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Characterization of polymer based composite using neuro-fuzzy model

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ABSTRACT

Dealing with a large quantity of waste useless tires can be considered as a big challenge nowadays. There are huge problems affected on the green world because it is non-biodegradable materials and pose a significant environmental problem. The aim of this work is to prevent the air and soil pollution that generated from burning the huge quantity of waste tires (natural and styrene-butadiene rubber) to derive fuel in cement kilns, paper mills, power plants and manufacturing hump and gymnasium floor. It is present as a valuable resource to prepare useful composite materials by mixing liner polymer of high density polyethylene with crosslink hard mulch (its area nearly 20 mm^2) waste tires with percentage of 0, 17, 29, 38, 44, 50, 75, 85 and 90%. The average of three tests for each ratio was taken to comprise semi interpenetrating polymer network. The specimens were evaluated to determine their mechanical properties that include shore hardness, elastic modulus, Impact strength and compression strength. The results show the 85% is the best ratio due to an increasing in the mechanical properties of specimens on the other hand, theoretical estimate of the properties of composite specimens was done by using Neuro-fuzzy modelling. Observed good agreements between experimental and theoretical work was obtained.
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1. Introduction

Blending Polymer matrix with filler materials was applied to produce composite materials due to their amended characteristics. Recently, a new composite material consisting of polymer matrix and rubber with particle diameter 100 μm were used.

Prakash et al. have been mixed high density polyethylene with polypropylene to study their physical properties and the results showed that there is change was happened in their physical properties[1].Moreover, Ragunathanet al. was evaluated the mechanical properties of composite material with and without compatibilizer and the results noted that there is change inthe mechanical properties of composite materials [2]. On the other hand, Kaharet al. evaluated high density polyethylene, natural rubber and sweet starch by using the Avrami equation [3]. Also, Mohd et al, have been studied the possibility to improve the mechanical properties of high density polyethylene matrix with saw dust composites [4].

Supri et al., evaluated the mechanical properties of high density polyethylene, natural rubber and chicken feather fiber with caprolactam [5]. Moreover, Hussein studied the physical properties of high density polyethylene and crumb rubber powder with the asphalt [6]. Furthermore, Lijie was estimated the mechanical properties of high density polyethylene/rubber tire polymer specimen [7]. In addition, Muhamad et al, have been studied the possibility to improve the physical properties of high density polyethylene with natural rubber [8].

Almtori has been applied neruo fuzzy model as a theoretical work and made experimental works for composite materials to study their physical properties. The result shows that there is a good agreement between experimental work and theoretical test of neuro fuzzy model [9].

Great qualities of reused tire were utilized to fix disappointment prompted easily by limited drying shrinkage [10]. Lately, intrigue and utilization of counterfeit neural systems (artificial neural networks (ANNs)) have expanded to reduce the effort and cost because of their effortlessness and effectiveness in making input–output discovery models. Artificial neural networks have been connected in assorted territories, for example, medication, business, material science, topography, building, and natural designing specifically [11–13].

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There is no calculation exists for characterizing Shore hardness, Elastic modulus, and Compression energy for tire [14–16].

Stalin and et al. have been blended the bio waste bagasse and coir fibres with different proportions as reinforcements to vinyl ester-based matrices and the results observed that there is an improvement in strength and stiffness [17]. They were used reinforced vinyl ester matrix with polyalthial ongifolia seed filler ranging from 5 to 50 wt%. The result shows that the composite exhibited optimum mechanical properties at 25% wt of filler loading; ultimate tensile strength and modulus were approximately 32.50 MPa and 1.23 GPa, respectively [18]. On the other hand, Nagaprasad studied the waste date seed filler reinforced vinyl ester with varying fillers loadings from 5% to 50%.Obtained that 30 wt% of the composites exhibited the highest mechanical properties [19].

Stalin evaluated the usage of tamarind seed filler as reinforcement in vinyl ester composites and the result shows that there is an improvement in mechanical and physical properties [20].

Athijayamini was investigated vinylester with bagasse and coir fibres to observe the mechanical properties of their composites which were increased after alkali fibers treatment [21].

