Journal of Soft Computing in Civil Engineering 4-3 (2020) 79-105

Contents lists available at **SCCE**

Journal of Soft Computing in Civil Engineering

Journal homepage: www.jsoftcivil.com

Prediction of Mechanical Strength Attributes of Coir/Sisal Polyester Natural Composites by ANN

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https://doi.org/10.22115/SCCE.2020.226219.1200

ARTICLE INFO

Article history:
Received: 09 April 2020
Revised: 16 May 2020
Accepted: 24 July 2020

Keywords:
Tensile strength;
Flexure strength;
Impact strength;
Polymer matrix;
Plant fibers.

ABSTRACT

Coir and Sisal are agriculture wastes that are effectively and financially accessible in the distinctive piece of Karnataka and other various states of republic India. These are generally treated as bio-compostable material by the customary horticulture/agriculture professionals. Aftereffects of past research related to fabrication, testing, analysis and design of conventional (synthetic fiber reinforced) composite materials portray that, strength to weight proportion is the basic criteria for a tailored design of composite materials. Viable utilizations of low-density reinforcing materials as the constituent materials of composites demonstrate great strength to weight ratio. Hence, 2 mm, 3 mm, 4 mm, 5 mm and 6 mm thick composite panels made up of 10 mm long coir/sisal fiber fortified in a polyester matrix of coupons are utilized for the experimentation process. The present study exhibits that the feed-forward Artificial Neural Network (ANN) model developed to predict the mechanical properties of coir/sisal polyester composite could be the acceptable mathematical tool for the prediction of mechanical properties of treated and untreated, arbitrarily oriented coir/sisal fiber strengthened polyester composite instead of the complicated experimental procedure. It exhibits that where traditional technique feels hard to estimate mechanical properties of coir/sisal fiber fortified polyester composite materials, the ANN model supports to foresee it. ANN approach avoids remembrance of equations and generalizes the problem domain and reduces the human error.

How to cite this article: Keerthi Gowda BS, Easwara Prasad GL, Velmurugan R. Prediction of mechanical strength attributes of coir/sisal polyester natural composites by ANN. J Soft Comput Civ Eng 2020;4(3):79–105. https://doi.org/10.22115/scce.2020.226219.1200.

1. Introduction

Human endeavours towards a steady change in individual satisfaction have realized a huge gathering of new materials and innovations. As a general rule, the various stages in the progression of humankind are portrayed by winning material of the period viz. stone age, Bronze Age, Iron Age, etc. Consolidating two kinds of materials having distinctive properties to secure a material having far transcendent properties than the individual materials is not a present practice. The requirements for materials that are stronger, lightweight, corrosion and chemical safe and porous to electromagnetic radiations have lead to the methodology of composites. In the initial phases of development, composites were pervasively used as a part of flight (aviation) applications, yet in the later day's specialists, designers, electrical architects, and mechanical specialists have comprehended the capacity of composites in their application.

In the current investigation, an exertion is made to foresee the mechanical properties of coir/sisal fiber-fortified composite materials. Here, randomly arranged coir/sisal fiber strengthened polyester composite coupons of thicknesses 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm were manufactured by utilizing a hot compression moulding strategy. Treated/untreated filaments of length 10 mm are utilized as fortification/reinforcement for fabricating the composite coupons. A blend of unsaturated polyester resin, methyl ethyl ketone peroxide, and cobalt naphthenate of proportion 50:1:1 is utilized as a matrix for the composite manufacturing process. Every composite board of fiber volume fraction (FVF) 10 %, 15 %, 20 %, 25 %, and 30 % were tested for its tensile, flexural, and impact strength attributes according to ASTM D-3039, ASTM D-7264, and ASTM D-256 standards respectively. A soft-computing procedure is embraced by building up an ANN to anticipate the mechanical (tensile, flexure and impact) properties of composite materials, which reduces the manual involvement and its related troubles to investigate the same. Perceptible research studies which spread the light on natural composites and use of ANN in the field of engineering are discussed.

Dynamic attributes, (for example, natural frequency) of the coir fiber-strengthened composites are associated with its mechanical properties and it may be estimated by examining its mechanical properties [1–3]. Ali [2] detailed that coconut strands are ductile and energy absorbent material. Sathiyamurthy et al [4] have depicted in their investigation that Artificial Neural Network (ANN) models can be successfully used for the forecast of mechanical properties of inorganic filler implanted coir polyester composites. Rajamuneeswaran et al [5] have shown that impact strength quality of coir fortified polyester composites can be upgraded by the interruption of crab carapace as filler. Khan and Joshi [6] have revealed in their investigation that mechanical and morphological characteristics of coir strands can be improved by treating them with ferric nitrate and ammonium chloride. Ganesh et al [7] have detailed in their investigation that strength to withstand the impact of coir-vinyl ester composites can be improved by the interruption of termite mound particulate as filler materials.

Further, Anyakera [8] has revealed that coconut palm frond filaments are of equipped choices to supplant manufactured/synthetic strands as support/reinforcement in the polyester, which can be utilized for the utilization of building constructions, and he inferred that surface treatment to coconut frond filaments improves the mechanical properties of composites. Tran et al [9] have depicted that interfacial adhesion of untreated coir strands with polypropylene matrix shows hydrophobic properties with a low polar fraction of the surface energy. However, 5 % of alkaline-treated coir shows higher surface energy with an increased polar fraction. In conclusion, they revealed that understanding between wetting investigation and composite interface mechanical tests is acceptable. Ahad et al [10] revealed that Banana Fiber and Coconut husk have enhanced their surface roughness by Antacid Treatment (NaOH). Here the banana fiber and coconut nut have been used as reinforcement. This research reveals that the increase in the mechanical properties of the composite is due to the increased surface roughness of the materials. Prasad et al [11–14] indicated that ANN is one of the adoptable foreseeing tools to forecast the properties of engineered materials and especially composites. It limits troubles like trial work which requests high starting venture, labor, and time. Gowda et al [15] detailed the probabilistic conduct of tensile properties of coir fiber-strengthened polymer framework composites. They reasoned that, by inferring the ranges of the tensile strength of coir polyester composites, it will be useful to manufacture the coir polyester composites of wanted thickness and FVFs dependent on required tensile strength.

Additionally, Hajjar et al [16] have reported that discrete three-layer analytical representation model of the quasi-isotropic braided layers for calculating elastic constants of a glass-fiber composite with an epoxy resin system containing a high bio-content show a reasonable prediction within the range of the properties measured compared to simple and discrete models. Malik and Arif [17] have reported in their study that ANN model with 21 neurons and ANN model with 24 neurons showed the best result in the predictions of absorbed energy of carbon fiber reinforced epoxy composite plates and glass fiber reinforced epoxy composite plates compared to others based on the least root mean square error values. Atabey [18] had reported in their study that Finite Element results are in excellent agreement with Radial basis neural network results while detecting and predicting the crude oil type inside the glass fiber reinforced epoxy composite pipelines. Gomes et al [19] have reported that design optimization of composite prosthetic tubes using ANN and Genetic Algorithm is recommended for structures where composites are the key load-carrying members such as orthopedic prosthesis. Kavimani and Prakash [20] have reported that Taguchi coupled ANN model developed to predict specific wear rate value of reduced graphene oxide reinforced magnesium metal matrix composite through a novel solvent-based powder metallurgy route based on the variation of input parameter facilitates better predictability with R-value of 98.4% when compared with the outcomes of the regression model.

Sreekumar et al. [21] studied the dynamic mechanical behaviour of sisal fiber reinforced polyester composites prepared by the resin transfer moulding method. The test showed that in all temperature ranges, the value of the storage modulus reached a peak at 40% fiber volume content. The results of Ma et al. [22] have revealed that the mechanical properties of the natural fiber-reinforced polymer matrix composites are reduced when there is an increase in the twist level of the fiber strands. They used sisal yarn as a reinforcing material with phenolic resin to make composite plates. Two different turnings of the 300 mm long sisal filaments, such as 30 turns per meter and 50 turns per meter were used to analyze the tensile and flexure properties.

Very limited information is available on the prediction of tensile, flexure and impact strength like mechanical attributes of plant fiber reinforced polyester matrix composites. Casting and testing of composites requires lot of skilled workers and repetitive laboratory work procedure. So there is a need to do investigation on forecasting of mechanical strength attributes of plant fiber reinforced (example coir, sisal, flax and hemp fibers) polyester matrix composites to foresee its strength properties. The ANN concept will support to predict it for specific applications where there is no requirement of human involvement in testing and fabrication process and also in less budget research studies, because it avoids repetitive laboratory work. Hence in the current investigation study along with impact strength properties prediction of both tensile and flexure strength attributes of raw (untreated) coir/sisal and 5% NaOH treated coir/sisal fiber reinforced polyester matrix composites are conducted.

2. Experimentation methodology

In this section the different materials used and procedure adopted in the fabrication of coir/sisal polyester composites and the experimental procedures adopted for obtaining the mechanical properties of composites are presented.

2.1. Materials

The raw materials used in the present study are Coir fibers (Fig.1) of density 1.14 g/cc and Sisal fibers (Fig.2) of density 1.4 g/cc as reinforcements; Polyester resin/General purpose resin of density 1.14 g/cc as matrix solution, Cobalt Napthanate as accelerator and Methyl Ethyl Ketone Peroxide as Catalyst. All the reinforcing fibers were procured by local agriculturists around Mysore region of Karnataka, India and chemicals required to prepare the matrix solutions were supplied by the M/S Pragathi industries, Mysore, Karnataka, India. Chemical and physical properties of coir and sisal fibers are portrayed in table 1.

Fig. 1. Raw coir fibers.

Fig. 2. Raw sisal fibers.

Table 1
Physical and chemical attributes of coir and sisal fiber.

