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APPLICATION OF ANN AND RSM ON STRENGTH PROPERTIES OF ALKALI MERCERIZED HYBRID RAMIE-ISORA FIBRE REINFORCED BIODEGRADABLE POLYMER COMPOSITES

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ABSTRACT : *The study is undertaken to find application of ANN and RSM on mechanical properties of alkali mercerized hybrid ramie-isora fibre reinforced biodegradable polymer composites. For this purpose hybrid ramie-isora fibre NaOH treatment concentration of 5 %, 10 % and 15 % were used. Samples were casted by using nine different sample mixtures with 3 Hrs, 6 Hrs and 9 Hrs hybrid ramie-isora fibre NaOH treatment durations. At the end of curing these casted samples were subjected to material strength tests like young's modulus, yield strength and ultimate strength test. As can be seen in Figs. 3, 6 and 9 the training of the hybrid ramie-isora polyester composite young's modulus, yield strength and ultimate strength ANN models are completed at 4 epochs with 1.34632e-028, 1.05181e-029 and 1.68849e-028 performances giving goals are 0 as desired for the validation of its tested values. Hybrid ramie-isora polyester composite young's modulus, yield strength and ultimate strength ANN models output-target fits with the models of the form* $y = aT + b$ *have 38.04 %, 80.94 % and 37.31 % accuracies as observed from Figs. 4, 7 and 10 compared to RSM model possessing 99.82 %, 78.28 % and 99.82 % accuracies also seen in Tables 6,. Hence, RSM model computational techniques present a better study and results for young's modulus and ultimate strength judging from the accuracies of the models. While ANN model computational techniques present a better study and results for yield strength only judging from the accuracies of the models also. The control polyester composite materials young's modulus, yield strength and ultimate strength are 155.65 MPa, 1.20 MPa and 2.36 MPa. The hybrid ramie-isora fibre with NaOH treatment of 5 %, 10 % and 15 % possess young's modulus of 256.25 MPa, 253.92 MPa and 269.41 MPa, yield strength of 1.59 MPa, 1.71 MPa and 1.84 MPa and ultimate strength of 3.56 MPa, 3.36 MPa and 4.62 MPa, respectively. Young's modulus improved by 63.14 to 81.41 %, yield strength enhancements of 10 to 97.50 % and ultimate strength increased by 38.98 to 93.22 %. Also, from strength properties models it is found that the hybrid ramie-isora fibre polyester polymer composites has optimum young's modulus and ultimate strength with yield strength of 274.9 MPa and 94.409 MPa at 95 % adequacies with 2.121 MPa below 95 % adequacies at 5 % and 5 % with 5 % optimum hybrid ramie-isora fibre with NaOH treatment concentrations and 9 Hrs and 9.5 Hrs with 9 Hrs optimum ramie-isora fibre with NaOH treatment durations. At 99.82 % and 96.11 % with 78.28 % accuracies all at 0.7506 and 0.0292 with 0.0473 mean square errors. It was observed that hybrid ramie-isora fibre along with polyester mixture has significantly improved these properties. Regression analysis on experimental* results generated some artificial neural network and response surface methodology models predicting the results in good agreement.

KEYWORDS: *Hybrid natural fibre, Biodegradable Composites, Polymer matrix, Alkali mercerization, Strength properties; ANN; RSM*

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I. INTRODUCTION

One of the top problems facing the present generation is energy apart from environmental protections. To protect the environment and generate products that must not be environmentally harmful, novel strategies are required. Due to their properties, such as: low density, high specific strength and they are renewable, sustainable, and eco-friendly natural fibres an alternative replacement for synthetic fibres received numerous attentions as reinforcement for numerous polymers for advanced applications as reported by ((Kiruthika, 2017), (Ahmad et al. 2015), and (Saba et al. 2016)). To mitigate environmental pollution and encourage its protection, natural fibres renewable resources absorb carbon dioxide and possessing unique features, such as: low cost, abundant availability. Natural fibres have never generated any harmful gases when processed and are not abrasive to the processing equipment. Due to inherited hydrophilic and high flammability characters natural fibres successes in polymer reinforcements are limited. High moisture absorption, poor matrix-fibre interfacial adhesion and poor fibre dispersion are the results of natural fibre hydrophilicity character. Numerous researches had been conducted on the surface modifications of natural fibres to mitigate against these limitations as reported by ((Kiruthika, 2017), (Ahmad et al. 2015), (Gurunathan et al. 2015), and (Pickering et al. 2016)). Tremendous improvements on overall properties of the resulting composite materials due to natural fibre surface modifications had also been made reported in their studies by ((Kiruthika, 2017), (Ahmad et al. 2015), (Gurunathan et al. 2015), and (Pickering et al. 2016)). In order to improve the flame resistance of natural fibre, different flame-retardants have been added and/or used to modify its surfaces as recently reviewed in (Saba et al. 2016). Due to the superior properties of synthetic/artificial fibres when compared to natural fibres counterparts, deserve, however, special interest. As numerous conditions affects natural fibres properties such as growth condition, harvesting methods, and maturity. The limitations of synthetic fibres are environmental accumulation and/or landfill sites, high cost and their derivation from finite resources, viz. fossil fuels as reported by (Kiruthika, 2017). As unwanted and unwarranted environmental pollutions are as a result of gases generated (e.g. CO2, methane, nitrous oxide and many others) from fossil fuels processing. More so, harmful gases which cause dreadful diseases are liberated during composite productions that are abrasive to the processing equipments. For high-end applications, synthetic fibres have prolonged lifespan, which offers more advantage than natural fibres reported by ((Kiruthika, 2017), (Ahmad et al. 2015), (Saba et al. 2016), (Gurunathan et al. 2015), and (Pickering et al. 2016)). Synthetic fibres with special functionalities requisite for intended applications can be produced even though they have high strengths. For instance, carbon fibres render high electrical conductivity; high thermal conductivity and they have less or no moisture absorption, high strength and thermal stability. For high-end applications, such as: large-scale energy storage, wind turbines and aerospace these properties proved the produced composite material an opportunity. The shortcomings of the synthetic fibres can be solved by adding Fillers/fibres are added to synthetic fibres in-order to address its shortcomings, which are significantly cheaper, without compromising their valuable properties.