Stalin evaluated the bagasse/Coir fibers with vinyl ester composites which found the optimum weight percentage lead to provide the maximum mechanical property as shown for specimen consist of fiber length of 15 mm and different weight percentages of 10, 20, 30, 40 and 50% [22]. Moreover, he prepared AA6063-Si_3N_4 composites by stir casting technique and analyzing their wear behavior using the Taguchi grey relational analysis of the synthesized composites. They found From the Taguchi grey relational analysis technique a minimum wear rate of 0.0002 $mm^3\ min^{-1}$ was obtained for 10% wt reinforcement, 29.43 N load, 3 $m\ s^{-1}$ is sliding velocity and 1500 mm sliding distance. Furthermore, from ANN model and TLBO algorithm, it is probable to attain 0.000183 $mm^3\ min^{-1}$ wear rate for the process parameter values of 9.892% of wt reinforcement, 9.837 N of load, 2.936 $m\ s^{-1}$ sliding velocity and 1130.7 mm sliding distance [23].

Ayyanar studied the mechanical properties of vinyl ester with aligned unidirectional bagasse fiber composites such as tensile, flexural, shear and impact strength. Showed that the tensile strength increased linearly up to 44 wt% and then dropped as well as tensile modulus increased linearly from 17 wt% to 60 wt%. In the case of flexural properties, the flexural strength increased up to 53 wt% and started to decrease. However, the flexural modulus also increased linearly up to 60 wt%. In addition, he found that the impact strength values of composite are higher than the value of matrix materials for all the specimens. The short beam shear strength values were also increased up to 53 wt% and then dropped [24].

Stalin evaluated the bagasse fiber/coir/alumina as filler with matrix vinyl ester to be composites were fabricated by varying micro level alumina particle weight percentages of 10, 15, 20, 25 and 30% with the optimum fiber content [25].The maximum range of mechanical properties was identified at composites having the fiber content of 40 wt%. Tensile strength was improved with percentage of 23% and the flexural strength and impact strength were improved too with percentage of 34% and 13% respectively. It had been found that obtained for composite material with 15%alumina.

Rajamuneeswaran studied and compered the mechanical properties of different thermosetting polymers that include epoxy, polyester, and vinyl ester reinforced with coir fiber, calcium carbonate filler materials, fiber Length, fiber diameter, fiber and filler content [26].

Table 1
The blending and prepared specimens.

Specimen No.	1	2	3	4	5	6	7	8	9
Mulch tire %	0	17	29	38	44	50	75	85	90
HDPE %	100	83	71	62	56	50	25	15	10

Table 2
Shore D hardness of specimens.

Specimen No.	1	2	3	4	5	6	7	8	9
ShoreD Hardness	21	25	43	56	65	74	80	84	81

Table 3
Elastic modulus of specimens.

Specimen No.	1	2	3	4	5	6	7	8	9
Elastic Modulus MPa	0.86	0.95	1.5	1.9	2.4	3.0	3.45	3.8	3.50

Table 4
Impact strength of specimens.

Specimen	1	2	3	4	5	6	7	8	9
I. Str. J/m2	56	67	113	149	173	197	213	224	216

Table 5
Compression strength of specimens.

Specimen No.	1	2	3	4	5	6	7	8	9
Compression Strength MPa	56	62	97	123	15 5	194	195	198	197

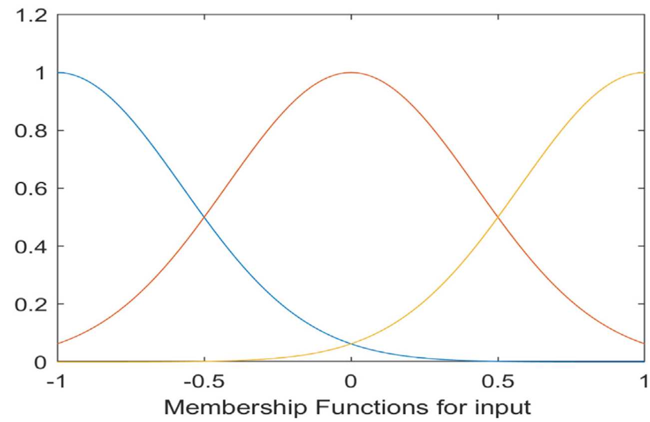

Fig. 1. Membership functions for the input.