Properties	Sisal fiber	Coir fiber
Physical properties [23]		
Specific gravity	1.370	1.177
Water absorption (%)	110	93
Tensile strength (M Pa)	347-378	95-118
Modulus of elasticity (GPa)	15	8
Chemical composition [2,21]		
Cellulose (%)	65–78	35-60
Hemicelluloses (%)	10–14	15-28
Pectin (%)	10	< 0.5
Lignin (%)	9.9	20-30
Waxes (%)	2	<0.5

2.2. Specimen preparation

Short coir fiber of length 10 mm and short sisal fiber of length 10 mm are used as reinforcement with polyester resin (regularly known as "general purpose resin") with Methyl Ethyl Ketone Peroxide (MEKP) catalyst and Cobalt Napthanate hardener. The catalyst, hardener, and resin mixed solution are mixed well in the volumetric proportion of 1:1:50 respectively. The composite specimen for thicknesses of 2 mm, 3 mm, 4 mm, 5 mm and 6 mm are fabricated with every FVF of 10 %, 15 %, 20 % 25 % and 30 % individually by using hydraulic hot pressure moulding procedure.

The raw and unprocessed coir/sisal fibers are obtained from the source plats. These fibers are processed through a bunch isolating machine to eliminate the husk. The fibers obtained from bunch (knot) isolating machine is dried in hot daylight for 48 hrs else it can likewise be dried in hot air oven at a temperature of 60 degree centigrade for 10 hours to remove its dampness content. Finally, the fibers are cut to a length of 10 mm. To get treated fibers, the raw fibers were soaked in the 5 % NaOH solution for 24 hours and again dried. Further the spacer frames (Fig-3) of size 300 mm x 300 mm of thickness 2 mm, 3 mm, 4 mm, 5 mm or 6 mm (to get specimen of respective thicknesses) are set on the base plate of hydraulic hot compression moulding machine. Resin, catalyst and accelerator were blended in the proportion of 50:1:1 and mixed well. The chopped coir/sisal fibers of 10 mm length of desired FVF (10 %, 15 %, 20 %, 25 % or 30%) are spread inside the spacers uniformly. The resin is then applied consistently on the disseminated fibers. The top base plate is then moved such that the material spread is squeezed and pushed down to evacuate any air bubble. Finally, the load is applied for 60 minutes in the mould by maintaining the temperature of 80 degree centigrade. The composite specimen is removed from the mould (Fig-4) and allowed for curing at room temperature for 24 hrs after which the desired coir/sisal polyester composite specimen can be cut for required size for testing.

2.3. Testing methods

The distinctive test routines (experimental tests) adopted to assess the mechanical properties like tensile property, flexure property and impact property of coir/sisal polyester composites are presented in detail. Here all the experiments preformed during the assessment of respective properties of composites are conducted in the room temperature (26±2) degree Centigrade. Cutting of all the test specimens from their respective composite panels is carried out by using professional cutting machines. The specimens of each composite were cut to the required measurements (as specified in the respective ASTM code provisions) to conduct the tests. Here 5 test coupons of each specimen category are tested to evaluate the respective mechanical properties.

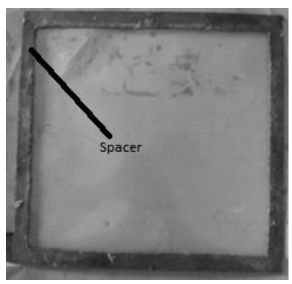

Fig. 3. Mild steel spacer frame mould for specimen casting.

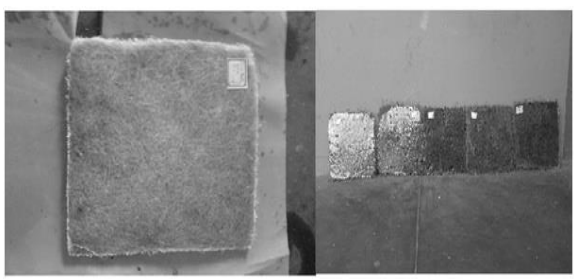

Fig. 4. Composite specimen of different volume fractions and different thickness.

The tensile strength of composites are mainly depends on the volume or weight fractions of fiber content; length of the fibers; nature or type of reinforcement and external or additional additives. In the present study tensile tests for composites were conducted according to ASTM D3039 [24] standard. The specimens subjected to tension test were of size 250 mm x 25 mm (including grip length of 50 mm). The grippers distribute gripping stresses and controls failure created by grip jaws. All the tension tests were conducted on a computer controlled universal testing machine of 5-ton capacity (Fig 5). The specimens before testing are shown in Fig 6 and after testing are shown in Fig 7 respectively.

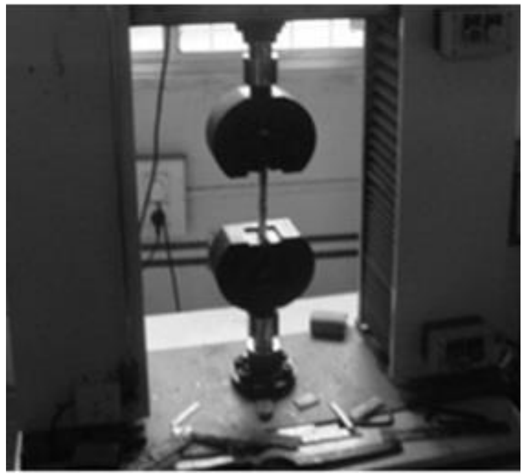

Fig. 5. Tension test setup.

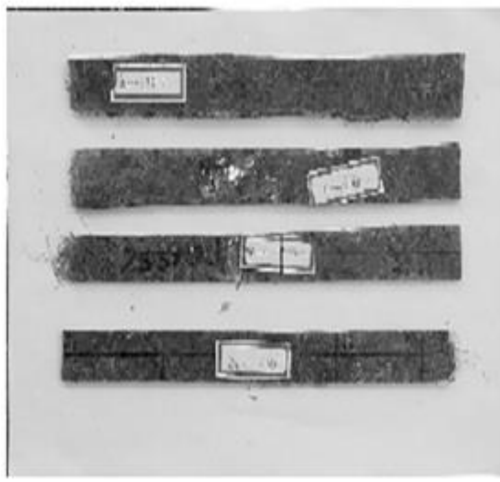

Fig. 6. Specimens before tensile test.

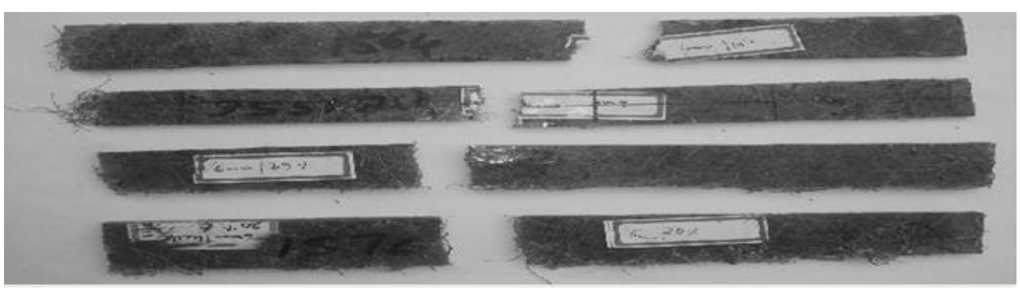

Fig. 7. Specimens after tensile test.

Flexure test is conducted according to ASTM test method D7264 [25]. A flexural property depends on the surface of the specimen. As no specimen is consummately symmetric, such contrasts will move the neutral axis and will be further influenced by even asymmetry in the laminate. Flexural properties might likewise differ with specimen thickness, moulding and/or testing environments, and rate of straining. Specimen Size is considered such that the flexural properties are obtained precisely from the tests. For flexural strength, the standard support-to-thickness proportion is used such that failure happens at the external surface of the specimen, because of the bending moment. The standard span-to-thickness proportion is 32:1, the standard specimen thickness is 4 mm, and the standard specimen width is 13 mm with the specimen length being around 20 % longer than the support span. Hence in the present study three-point bending test was conducted by adopting span-to-thickness proportion as 20:1. The tested specimens before and after testing are shown in Fig 8 and Fig 9 respectively.

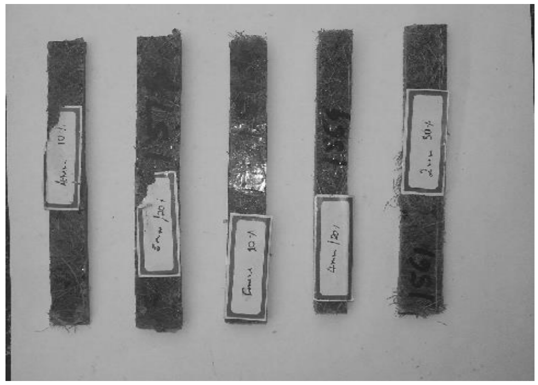

Fig. 8. Specimen before flexure test.

Fig. 9. Specimens after flexure test.

A regular way to deal with impact properties is to choose material toughness by estimating the energy required to break a test coupon of a particular geometry. Here the Izod impact test composite coupons were directed to evaluate the impact energy (N-m) as demonstrated by the ASTM D256-04 [26] (Fig-10). The indented coupons were kept in cantilever way and the pendulum swings around to fracture the coupon (Fig-11). The coupon size is 65 mm x 12.7 mm.

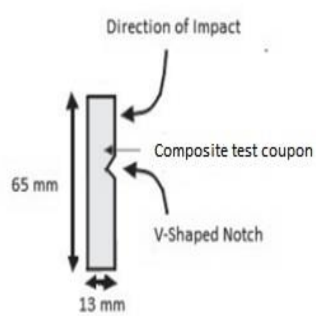

Fig. 10. Coupons before impact test.