In the recent past years, the quest to embed two or more filler materials into matrix base has been ever increasing. The number of published works that are hybrid composites related has been steadily increasing. The increase resulted from one objective, i.e. to have improved properties and enhanced performances of such composite in order to achieve desired properties. The main aim was to mitigate the limitations of single filler reinforced polymer matrix with other filler(s) that have similar or even better properties when compared to the initial single filler. This new concept is known as 'hybridization', in which two or more fillers can be incorporated into a common polymer matrix to mitigate the limitations of the first filler. Again, this concept also applies to the blending of two or more polymers and reinforced with one filler or more fillers and again, by adding the same filler type that has two or more sizes or dimensions, i.e. auto-hybridization. Hybridization processes cross over numerous and tremendous research areas, such as: mechanics, chemistry, engineering, physics, science and technology, polymer science, electrochemistry, metallurgy and metallurgy engineering and energy fuels. Irrespective of the research area, the main objective was to come up with the combination of three or more materials that have better performances and properties when compared to their counterpart material for an intended application. The aim of two or more fillers added into a polymer matrix and/or polymer blend is to ensure that they can learn from each other and match in coordination, so that they have an excellent performance and lower overall cost as reported by (Okoronkwo et al. 2022).

The sequence and fibre orientation of hybridized composites were found to play a major role on the resulting properties reported by (Ezeokpube et al. 2019). The main objective of their research works was to come up with an optimal combination of fillers and/or blends hybridized composites towards intended application. The interfacial adhesion between the matrix and fillers of the conventional single fibre reinforced composite materials was found to play a significant role on the composite properties as reviewed from (Okoronkwo et al. 2019). To improve the interfacial adhesion of the fibres and matrices, different treatment chemicals were investigated. Some of the prerequisites of the hybridized composite materials include: low cost and a balance of the weight-to-performance ratio reported by (Okoronkwo et al. 2016). Depending on the intended application, the term 'hybrid effect' was adopted to define the results obtained during the investigation. Basically, the hybridized composite is compared with the conventional composite product viz. single fibre reinforced composite and the results can either be negative or positive 'hybrid effect'. The positive hybrid effect can be defined as better performance obtained from hybridized composite material as compared to the single reinforced composite material, while the opposite prevails for negative hybrid effect as report by (Madu et al. 2018). Researchers' attention has been drawn to replacing a number of percentages of classic fibres used for intended application with other fillers, which are lighter, easily accessible, and cheaper. Natural fibres has shown some of these properties such as low density, cheaper and availability then more research works has been dedicated in employing them to replacing some percentage of classic synthetic fibres as seen from the research by (Onukwuli et al.2015).