Stalin produced aluminum alloy (AA 6063) matrix composite with different percentage of Si_3N_4 content through stir casting route. It was found that the minimum wear rate obtained for the composite contains 10 wt% Si_3N_4, load of 29.43 N, sliding distance of 1500 m and the sliding velocity of 3 m s^{-1} [27].

Sudha studied the effect of MoO_3 percentage applied as reinforcement material to aluminium matrix. It was used with percentage of 5, 10, 15 wt% through powder metallurgy route. The result noticed that percentage of reinforcement was the most influencing factor affecting the maximum compressive strength and strain as well as sintering temperature plays vital role in their corrosion rate. Furthermore, low corrosion rate was obtained at 5 wt% MoO_3, 300 MPa compaction pressure and 400 °C sintering temperature. The highest compressive strength obtained at 15 wt% MoO_3, 300 MPa compaction pressure and 400 °C sintering temperature. Moreover, high compressive strain was obtained at 5 wt% MoO_3, 250 MPa compaction pressure and 400 °C sintering temperature [28].

Marichamy studied the fabrication of duplex brass alloy by stir casting technique and the effect of parameters such as current, voltage, pulse on time and flushing pressure on surface roughness. The response model has been validated with analysis of variance (ANOVA). Peak current was identified as the significant factor affecting the surface roughness during machining [29].

Stalin et al. used the Taguchi's method to optimize powder metallurgy process of aluminum and molybdenum trioxide to controlled porosity and high strength to weight ratio. Noticed that weight percentage of MoO_3 and compaction pressure were the most influencing parameters [30].

2. Experimental work

2.1. Materials

Materials that used in this research consist from liner polymer high density polyethylene and crosslink hard mulch of waste tires. By blending mulch tire with area less than 20 mm^2 to applied as filer material for polymer matrix specimen with dimension of (10×10×2) cm specimen. It is used with percentage of 0, 17, 29, 38, 44, 50, 75, 85 and 90% and the mixing materials were casting under pressure of 100–120 MPa at 175–180 °C for 30 min as shown in Table 1.