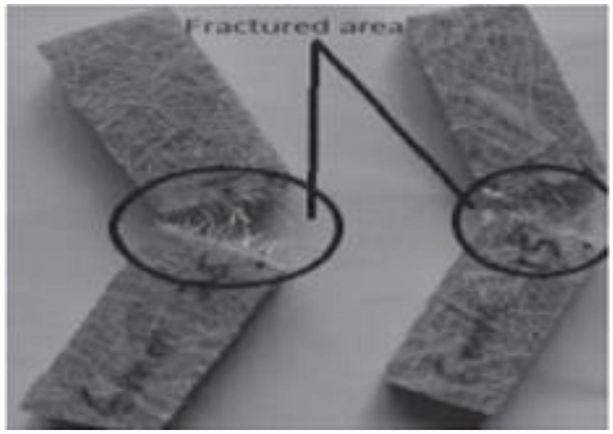

Fig. 11. Fractured test coupon after impact test.

Initially, all the specimens of both coir and sisal fiber reinforced polyester matrix composite is tested for its theoretical and experimental (actual) density. Theoretically weight density of composite is the ratio of weight to volume ratio of fibers and matrix. Likewise, experimentally, weight density of untreated coir polyester composite is the ratio of weight to volume of considered composite coupons. For illustration the experimentally computed weight and volume of matrix and fibers used to fabricate 5 mm thick 25 % FVF's flexural strength specimen of untreated coir polyester composite is 6.669 gms and 5.85 cc; 2.223 gms and 1.95 cc respectively. Here theoretically, weight density of untreated coir-polyester composite is worked out as 1.14 g/cc i.e., (6.669+2.223) divided by (1.95+5.85). But the actual (experimentally) weight density of untreated coir-polyester composite is 1.154 g/cc i.e., 9.007 divided by 7.8.

By considering 5 mm thick 25 % FVF's flexural strength specimen of untreated sisal-polyester composite, it is observed that weight of matrix used is 6.669 gms, weight of sisal fibers used is 2.73 grams, volume of sisal fiber was 1.95 cc and volume of matrix used is 5.85 cc. Here weight density of untreated sisal-polyester composite is worked out as 1.205 g/cc. Experimentally the weight density of untreated sisal-polyester composite was 1.2676 g/cc. From the above calculations it is observed that the density of composite specimens obtained from theoretical calculations and actual experimental values are found to match well. Further by using the direct specific gravity reading equipment the specific gravity values of the composite specimens are measured, they found to match well with the theoretical values. The above observations indicated that the composite specimens are free from voids.

2.4. ANN methodology

ANN is a family of parallel architects, equipped to learn and generalize from models/examples. The idea of building a neural system-based model for material behaviour is to train the neural system about the effects of a series of experiments using that material. In the event that the test results contain applicable data on material behaviour, at that time, the trained neural network will have sufficient data on the behaviour of the object to qualify the object for the new values. Such a trained neural system does not yet have the option of reproducing the experimental test results; furthermore, it is ready to estimate the results in different experiments by its generalization ability. The present investigation employs an ANN model of feed-forward supervised type for the expectation of tensile, flexure, and impact strength properties of coir/sisal fiber reinforced polyester composite. The training parameters are the number of iterations (epoch), the rate of learning, the error goal, and the number of hidden layers. These parameters are optimized until the convergence of the ANN training and thus the ideal training parameters are corrected. These ideal parameters are used for the testing and in the validation process. The general computational ANN model is represented by the term topology, which speaks to neurons in the input layer, the hidden layer, and the output-input layer. In any case, the neurons in the input layer and the output layer depend on the uncertainty of the problem domain. The number of hidden layers and neurons in it are fixed during the training process. Figure 12 depicts the ANN model adopted to predict the tensile strength, flexure strength and impact strength of coir/ sisal polyester composites. Here Levenberg Marquardt (LM) algorithm and Log-Sigmoid transfer function is adopted for the prediction process.

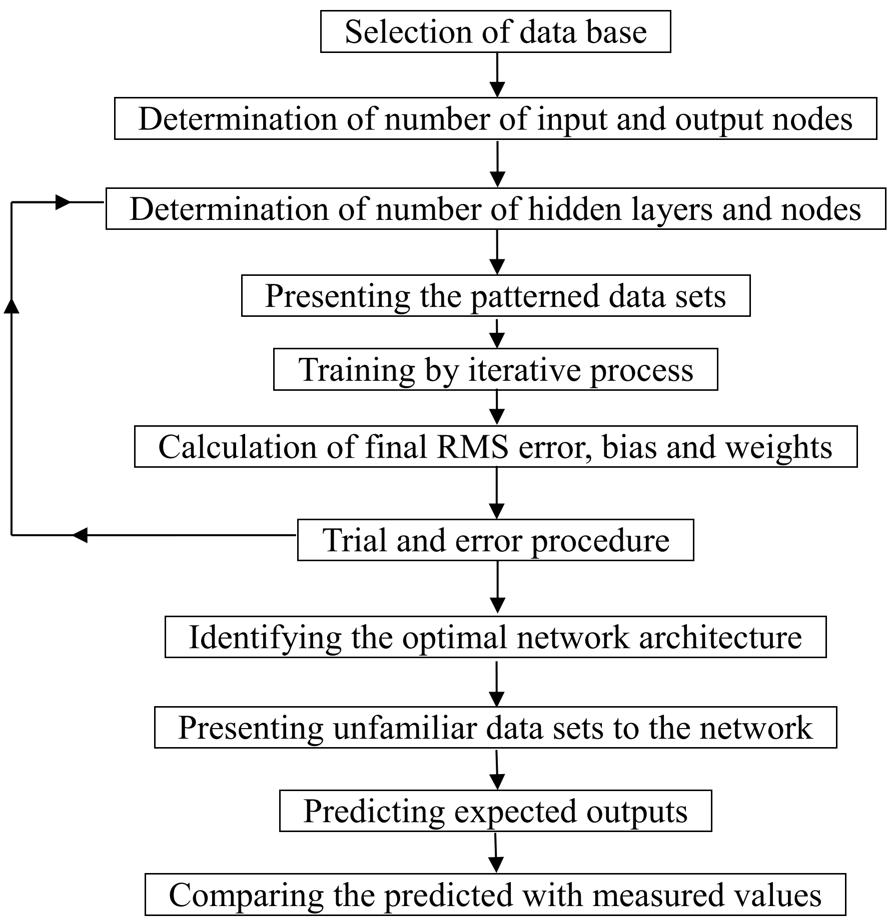

Fig. 12. Neural Network Model.

3. Result and discussion

In this section the results of the tests conducted to obtain the tensile, flexure and impact strength of coir/sisal polyester composites are discussed. These tests are conducted on five specimen coupons to check the uniformity of the results and to eliminate the defective specimens if any. Using these experimental results as input data the predictions were obtained from developed ANN optimum weighted matrix. Table 2 shows the tensile, flexure and impact strength properties of untreated and treated coir polyester composites. Table 3 shows the tensile, flexure and impact strength properties of untreated and treated sisal polyester composites. Here there are 25 input dataset (Thickness and FVF) and corresponding 25 number of output dataset (tensile, flexure and impact strength attributes), out of which randomly 20 data were considered for training process of the neural network and remaining 05 data were considered for validation/testing process in cases.

Table 2

Tensile, flexure and impact strength attributes of untreated and treated coir polyester composites.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)	Tensile strength of treated coupons (MPa)	Flexure strength of treated coupons (MPa)	Impact strength of treated coupons (N-m)
1	2	10	4.800	078.349	0.221	06.84	079.937	0.147
2	2	15	8.400	078.463	0.392	11.46	081.297	0.172
3	2	20	9.800	082.347	0.540	13.97	087.343	0.196
4	2	25	11.851	082.983	0.564	13.73	098.392	0.736
5	2	30	3.800	078.843	0.736	11.32	086.149	0.809
6	3	10	9.018	081.243	0.221	09.25	084.615	0.196
7	3	15	12.00	088.143	0.392	13.20	088.462	0.245
8	3	20	14.933	089.942	0.564	15.15	091.538	0.466
9	3	25	13.266	107.230	0.760	13.95	115.384	0.883
10	3	30	06.999	086.012	0.956	11.64	086.154	0.966
11	4	10	12.300	099.730	0.221	12.40	104.230	0.343
12	4	15	14.122	105.384	0.515	14.30	110.000	0.540
13	4	20	15.447	118.427	0.613	16.20	125.769	0.638
14	4	25	13.597	126.923	0.834	14.30	130.384	0.907
15	4	30	10.580	106.153	1.030	12.85	117.307	1.006
16	5	10	13.986	106.076	0.299	14.12	114.615	0.392
17	5	15	14.431	120.000	0.589	14.44	129.231	0.589
18	5	20	17.035	124.615	0.687	17.12	133.846	0.736
19	5	25	18.598	133.461	0.903	19.72	138.846	0.932
20	5	30	14.514	117.492	1.079	15.46	120.000	1.079
21	6	10	14.076	112.820	0.356	14.60	117.690	0.530
22	6	15	16.055	127.460	0.598	16.87	139.231	0.883
23	6	20	18.058	143.290	0.785	19.20	146.154	0.956
24	6	25	20.598	148.461	1.226	22.50	153.071	1.030
25	6	30	18.800	123.846	1.570	19.60	130.769	1.275

