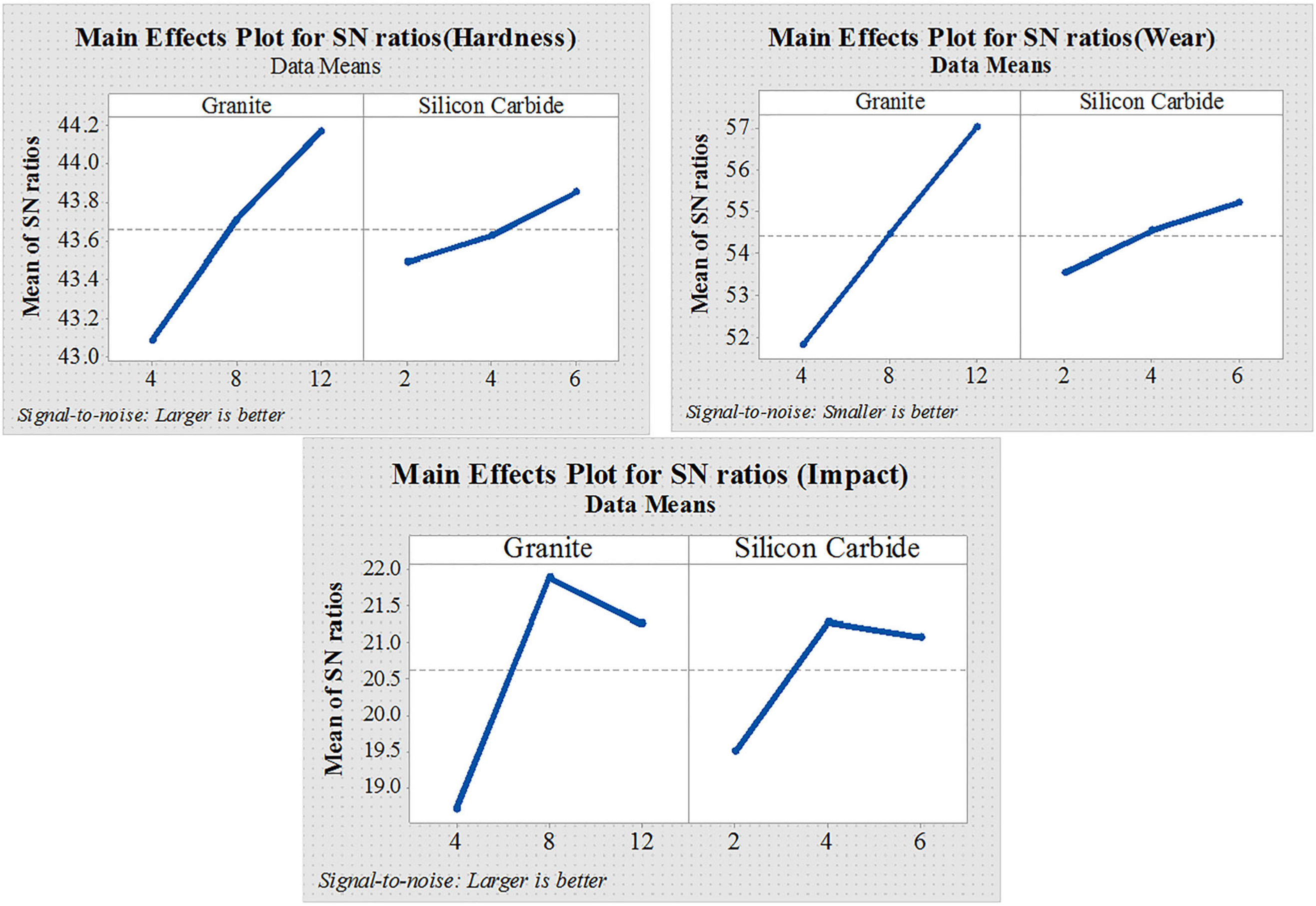
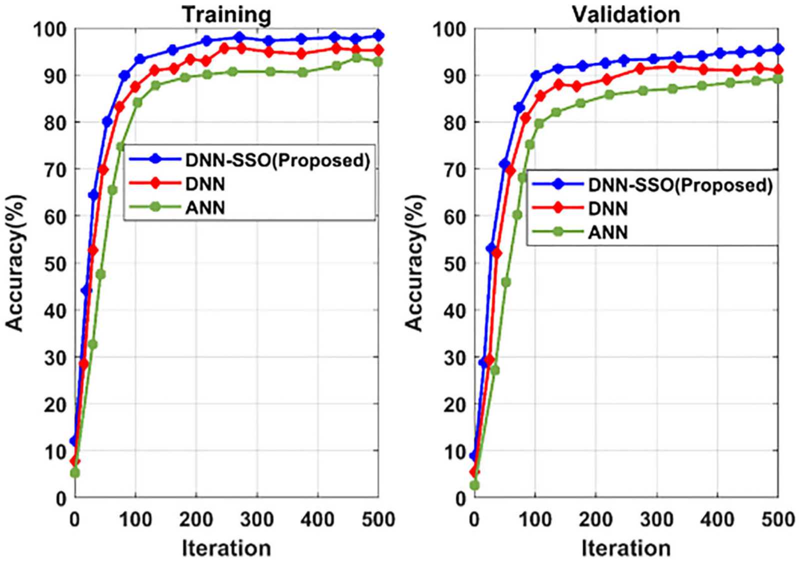
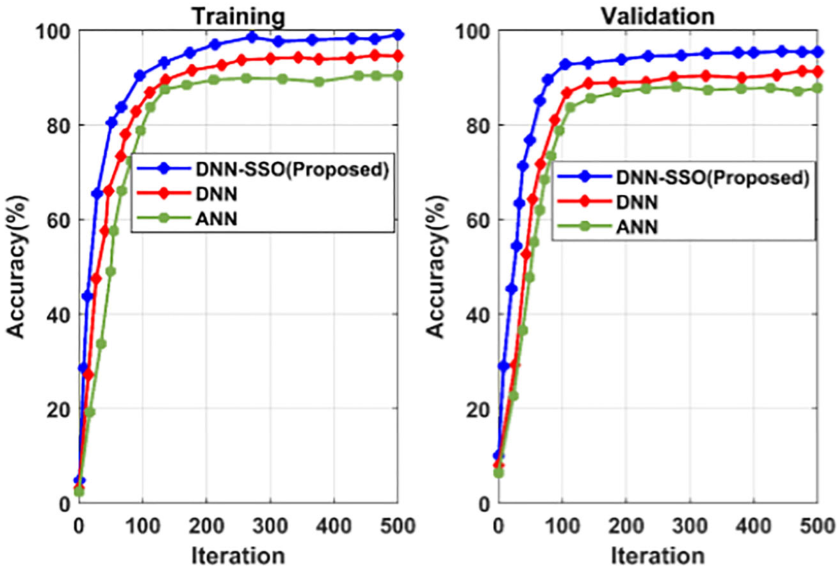