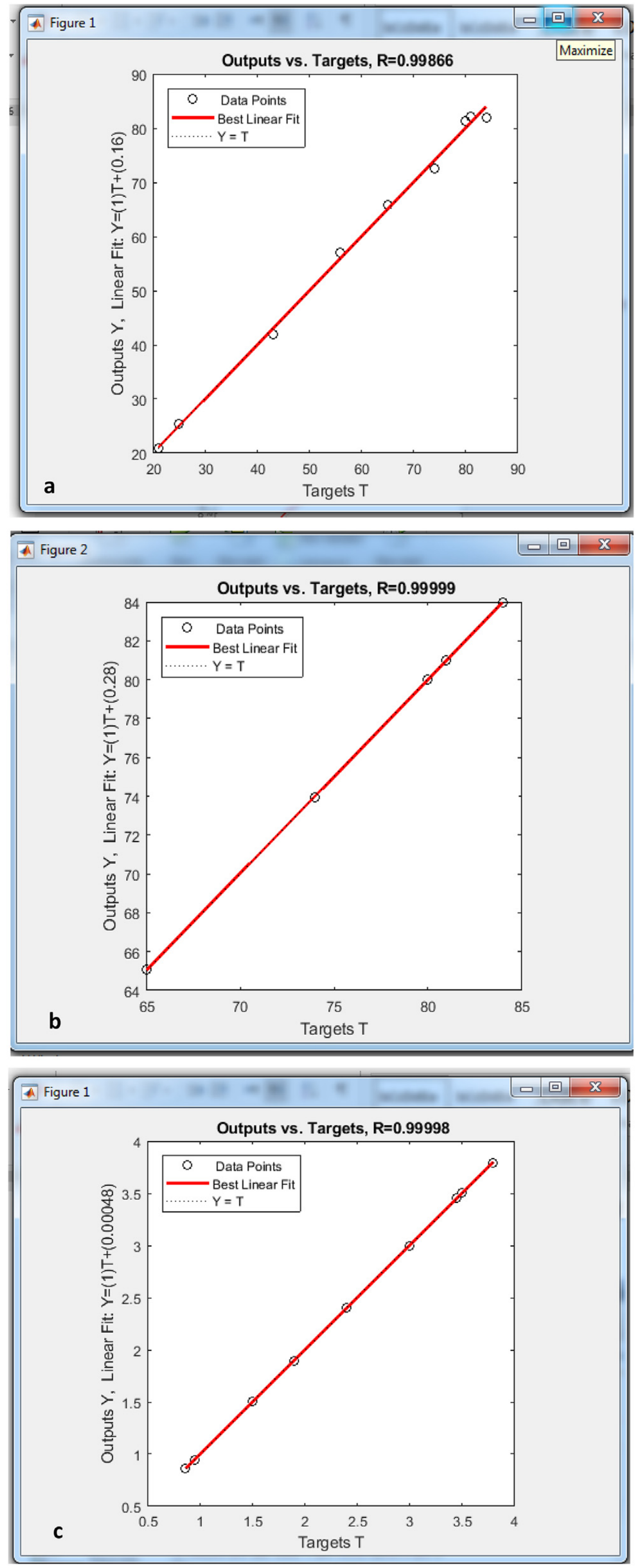

Fig 2. Comparison experimental (target) and predicted values for training and testing data set of mechanical properties. a) training (Shore hardness), b) testing (Shore hardness), c) training (Elastic modulus), d) testing (Elastic modulus), e) training (Impact strength), f) testing (Impact strength). g) training (Compression strength), h) testing (Compression strength).

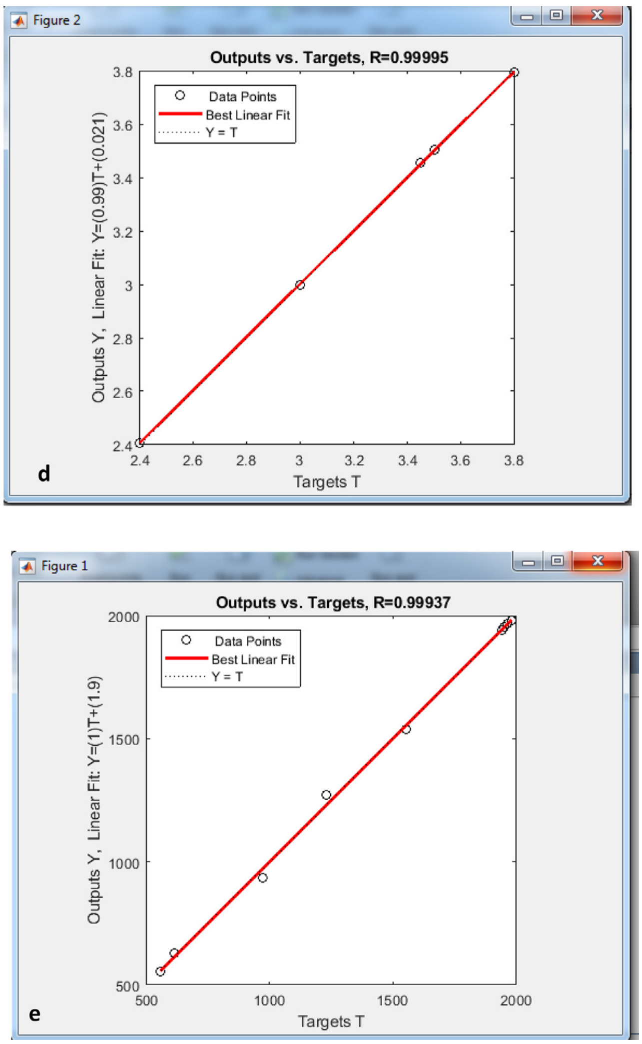

Fig. 2 (*continued*)

2.2. Shore D hardness

Shore D hardness test was applied to determine the hardness of (1x1) cm specimens.