Table 3
Tensile, flexure and impact strength attributes of untreated and treated sisal polyester composites.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)	Tensile strength of treated coupons (MPa)	Flexure strength of treated coupons (MPa)	Impact strength of treated coupons (N-m)
1	2	10	01.890	087.347	0.319	04.340	082.342	0.368
2	2	15	03.559	097.183	0.809	06.270	085.932	0.491
3	2	20	09.000	103.246	0.888	10.760	088.761	0.638
4	2	25	05.770	110.934	0.956	08.480	094.354	0.785
5	2	30	02.540	101.723	1.079	06.830	087.471	0.932
6	3	10	07.340	099.827	0.510	12.480	107.692	0.392
7	3	15	08.533	107.692	0.863	12.940	114.615	0.687
8	3	20	11.600	113.769	1.324	14.340	128.461	0.883
9	3	25	09.200	137.308	1.472	13.240	142.307	1.030
10	3	30	08.064	113.077	1.550	11.260	125.384	1.079
11	4	10	12.635	106.615	0.687	17.500	108.230	0.441
12	4	15	13.200	116.923	0.981	19.900	121.153	0.736
13	4	20	14.200	121.153	1.373	22.000	130.000	1.055
14	4	25	19.300	144.230	1.913	24.200	151.538	1.079
15	4	30	15.194	119.461	1.937	17.460	140.000	1.128
16	5	10	13.120	110.384	0.883	17.500	110.000	0.491
17	5	15	16.560	120.000	1.216	19.520	133.846	0.785
18	5	20	16.800	129.230	1.619	22.680	138.462	1.128
19	5	25	20.560	147.692	1.962	24.520	157.692	1.177
20	5	30	19.680	120.000	2.011	20.680	143.076	1.472
21	6	10	16.844	113.836	0.893	17.400	115.384	0.542
22	6	15	18.613	123.846	2.207	19.840	139.231	0.839
23	6	20	19.400	134.615	2.796	22.840	143.077	1.177
24	6	25	21.660	151.538	3.384	24.860	160.000	1.275
25	6	30	22.938	138.273	3.581	23.240	146.154	1.962

Tables 4 and 5 show the parameters considered for the ANN's training and testing process amid the forecasting tensile, flexure and impact strength of untreated coir polyester composites respectively. All the values inside of the parenthesis depict the respective values obtained during the ANN forecast process, and other data without parenthesis are experimentally derived values. If a new user want to do prediction by utilizing an already trained neural network, then by just doing turnoff of optimization and forward passing the input (maybe after normalization, here the normalization is a process of dividing all the input and output data by their respective peak value) can just get the output. Figure 13 shows the training performance curve developed amid the training process of untreated coir polyester composites. The learning rate is a hyper-parameter that controls the amount we are modifying the weights of our network system as for the loss gradient. The lower the value, the slower we travel along the descending incline. Regularly learning rates are arranged at random by the user. Consequently in the current investigation study learning rate is adopted between 0.4 to 0.6 with an error goal of $10^{(-5)}$. The correlation coefficient measures the relationship between experimental and predicted output variables. Correlation value nearer to +1 indicates a perfect positive relationship: as one variable increases in its values, the other variable also increases in its values. In our present study correlation coefficient value of 0.999 in all cases indicates a strong relationship between experimental and predicted output data and both are in the same trend. Figures 14, 15 and 16 show the variation of predicted (forecasted) values of tensile strength, flexure strength and impact strength (of every FVF) from 10 % to 30 % FVFs respectively.

Table 4
Tensile, flexure and impact strength attributes of untreated coir reinforced polyester composites used for training of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	10	4.8(4.84656)	78.349(77.5943)	0.221(0.211678)
2	2	15	8.4(8.32421)	78.463(79.1281)	0.392(0.395853)
3	2	25	11.851(11.37587)	82.983(83.4775)	0.564(0.572185)
4	2	30	3.8(3.88644)	78.843(78.905)	0.736(0.72469)
5	3	10	9.018(9.07964)	81.243(81.4729)	0.221(0.214629)
6	3	20	14.933(14.54126)	89.942(91.6649)	0.564(0.558587)
7	3	25	13.266(13.06545)	107.23(104.6503)	0.76(0.761061)
8	3	30	6.999(6.96946)	86.012(85.5685)	0.956(0.963655)
9	4	15	14.122(14.0757)	105.384(107.3463)	0.515(0.500429)
10	4	20	15.447(15.23475)	118.427(117.2587)	0.613(0.620403)
11	4	25	13.597(13.61591)	126.923(125.7782)	0.834(0.836856)
12	4	30	10.58(10.55407)	106.153(105.497)	1.03(1.030957)
13	5	10	13.986(14.03575)	106.076(105.8809)	0.299(0.311303)
14	5	15	14.431(14.66611)	120(119.2209)	0.589(0.571317)
15	5	20	17.035(16.98402)	124.615(124.5958)	0.687(0.701886)
16	5	25	18.598(18.16504)	133.461(132.2936)	0.903(0.89456)
17	6	10	14.076(14.07669)	112.82(112.816)	0.356(0.35603)
18	6	15	16.055(16.02955)	127.46(127.4361)	0.598(0.60269)
19	6	20	18.058(18.11102)	143.29(142.5211)	0.785(0.802332)
20	6	30	18.8(18.73739)	123.846(125.2744)	1.57(1.566308)

Table 5
Tensile, flexure and impact strength attributes of untreated coir reinforced polyester composites used for testing of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	20	9.8(9.73049)	82.347(82.057)	0.54(0.528924)
2	3	15	12(12.07165)	88.143(87.0841)	0.392(0.400005)
3	4	10	12.3(12.34762)	99.73(96.568)	0.221(0.270643)
4	5	30	14.514(14.85185)	117.492(117.6714)	1.079(1.08808)
5	6	25	20.598(20.22963)	148.461(144.8811)	1.226(1.214313)

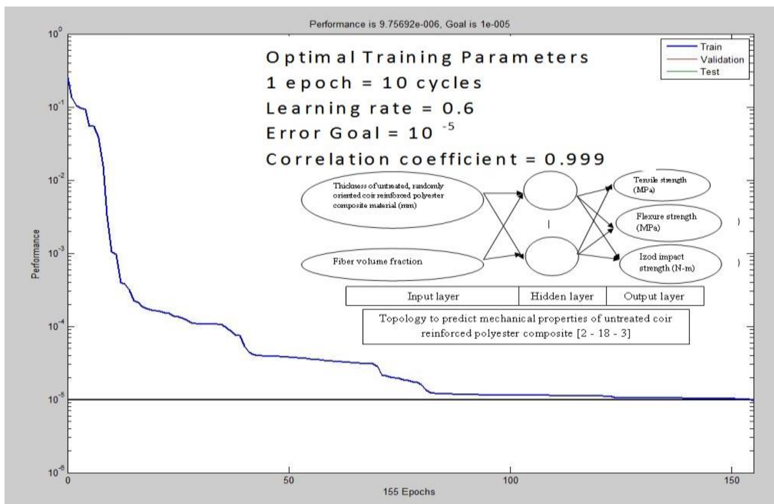

Fig. 13. ANN training performance curve developed during prediction of tensile, flexure and impact strength attributes of untreated coir reinforced polyester composites.

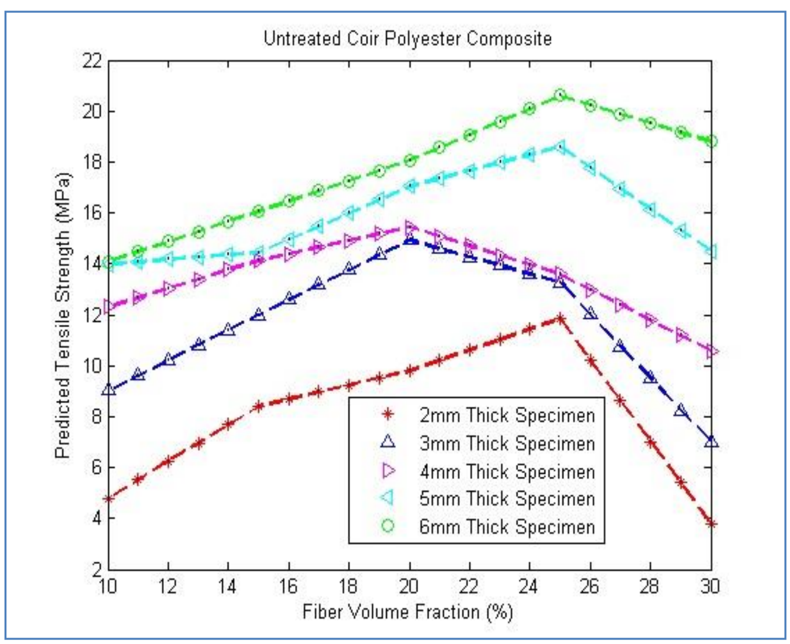

Fig. 14. Variation of predicted tensile strength of untreated coir reinforced polyester composites with FVF.

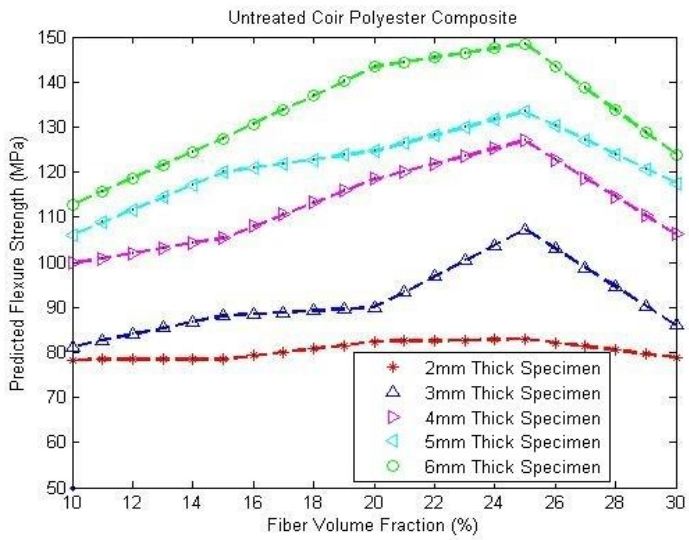

Fig. 15. Variation of predicted flexure strength of untreated coir reinforced polyester composites.