Fig. 17 SN Plots for Al7075

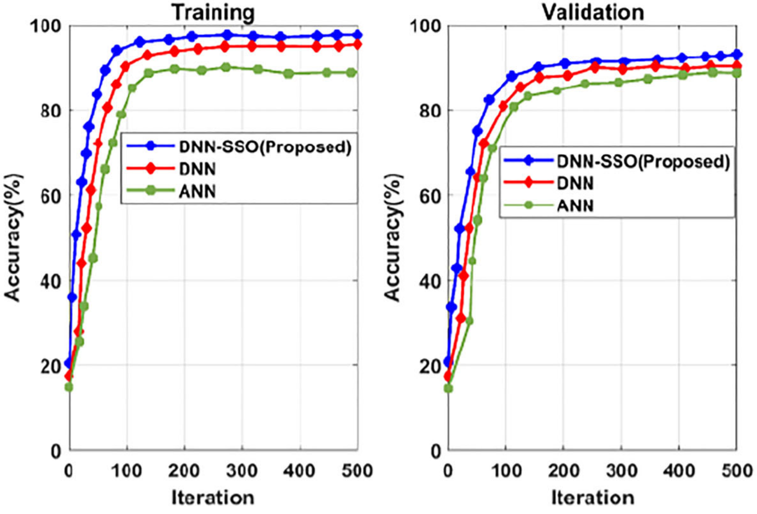
Fig. 18 Analysis of Training Accuracy and Validation