2.3. Modulus of elasticity

Modulus of elasticity of specimens was calculated using Eq. (1) where E is Modulus of elasticity, Sh is Shore hardness [9].

$$Log_{10}E = (235 * Sh - -6403) * 10^{-4} \quad (1)$$

2.4. Impact strength

Impact strength of composite (6.35 × 1.27 × 0. 32) cm specimens was calculated using Eq. (2) where σ_I inkJ/m^2, EI in kJ and A is m^2.

$$\sigma_I = EI/A \quad (2)$$

2.5. Compression strength

Compression strength was measured using Eq. (3) where: σ is compression strength N/ m^2 and F is compressive load in N. Specimen dimension (10 × 10 × 2) cm.

$$\sigma = F/A \quad (3)$$

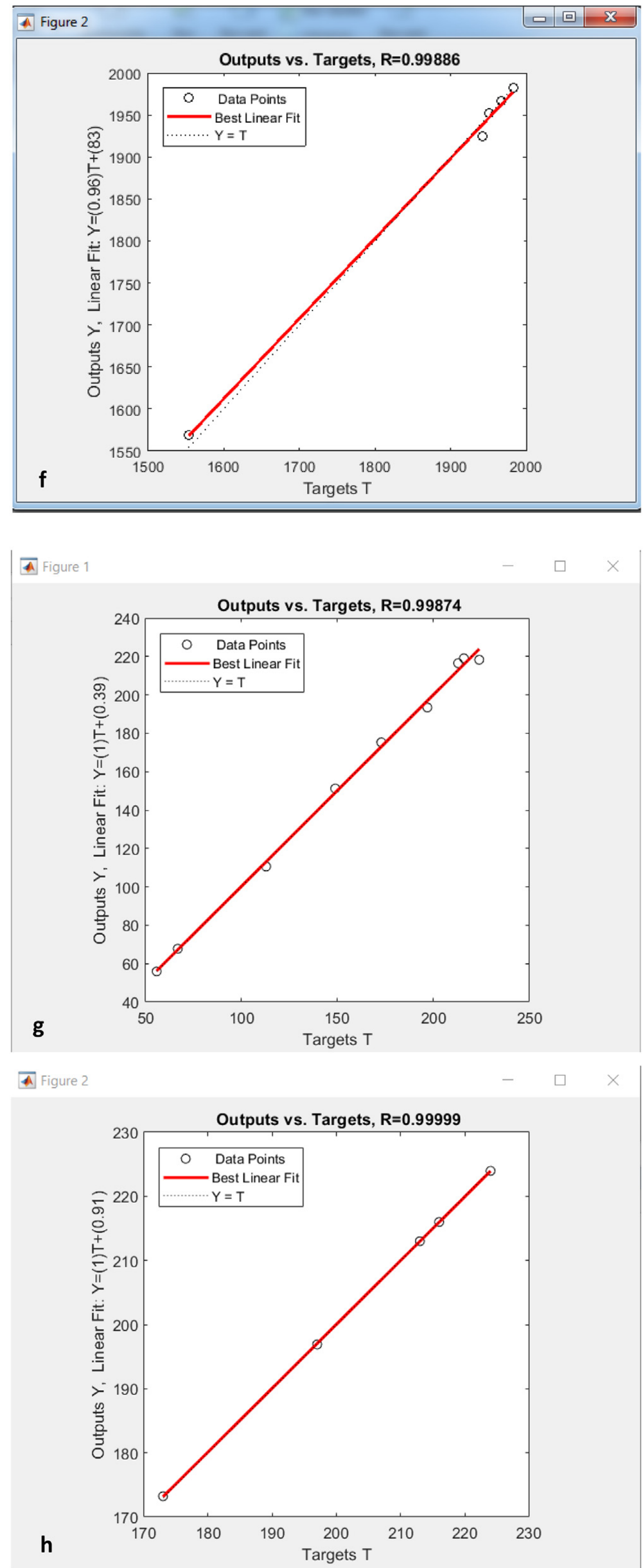

Fig. 2 (*continued*)

3. Results and discussions

3.1. Experimental results

3.1.1. Shore hardness

Shore D hardness was measured for all specimens and the results shown in Table 2.

3.1.2. Elastic modulus

Elastic modulus for specimens is measured according to the ASTM D2240 and the results shown in Table 3.