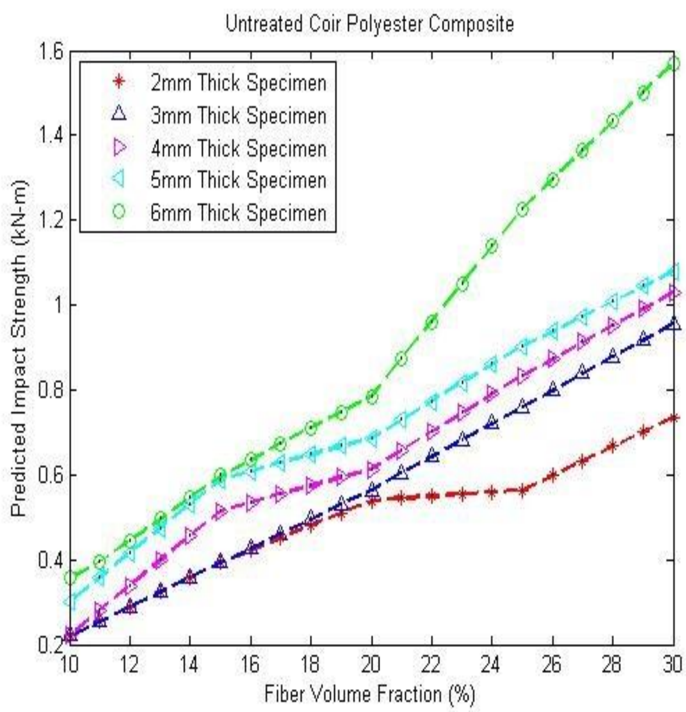

Fig. 16. Variation of predicted impact strength of untreated coir reinforced polyester composites.

Tables 6 and 7 depict the parameters considered for the training and testing of the ANN during prediction procedure tensile, flexure and impact strength of treated coir polyester composite respectively. As in untreated coir polyester composite specimens, here also thickness and FVFs were considered as input parameters and their respective tensile, flexure and impact strength were as output parameters. All the values inside of the parenthesis depict the respective ANN anticipated (predicted) values and other data without parenthesis are experimentally derived ones. Figure 17 represents the ANN's training performance curve developed during the forecast process of mechanical properties of treated coir polyester composites. Figures 18, 19 and 20 show the variation of anticipated tensile, flexure and impact strength of treated coir polyester composite with FVFs respectively. All these figures show the same pattern as obtained from experiments.

Table 6
Tensile, flexure and impact strength attributes of treated coir reinforced polyester composites used for training of ANN**.**

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	10	6.84(6.91126)	79.937(79.7224)	0.147(0.154626)
2	2	15	11.46(11.31401)	81.297(81.7368)	0.172(0.163891)
3	2	20	13.97(13.91968)	87.343(87.5682)	0.196(0.207023)
4	2	30	11.32(11.36937)	86.149(86.144)	0.809(0.804164)
5	3	15	13.2(13.18204)	88.462(88.9443)	0.245(0.256559)
6	3	20	15.15(14.95791)	91.538(92.0938)	0.466(0.472001)
7	3	25	13.95(13.79133)	115.384(112.744)	0.883(0.869266)
8	3	30	11.64(11.59027)	86.154(86.0982)	0.966(0.971036)
9	4	10	12.4(12.52456)	104.23(103.9649)	0.343(0.347809)
10	4	20	16.2(16.00987)	125.769(125.5229)	0.638(0.656618)
11	4	25	14.3(14.29041)	130.384(129.8737)	0.907(0.884706)
12	4	30	12.85(12.75395)	117.307(117.6898)	1.006(1.00963)
13	5	10	14.12(14.14503)	114.615(114.9243)	0.392(0.397026)
14	5	15	14.44(14.62553)	129.231(128.9279)	0.589(0.594082)
15	5	25	19.72(19.12481)	138.846(137.0211)	0.932(0.931551)
16	5	30	15.46(15.49738)	120(119.2945)	1.079(1.080758)
17	6	10	14.6(14.66622)	117.69(117.6226)	0.53(0.528181)
18	6	15	16.87(16.8269)	139.231(140.3815)	0.883(0.863959)
19	6	20	19.2(19.30005)	146.154(146.0101)	0.956(0.954594)
20	6	25	22.5(22.27243)	153.071(152.027)	1.03(1.038487)

Table 7
Tensile, flexure and impact strength attributes of treated coir reinforced polyester composites used for testing of ANN.

SI No.	Reinforcement Type	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	Treated Coir	2	25	13.73(13.45653)	98.392(96.6989)	0.736(0.697968)
2	Treated Coir	3	10	9.25(9.63622)	84.615(85.0143)	0.196(0.189324)
3	Treated Coir	4	15	14.3(14.36401)	110(111.5638)	0.54(0.528245)
4	Treated Coir	5	20	17.12(17.08228)	133.846(135.2067)	0.736(0.730272)
5	Treated Coir	6	30	19.6(19.85662)	130.769(133.7124)	1.275(1.222416)

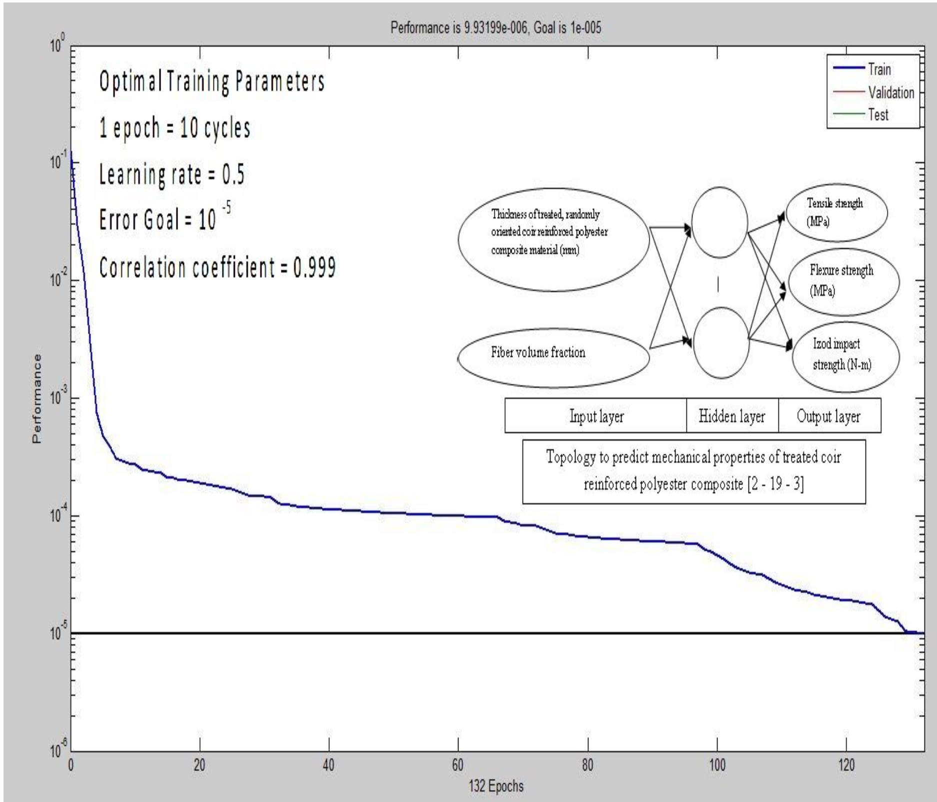

Fig. 17. ANN training performance curve developed during the prediction of tensile, flexure and impact strength attributes of treated coir reinforced polyester composites.

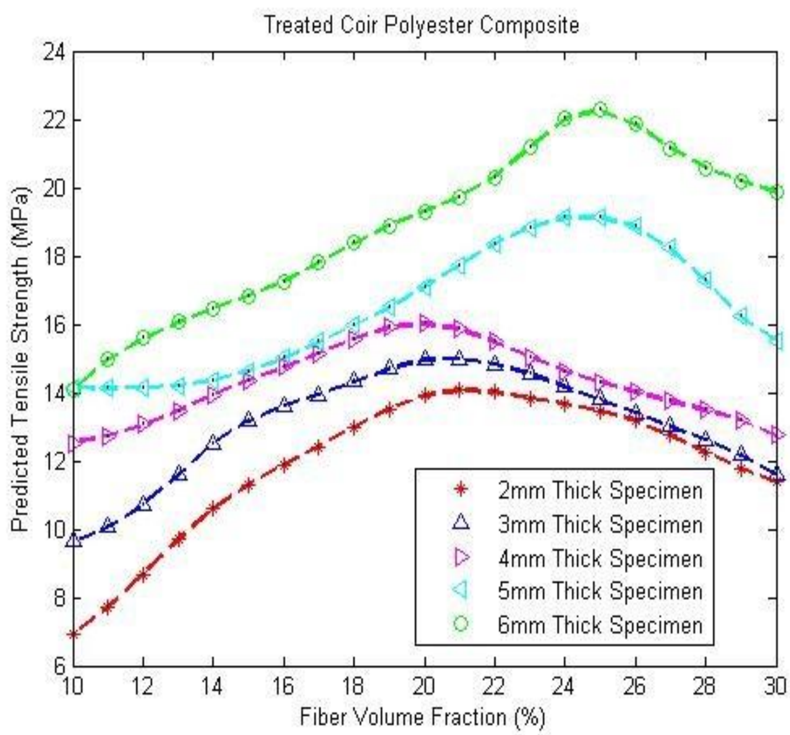

Fig. 18. Variation of predicted tensile strength of treated coir reinforced polyester composites.