(a) Hardness (BHN)



(b) Impact Energy (J)



(c) Wear rate (mm^3/m)

improving the weight percentage of reinforced particles, the wear availability gets reduced. This is due to, the increasing of hard particles suppress the inter particulate distance and the cause of abrasion. Thus, better wear resistance is to be gained from the enhanced addition of nanoparticles. By comparing with overall weight proportions, the minimal wear rate is observed from Aluminium alloys contributed with 12%Gr and 6% SiC. The predicted wear rate outcomes using DNN-SSO, DNN, and ANN are shown in fig. 14. From experimentation, obtained lower wear rate for Al7050 (12Gr + 6SiC) is 0.00231 mm^3/m and Al7075 (12Gr + 6SiC) is 0.00125 mm^3/m.

The maximum wear obtained from both the SiC and granite particles reinforced Aluminium alloys is given in fig. 15. In which, the maximum wear rate is gained in the Al7050 than Al7075 reinforced composites. The wear behaviour mainly depends on the material characteristics and sliding distances. For longer sliding distances, deeper defects may occur due to the maximum temperature occurs in the interfaced contact surface. On the worn-out surface, the wear cracks were also achieved due to the material removal actions. This may also result, work hardening and delamination. The formation of increased abrasion and the cracks results in maximum surface roughness and wear rates.

Similar to hardness and the impact energy, better validating outcomes are observed from the proposed DNN-SSO method than DNN and ANN. For Al7050 (12Gr + 6SiC), the predicted wear rate using DNN-SSO, DNN, and ANN are 0.00236 mm^3/m, 0.0024 mm^3/m, and 0.002534 mm^3/m. Similarly, the predicted values for Al7075 (12Gr + 6SiC) are 0.00127 mm^3/m, 0.00133 mm^3/m and 0.00152 mm^3/m.

4.4 Taguchi Optimization

From Taguchi optimization, S/N ratio values of both Al7050 and Al7075 are tabulated in Table 5 and Table 6. The analysis is mainly conducted to determine the best reinforcing parameter. From the experimentation, the best reinforcement ratio is determined as Al7075 (12Gr + 6SiC) and Al7050 (8Gr + 4SiC). By comparing SiC and granite particles, the best reinforcing agent is determined based on this optimization approach. Figs. 16 and 17 demonstrate the SN plots for both Al7050 and Al7075. From the figures, it reveals that the granite particle is more contributed to both Aluminium alloys than the silicon carbide.

From the overall experimental analysis, the hardness and wear rate is favorable in Al7075 composites; however, Al7050 promotes better impact strength. The variation of gained impact energy between the Al7075 composites and Al7050 is minimum. Thus, Granite and SiC reinforced Al7075 are selected as better composites by considering the mechanical characteristics. Fig. 18 represents the training and the validation accuracy for different neural network-based predictions at various iterations. Such training accuracy is determined by combining the hardness, impact strength and wear rate of Al7050 and Al7075 composites and are given in fig. 18 (a-c). In which, proposed hybrid DNN-SSO based prediction achieves better accuracy rates than the accuracy of DNN and ANN. Initially, both the training and the validation accuracy have fluctuated and at particular iteration, the gained accuracy starts to follow stability.