3.1.3. Impact strength

The impact strength of specimens were prepared according to ASTM D256 and the results shown in Table 4.

3.1.4. Compression strength

Compression test was done according to IQS 5:1984 and the results show in Table 5.

3.2. Neuro-fuzzy model

3.2.1. Adaptive Neuro-fuzzy inference system (ANFIS)

ANFIS is presented by Jang and executed Takagi–Sugeno fuzzy rules [31]. An ANFIS goes for methodically creating obscure fuzzy rules from a given in-put and out-put data. Along these lines, in parameter evaluation, where the given information is to such an extent that the framework partners quantifiable framework factors with an interior framework parameter, an utilitarian mapping might be built by ANFIS that approximates the methodology of estimation of the inward system parameter. In spite of the fact that ANFIS has an organized learning portrayal as fuzzy "if-then" rules, it comes up short on the versatility to manage a changing outside condition. Moreover, neural system learning ideas have been joined in Neuro-fuzzy model. The versatile surmising framework is a system which comprises the number of interconnected hubs. So using the MATLAB is utilized in this investigation. MFs and No. to every in-put parameter are fittingly chosen when the testing informational collection has the most correlation R.

3.2.2. Membership functions (MFs)

Fig. 1 demonstrates the last membership functions for input variables 3-Gaussian MFs of the Mechanical Properties.