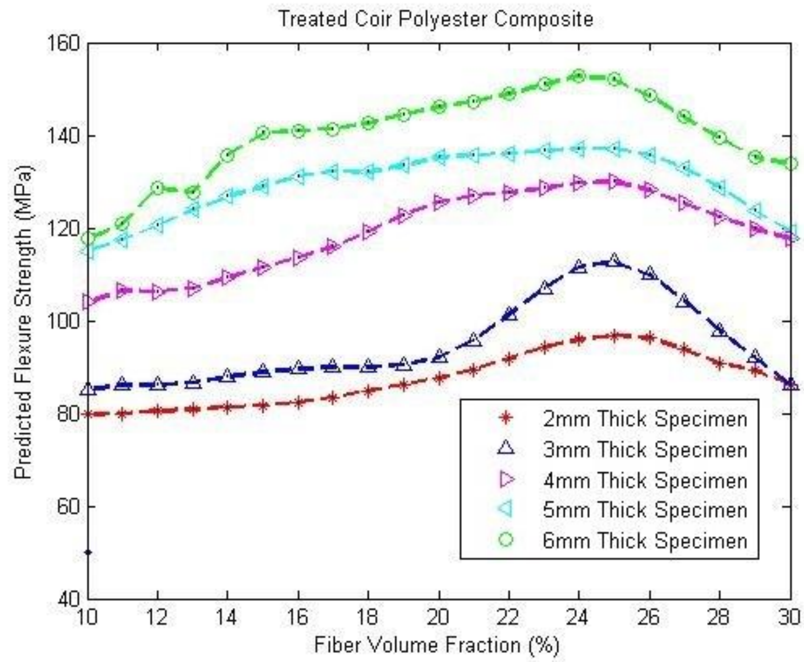

Fig. 19. Variation of predicted flexure strength of treated coir reinforced polyester composites.

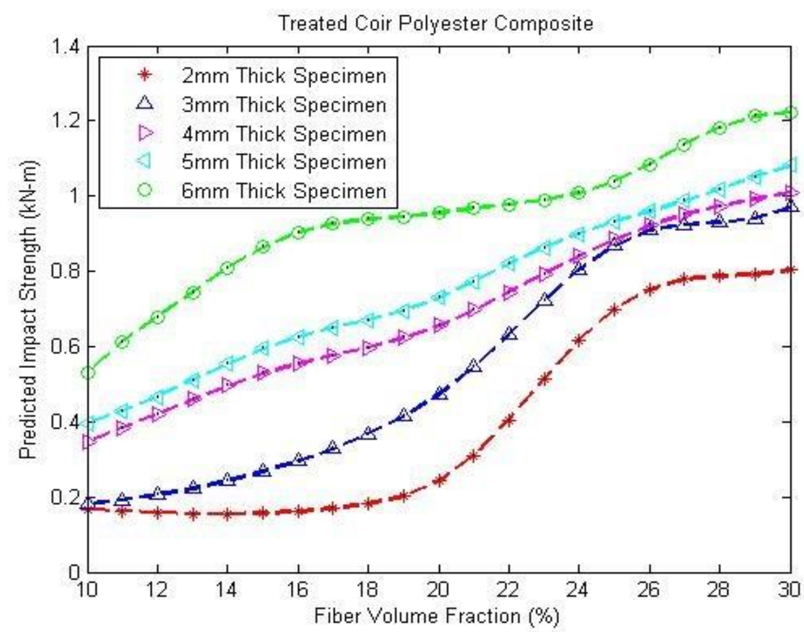

Fig. 20. Variation of predicted impact strength of treated coir reinforced polyester composites.

Table 8 and 9 show the parameters that considered for the ANN training and testing amid the forecasting procedure tensile, flexure and impact strength of untreated sisal polyester composites respectively. Here all the parameters inside of the parenthesis represent the respective ANN anticipated values and other data without parenthesis are experimentally derived. Figure 21 shows the training performance curve developed amid the forecast procedure of mechanical properties of untreated sisal polyester composites. Figures 22 to 24 show the variation of tensile strength, flexure strength and impact strength of untreated sisal-polyester composites with FVFs respectively. Here it is observed that pattern of variation of ANN's anticipated values are same as the variation of experimentally determined values.

Table 8
Tensile, flexure and impact strength attributes of untreated sisal fiber reinforced polyester composites used for training of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	15	3.559(3.711)	97.183(96.2849)	0.809(0.777888)
2	2	20	9(8.58305)	103.246(103.4741)	0.888(0.88754)
3	2	25	5.77(5.63205)	110.934(109.915)	0.956(0.947801)
4	2	30	2.54(2.64199)	101.723(97.2376)	1.079(1.092458)
5	3	10	7.34(7.5902)	99.827(99.3438)	0.51(0.509942)
6	3	15	8.533(8.7999)	107.692(107.6572)	0.863(0.867598)
7	3	25	9.2(9.35809)	137.308(131.7336)	1.472(1.466271)
8	3	30	8.064(8.09689)	113.077(112.9628)	1.55(1.533295)
9	4	10	12.635(12.64909)	106.615(106.2528)	0.687(0.668408)
10	4	20	14.2(14.2802)	121.153(122.782)	1.373(1.389125)
11	4	25	19.3(18.88974)	144.23(142.0336)	1.913(1.881803)
12	4	30	15.194(15.24611)	119.461(119.3845)	1.937(1.92979)
13	5	10	13.12(13.09233)	110.384(111.5856)	0.883(0.84794)
14	5	15	16.56(16.31811)	120(120.3769)	1.216(1.220255)
15	5	20	16.8(16.90513)	129.23(130.1705)	1.619(1.600705)
16	5	25	20.56(20.37259)	147.692(145.0788)	1.962(1.93338)
17	6	10	16.844(16.73903)	113.836(111.9101)	0.893(0.935)
18	6	20	19.4(19.52896)	134.615(135.4583)	2.796(2.788214)
19	6	25	21.66(21.63531)	151.538(150.3064)	3.384(3.356602)
20	6	30	22.938(22.97495)	138.273(137.9481)	3.581(3.563581)

Table 9
Tensile, flexure and impact strength attributes of untreated sisal fiber reinforced polyester composites used for testing of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	10	1.89(1.9854)	87.347(91.6718)	0.319(0.334966)
2	3	20	11.6(11.09012)	113.769(116.3345)	1.324(1.303605)
3	4	15	13.2(13.20581)	116.923(115.8766)	0.981(0.981407)
4	5	30	19.68(20.16563)	120(118.322)	2.011(1.988684)
5	6	15	18.613(18.4685)	123.846(123.6159)	2.207(2.158062)

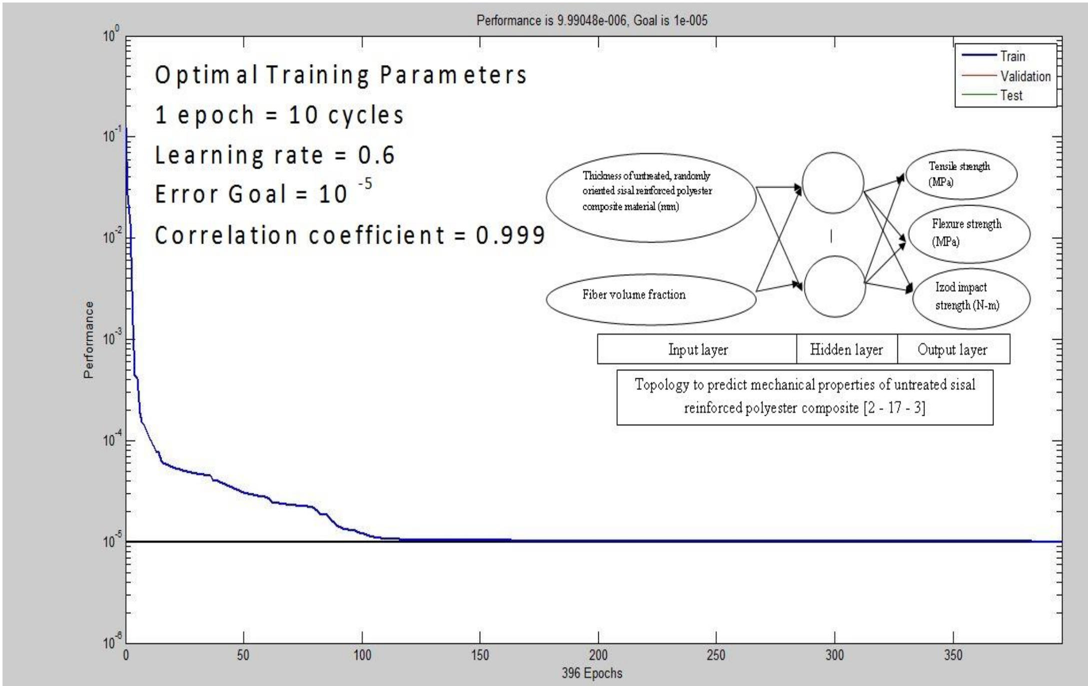

Fig. 21. ANN training performance curve developed during prediction of tensile, flexure and impact strength attributes of untreated sisal fiber reinforced polyester composites.

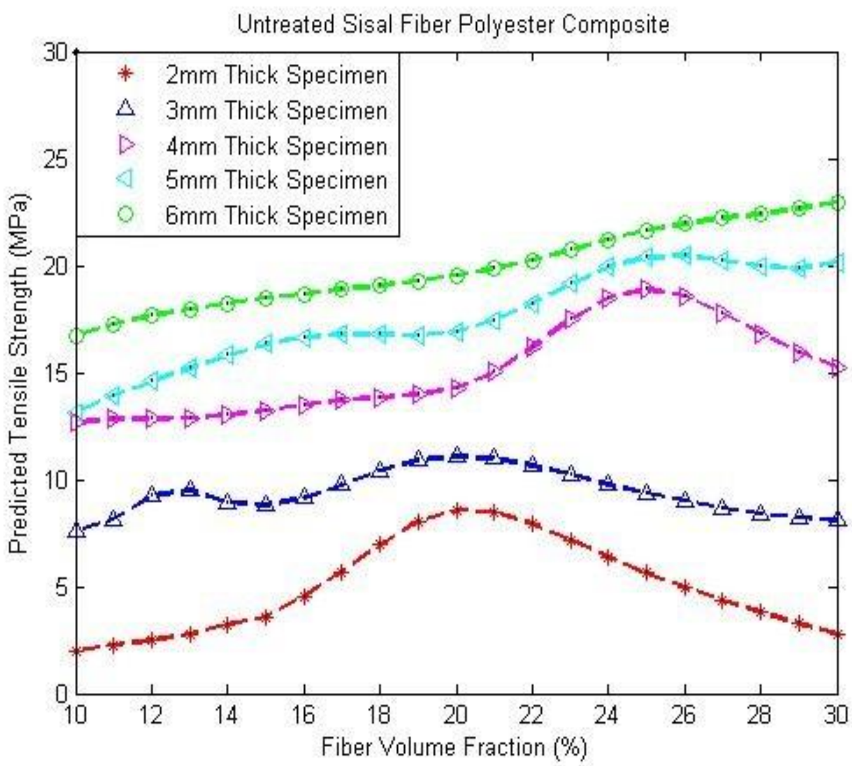

Fig. 22. Variation of predicted tensile strength of untreated sisal fiber reinforced polyester composites.