The gained better accuracy for the hardness is 99.2%, Impact energy is 99.6% and 98.8%. Table 7 represents the maximum training accuracy gained from the DNN-SSO, DNN, and ANN.

The Root Mean Square analysis (RMSE) of the proposed DNN-SSO, DNN, and ANN are given in fig. 19. In which, the gained error values are maximum for the non-hybrid predictive models namely DNN and ANN. This is mainly due to the random updating of weight values. Besides, in DNN-SSO, the weight values are updated and optimized by the SSO algorithm. By comparing with the overall properties, the RMSE obtained using DNN-SSO, DNN and ANN are in the ranges of 0.036, 0.045, and 0.0752.

Table 7 Comparison of Training accuracy of different Prediction models

Properties	DNN-SSO proposed	DNN	ANN
Hardness	99.2	96.1	91
Impact energy	99.6	94	92.3
Wear	98.8	94	89.3

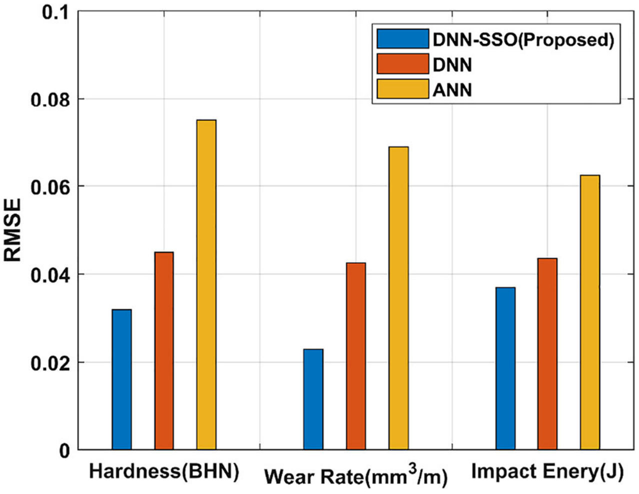


Fig. 19 RMSE Analysis of Different prediction Methods

5 Conclusion

The mechanical and microstructure characteristics of stir cast Al7050 and Al7075 composites were studied successfully from the experimentation. The SiC and Gr reinforced aluminium exhibits superior mechanical characteristics with better wear resistance. Besides, the predicted values using DNN-SSO promote closer values to the experimentation than the non-hybrid neural networks like DNN and ANN. Both Aluminium composites are reinforced with 12 wt.% of Gr and 8 wt.% of SiC promotes the increased hardness and wear resistance. The impact strength was optimal for the Aluminium composites reinforced with 8 wt.% of Gr and 4 wt.% of SiC particles. Increased hardness strength of 129.20 BHN and 141.22 BHN was achieved for both Al7050 (12Gr + 6SiC) and Al7075 (12Gr + 6SiC). The hybrid DNN-SSO based predicted hardness was 129.32 BHN and 141.29 BHN. The observed minimum wear rate for the 12Gr + 4SiC reinforced Al7050 and Al7075 were 0.00231 mm^3/m and 0.00125mm^3/m. Besides, the predicted wear rate outcomes were 0.00236 mm^3/m, 0.00127 mm^3/m. The maximum impact energy of 13.35 J, 11.6 J was observed for the Al7050 and Al7075 composites which contain 8 wt.% of Gr and 4 wt.% of SiC particles. The predicted outcomes for Impact energy were 13.41 J and 11.73 J for Al7050 (8Gr + 4SiC) and Al7075 (8Gr + 4SiC). In general, from the overall experimented and predicted outcomes, the reinforced alloy made of Al7050 shows better results in Impact and Al7075 shows better results in hardness and wear.

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Authors' Information Authors are aware of submitting the manuscript.

Code Availability Custom code.

Authors' Contributions Both authors have contributed significantly to the manuscript.

Data Availability Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Declaration

Ethics Approval and Consent to Participate Approved to publish in this journal.

Consent for Publication Authors are agreed to proceed with the journal.

Conflict of Interest No Conflict of interests.

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