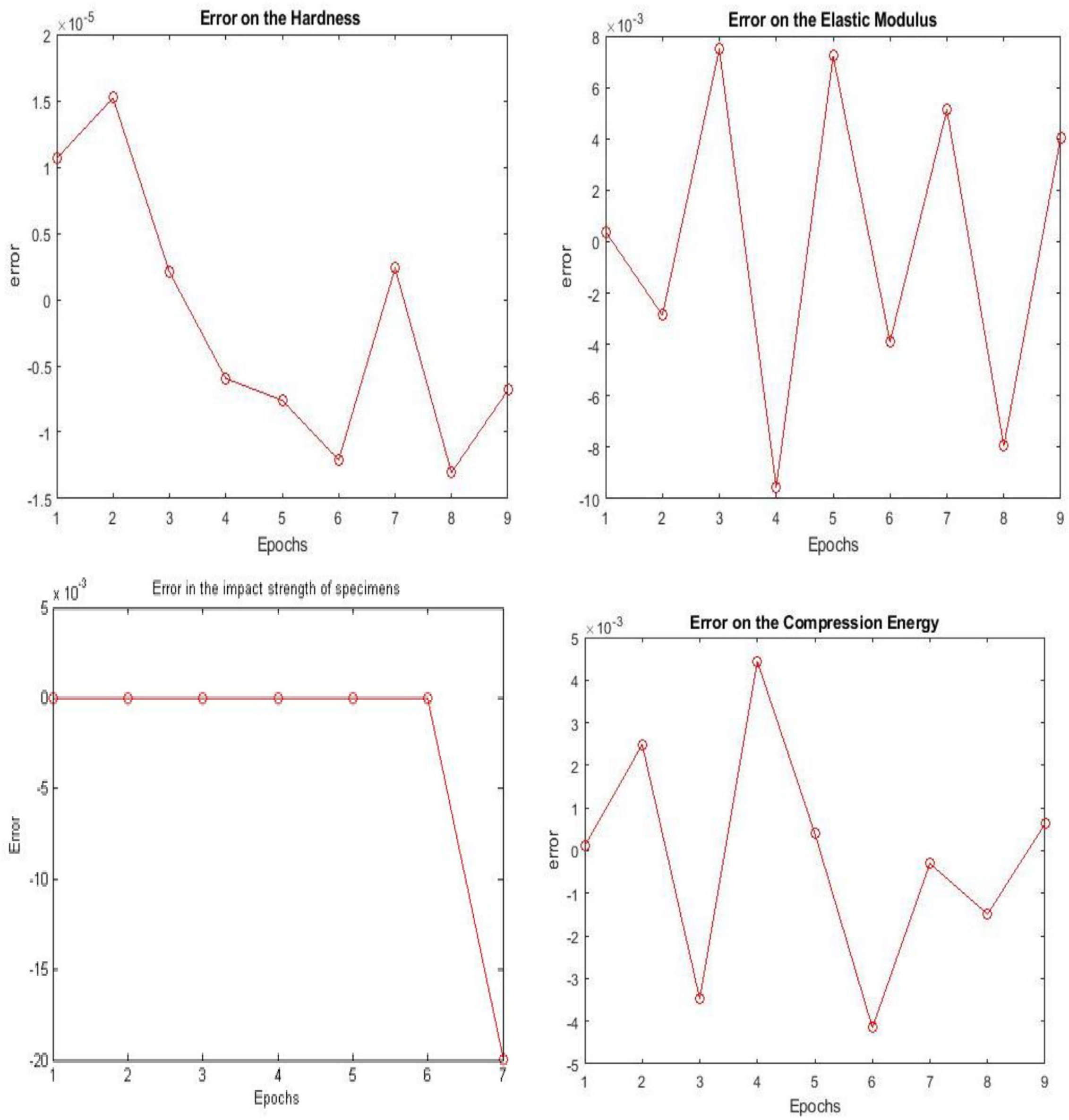

Fig. 3. RMSE curves for experimental and predicted of mechanical properties.

3.2.3. Modeling results

An examination of the forecasts from ANFIS and estimated from experimental tests are appeared in both preparing and testing informational indexes of mechanical properties as shown in Fig. 2. The results have all the earmarks of being adequate to have more than 0.99 of correlation R despite the fact that there is a tad dissipates in the testing information focuses. The near examination of the testing time frame execution of the model procedure utilizing RMSE error has been done which appeared in Fig. 3. The model of this research work gave the best execution which includes the most minimal RMSE and most noteworthy R for the testing time frames. Likewise, it very well may be seen that the demonstrating results are sensibly in great concurrence with the outcomes for all informational indexes and furthermore demonstrate the foreseeing capacity of ANFIS is fantastic.

3.3. Discussion

Figs. 4–7 shows polymer–polymer matrix composite with their mechanical properties. The results show that there is fast increasing in the mechanical properties of mixing material with increasing percentage of additive waste tire up to 44%.Thenstart to increase slowly with increasing the percentage of waste tire from 50 to 85%. Therefore, the mechanical properties of specimens increased with increasing the percentage of waste tire up to 85% due to reducing their chains mobility and increased their rigidity or compatibility. However, at percentage of 90 %the properties

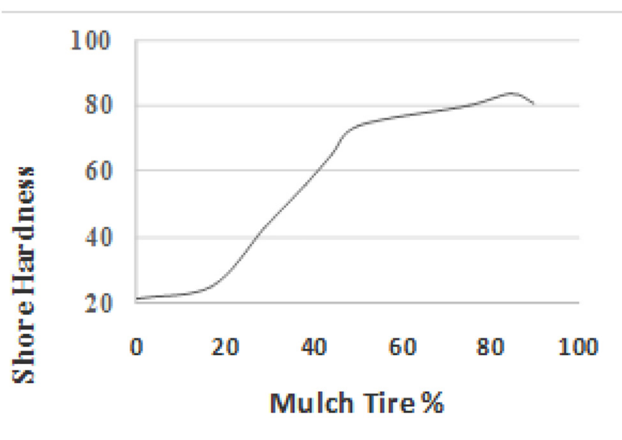

Fig. 4. Hardness & mulch tire.

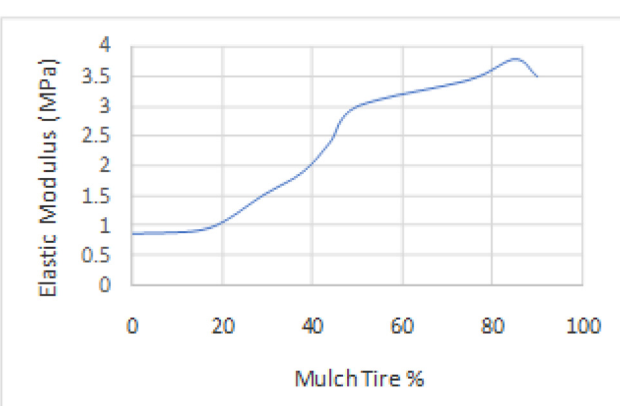

Fig. 5. Elastic modulus and mulch tire.