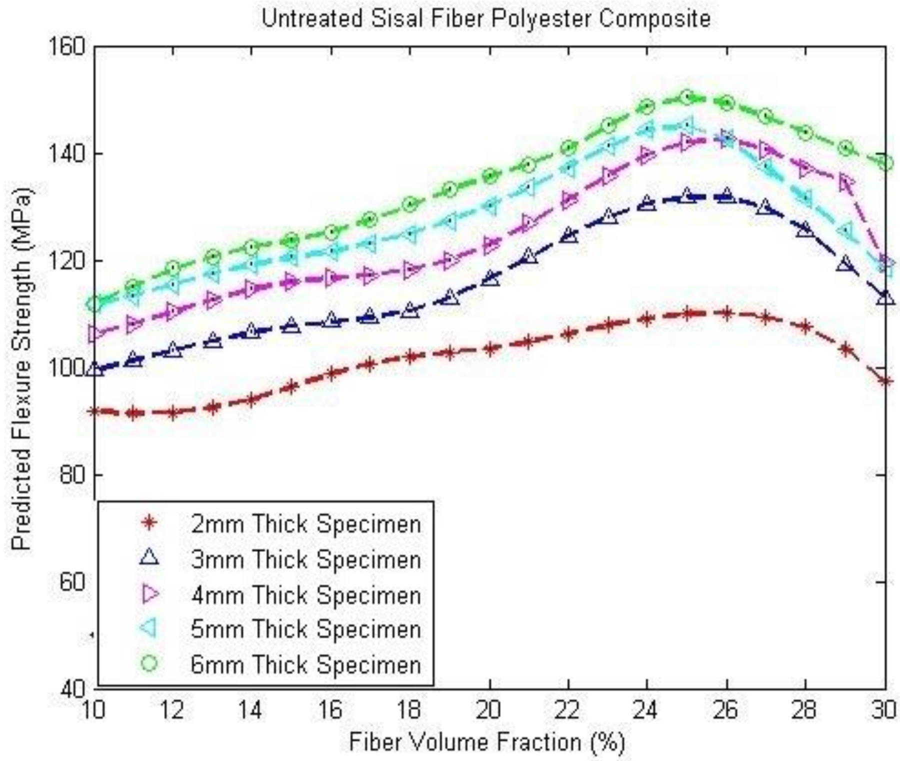

Fig. 23. Variation of predicted flexure strength of untreated sisal fiber reinforced polyester composites.

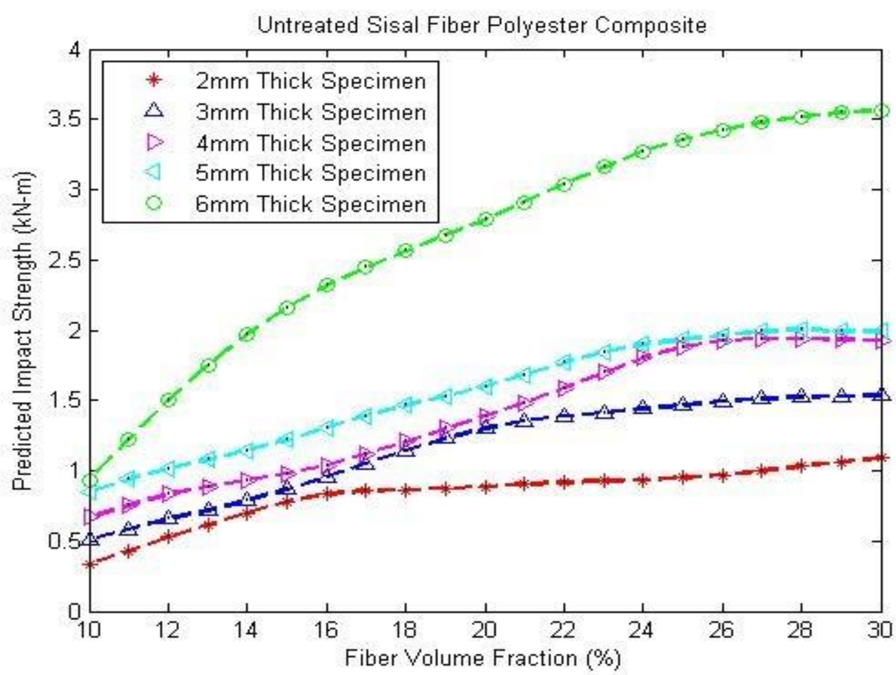

Fig. 24. Variation of predicted impact strength of untreated sisal fiber reinforced polyester composites.

Tables 10 and 11 describe the parameters considered for ANN training and testing amid the prediction procedure of tensile, flexure and impact strength of treated sisal polyester composites respectively. Here all the values inside the bracket describe the respective ANN anticipated values and other data without parenthesis are experimentally derived values. Figure 25 shows the training performance curve developed amid the forecast procedure of tensile, flexure and impact strength of treated sisal polyester composites. Figures 26 to 28 show the variation of ANN anticipated tensile, flexure and impact strength of treated sisal polyester composites respectively. Here it is observed that, pattern of variation of anticipated tensile, flexure and impact strength with FVF is as same as their respective experimental values.

Table 10
Tensile, flexure and impact strength attributes of treated sisal fiber reinforced polyester composites used for training of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	10	4.34(4.489)	82.342(83.6495)	0.367(0.376506)
2	2	15	6.27(6.33011)	85.932(85.9696)	0.490(0.507888)
3	2	20	10.76(10.40952)	88.761(89.4875)	0.637(0.635066)
4	2	25	8.48(8.491)	94.354(93.8126)	0.784(0.783862)
5	3	10	12.48(12.46007)	107.692(108.4581)	0.392(0.413255)
6	3	15	12.94(12.98319)	114.615(115.0338)	0.686(0.663078)
7	3	25	13.24(13.39213)	142.307(140.8283)	1.030(1.013234)
8	3	30	11.26(11.43694)	125.384(126.3599)	1.079(1.07311)
9	4	15	19.9(19.87198)	121.153(120.8094)	0.735(0.745815)
10	4	20	22(22.03065)	130(131.0093)	1.054(1.026731)
11	4	25	24.2(23.63898)	151.538(150.3665)	1.079(1.072054)
12	4	30	17.46(17.52201)	140(139.4486)	1.128(1.126225)
13	5	10	13.31(13.38953)	110(109.5831)	0.490(0.49144)
14	5	20	22.68(22.56434)	138.462(139.8939)	1.128(1.109702)
15	5	25	24.52(24.21858)	157.692(156.725)	1.177(1.186257)
16	5	30	20.68(20.71965)	143.076(143.3808)	1.471(1.470545)
17	6	10	17.4(17.4748)	115.384(115.9026)	0.541(0.543235)
18	6	15	19.84(19.9161)	139.231(137.7782)	0.838(0.823097)
19	6	20	22.84(22.70047)	143.077(143.4322)	1.177(1.165054)
20	6	30	23.24(23.19054)	146.154(146.367)	1.962(1.956847)

Table 11
Tensile, flexure and impact strength attributes of treated sisal fiber reinforced polyester composites used for testing of ANN.

SI No.	Thickness (mm)	FVF (%)	Tensile strength (MPa)	Flexure strength (MPa)	Impact strength (N-m)
1	2	30	6.83(7.04084)	87.471(87.2801)	0.932(0.906423)
2	3	20	14.34(14.00041)	128.461(128.1247)	0.883(0.891564)
3	4	10	17.5(17.69534)	108.23(107.339)	0.441(0.438604)
4	5	15	19.52(19.59335)	133.846(131.9807)	0.785(0.7744)
5	6	25	24.86(24.64605)	160(158.2879)	1.275(1.322127)

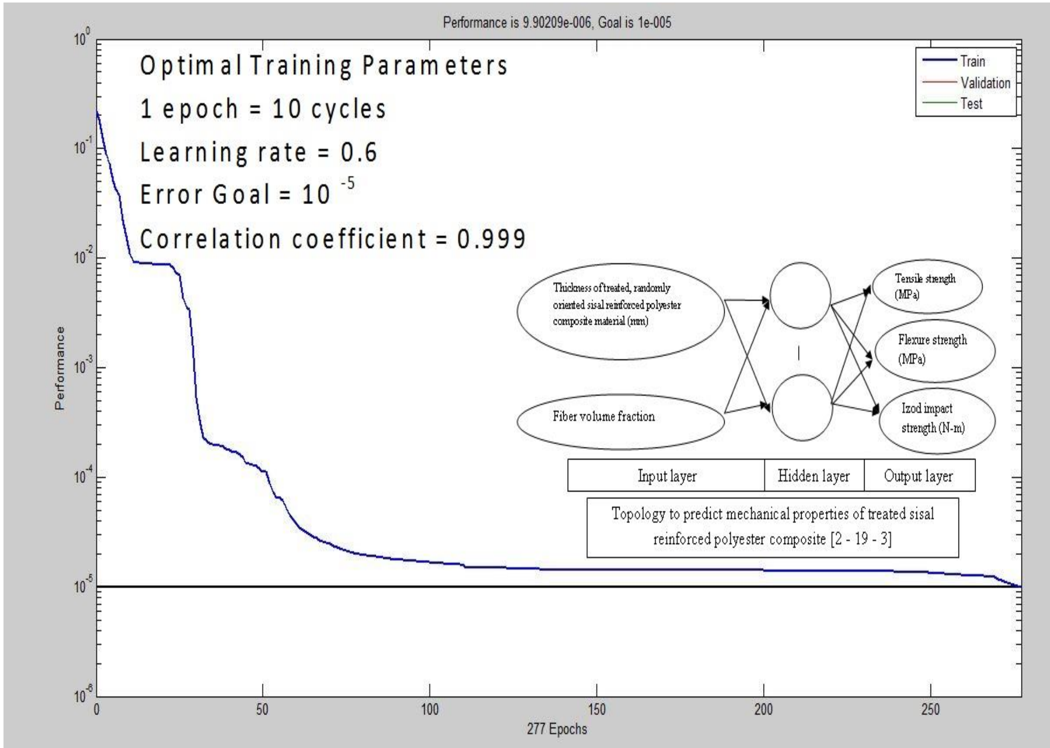

Fig. 25. ANN training performance curve developed during prediction of tensile, flexure and impact strength attributes of treated sisal fiber reinforced polyester composites.

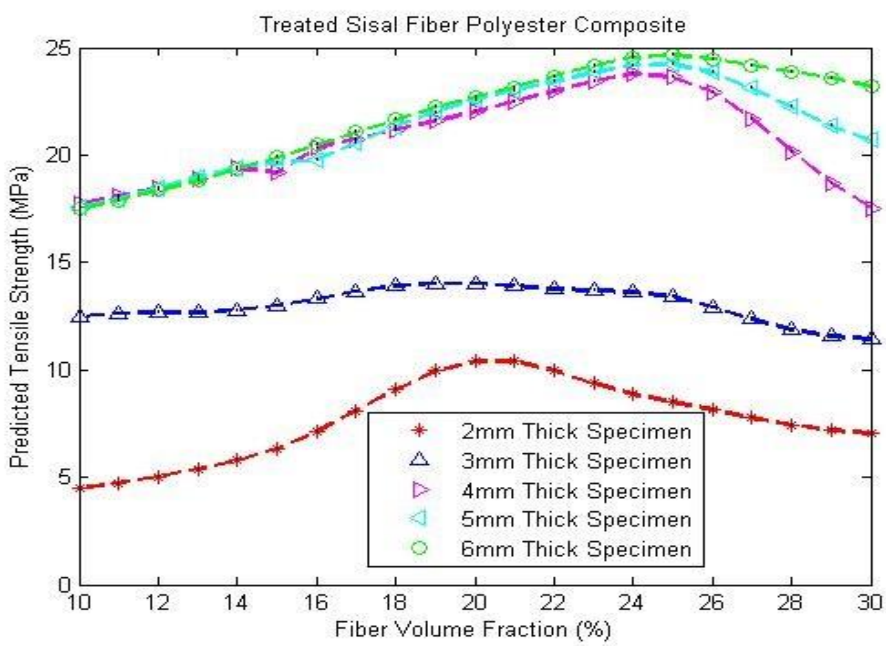

Fig. 26. Variation of predicted tensile strength of treated sisal fiber reinforced polyester composites.

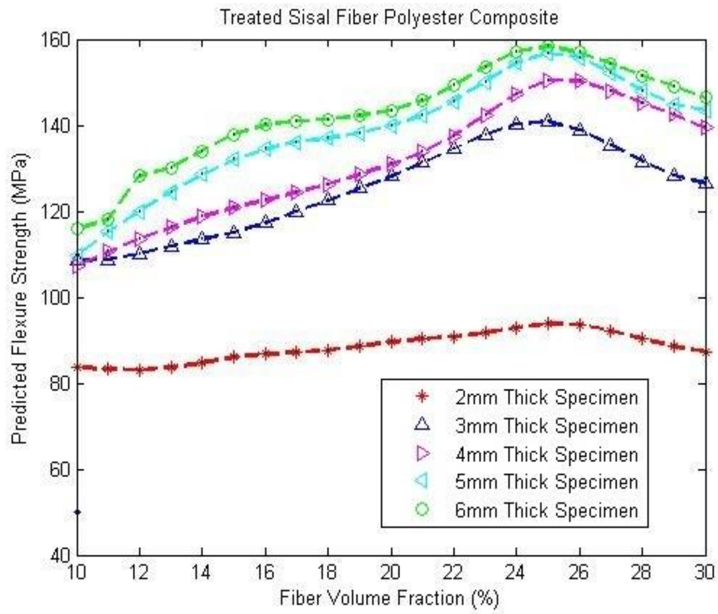

Fig. 27. Variation of predicted flexure strength of treated sisal fiber reinforced polyester composites.

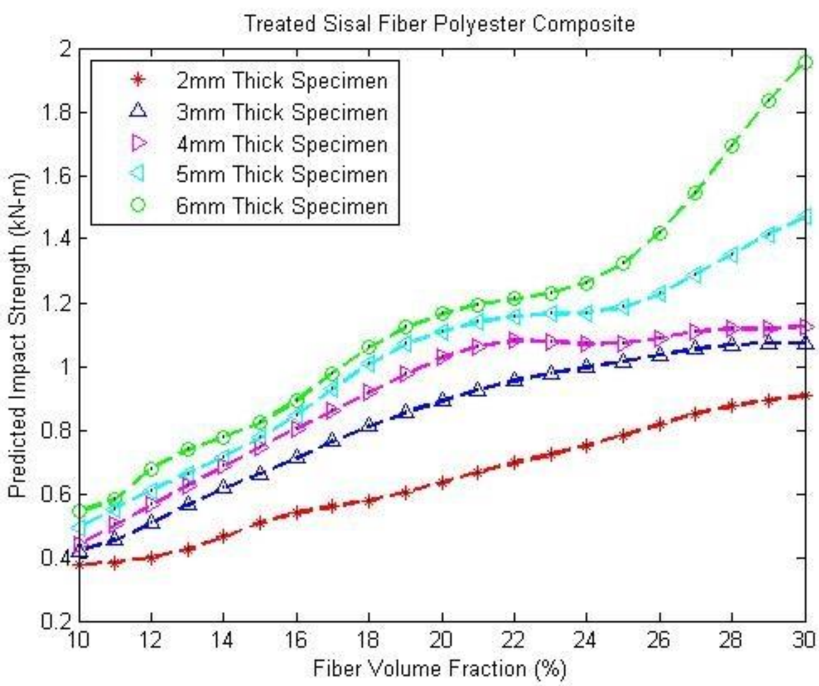

Fig. 28. Variation of predicted impact strength of treated sisal fiber reinforced polyester composites.

4. Conclusions

Tables 4, 5, 6 and 7 shows the contrast between ANN anticipated and experimental values of tensile, flexure and impact strength of both untreated and 5 % NaOH treated coir embedded polyester composite specimens. The above perceptions uncover the way that, ANN can be successfully used to anticipate the mechanical properties of coir polyester composites. Figures 13 and 17 show that, generated optimum weighted matrix amid the forecast procedure of mechanical properties of both 5 % NaOH treated and untreated coir-polyester composites are effective for prediction of sought mechanical properties of coir polyester composite when the lab techniques felt to be mind boggling, uneconomical or tedious. Figures 14 to 16 and 18 to 20 reveal that, obtained optimum weighted matrix amid prediction procedure of mechanical properties of both untreated and treated coir polyester composite can be effectively used for forecasting of mechanical properties of each coir polyester composites of FVF from 10 % to 30 % (Here all the anticipated values of mechanical properties are in the same pattern as experimentally obtained values).

Table 8, 9, 10 and 11 indicate that ANN can be successfully adopted to foresee the mechanical properties of both treated and untreated sisal fiber embedded polyester matrix composites (here the difference between ANN anticipated values and respective experimentally obtained values are found to match well). Figures 21 and 25 show that developed optimum weighted matrix to foresee mechanical properties of both treated and untreated sisal fiber embedded polyester matrix composites can be successfully used for the forecast (prediction) of its mechanical properties. Figures 22 to 24 and 26 to 28 reveal that developed optimum weighted matrix amid the forecast procedure of mechanical properties of both 5 % NaOH treated and untreated sisal fiber embedded polyester matrix composites can be used for predicting the mechanical properties of any specific specimen of particular thickness (2 mm to 6 mm) and FVFs (10 % to 30 %).

The prediction results of present study indicated that fixed optimum weighted matrix of ANN shows good agreement to compute the mechanical attributes values [11–14]. The correlation coefficient value of 0.999 between experimental and predicted data indicates that ANN is capable to predict tensile, flexure and impact strength attributes of coir/sisal polyester composites. ANN effectively reduces the conventional experimental investigation required to derive mechanical strength attributes of coir/sisal polyester composites[27] which involved participation of skilled labours, repetitive experimentation and time consumption. Validation of obtained ANN weighted matrix shows that designed ANN model are capable to predict the mechanical strength attributes of coir/sisal polyester composites with high range of accuracy (>95 %). Hence predicted results support to use the ANN infallibly for prognostication of mechanical strength attributes of coir/sisal polyester composites.

The use of alternative building materials such as plant fiber embedded composites reduces the use of river sand in construction practice (nowadays, it is one of the eco-social issues), and it renews the use of agro-wastes. The use of this type of alternative building material can adequately accelerate the construction practice in contrast to traditional methods. In addition, the commercial value of coir and sisal fiber will also increase.

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