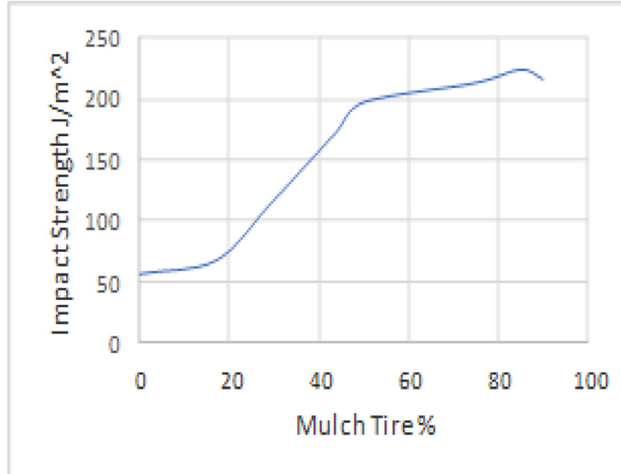

Fig. 6. Impact strength & mulch tire.

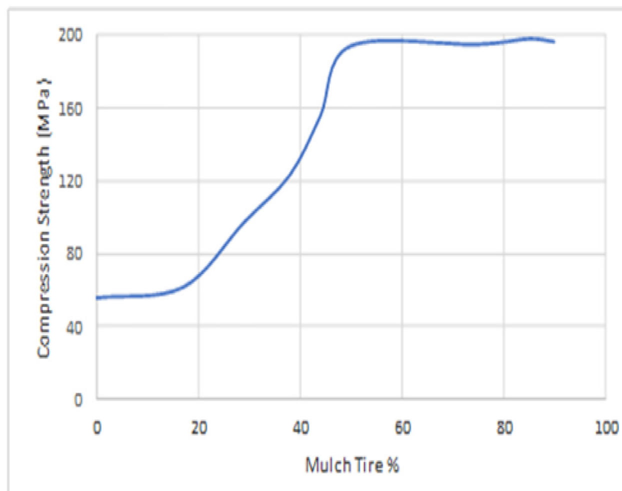

Fig. 7. Compression strength & mulch tire.

are decreasing because of the high ratio of fillers leads to decrease compatibility and flexibility.

Selection of database parameters was done based on the information of experimental work that collected from 45 published tests as shown in Tables 1–5.

ANFIS model is used as statistical evaluation for specimens. It is increasingly adaptable model with more alternatives for joining fuzzy idea of this present reality framework. In this research work, ANFIS approach was mix neural systems and fuzzy frameworks capacities to give the general structure of network system. The adaptive ANFIS models perform are valuable estimation apparatus for the mechanical properties. It has been upheld to estimate RMSE and R which are worldwide, progressively sensible and important error types, to be specific, the least RMSE and the most elevated R, in the ANFIS method.

4. Conclusion

The experimental results show that the added 85% waste tire to the composite is the best ratio that helps to increase the mechanical properties of specimen's**.** It is conceivable to utilize Neuro-fuzzy model that created in this exploration to gauge the specimen characteristics. Neural – Fuzzy model is superior to the neural program or fuzzy program on the grounds that the aftereffects of neural program change with every official case and the consequences of the fuzzy program are consistent for every official case. In any case, on account of Neural – Fuzzy model, Neural will use to locate the key inputs contributions for Fuzzy program by choosing the goal and consistent coefficients for participation since it are utilized to try and error. In this manner, Neural used to anticipate the best consistent coefficient to get steady and exactness results. The Neuro-Fuzzy model can spare time and endeavors just as the materials and waste by contemplating the impact of parameter as opposed to making numerous tests. For the future work, improvement with Neural – Fuzzy model ought to be utilized to assess the best sources of inputs and results.

CRediT authorship contribution statement

Safaa A.S. Almtori: Conceptualization, Methodology. **Imad O. Bachi Al-Fahad:** Software, Data curation, Supervision. **Atheed Habeeb Taha Al-temimi:** Visualization, Investigation. **A.K. Jassim:** Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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