As reported by (Saba et al. 2016), the combination of two or more fillers into a common matrix is known as hybrid composite. These matrix may be ceramic, steel or polymer. A blend of two or more polymers reinforced with one or more fillers is called hybrid in the case of polymeric materials seen in the works of (Madu et al. 2020). Auto-hybrid is commonly employed in the case of the same type of filler having different size/dimensions. In order to broaden the applicability of the composite materials, hybridization gives a new opportunity especially in advanced applications. The principal parameters, with significant effects on the properties of the hybrid composite product are. First are the materials employed (matrix and filler) depending mostly on the intended applications. For instance, it was observed that jute/glass hybrid showed higher reinforcement under compressive load than bamboo/glass composites, while the opposite was the case under tensile load seen from the works of (Samanta et al. 2015). It was observed that each application requires certain properties in order to achieve the desired goal. For example, (Onukwuli et al. 2016) employed analytical hierarchy process to obtain the desired natural fibres from thirteen candidates in an attempt to hybridize (individually) with glass fibre in order to produce automotive brake lever. They observed that kenaf fibres produced the top score when compared to others. The second factor involves the preparation method, which often relies on the filler and the matrix under research. Certain specifications have to be met, e.g., conditions (viz. Out-doors or indoors) in which that product must be used during the design of a new product. This can be achieved by conducting researches in comparison with commercially available product in the market and formulated according to their specifications. A balance between the Sustainability and performance balance of the product to accommodate the consumer as well as the environment must also to be considered. Other factors that must be taken into consideration e.g., whether the product will be used in open environment or indoors/under, protection storage needs to be considered as explained earlier. These aspects, viz.: weight, mechanical strength, density, recyclability, disposability, water absorption, raw material cost, manufacturing costs, compatibility with current recycling system in place and test methods (depending on the intended application) must have to be taken into account in order to produce the final product. The third most important parameter is the interaction between the fillers and the matrix. In order to enhance the interfacial adhesion between these components, which in most instances, will result in the improvement of the overall properties of the hybrid composites natural fibres must be treated by a coupling agent. Reported by (Rodriguez-Castellanos et al. 2016), the desired properties can be predicted by the rule of mixture model, assuming that there is no chemical/physical interaction between the fillers.

Strength properties of hybrid polymer composites depend on numerous factors. These factors include: the dispersion and distribution of the chosen polymer matrix reinforcements, polymer and reinforcements interfacial adhesion, large surface area, high reinforcements aspect ratio, reinforcements strength properties, effect of loading, surface modification, natural fibres dimension and orientation conducted and reported by (Okoronkwo et al. 2022). As observed in numerous studies, strength properties are usually reported as a function of loading, size and fibre treatment ((Bisaria et al. 2015), (Gupta et al. 2015), (Kureemun et al. 2018), (Okoronkwo et al. 2019), and (Ramana et al. 2017)). Tremendous researches have been observed on the development of hybrid polymer composites from thermo-sets and thermoplastic by employing synthetic and natural fibres as well as the combination of fibres with nano-materials, their strength and thermo-mechanical properties elucidated by ((Akil et al. 2014), (Kureemun et al. 2018), (Ramana et al. 2017), and (Safri et al. 2017)). Due to the advantages of one type can complement the disadvantage of another and thus, improve the properties and performance of the resultant composite material is the reason of using more than one type of reinforcement. The demand for the development of hybrid composite materials is increasing as they meet the requirements of many products, e.g., door panels and car interior in transport vehicle reported by (Kureemun et al. 2018). The prediction of the strength behaviour of hybrid composite materials depends on material parameters, e.g., the reinforcements (fibres or particles) strength properties, matrix strength properties, distribution and dispersion of reinforcements, volume fractions of the reinforcements and test conditions as conducted by (Ezeokupbe et al. 2018). Rule of mixture (ROM) is, often applied to predict the strength behaviours of hybrid composite materials. There are numerous models reported in the literature, based on ROM for the prediction of the strength properties of hybrid composite materials. These theoretical models include Voigt, Reuss, Hirsch and Tsai–Pagano investigated and reported by (Essabir et al. 2016). For composite materials hybridization modulus prediction by ROM, P as property of the components of the hybrid composites is replaced by E, which stands for modulus of each component. (Yusoff et al. 2016) reported that the modulus of a single type polymer reinforced with reinforcement (fibres or particles) can be evaluated. The volume fractions of the reinforcement (fibres in most cases) and polymer matrix can also be determined. (Madu et al. 2018) evaluated the Young's modulus (Ehc) of hybrid composites being the sum of two materials (polymer composite reinforced with fibre 1 and polymer composite reinforced with fibre 2). However, in the case of (Yusoff et al. 2016), (Kureemun et al. 2018), (Ezeokpube et al. 2021) and (Essabir et al. 2016) the Young's modulus of the hybrid composites were evaluated. Before using these models, it is important to assume that there is no interaction between the fibres in the hybrid, the fibres are well aligned, dispersed and distributed throughout polymer matrix with good interfacial adhesion between the fibres and the matrix and that the load applied is parallel to the fibres direction. It was observed, in most studies that the predicted elastic moduli were in agreement with experimental data as seen in (Kureemun et al. 2018), (Yusoff et al. 2016), and (Ezeokpube et al. 2021). For example, (Madu et al. 2018) reported that the incorporation of sisal fibres in a hybrid composite reinforced with banana fibres resulted in an increase in tensile strength and modulus up to the 50:50 ratio for materials tested in the longitudinal and transverse directions. As also observed, that further increase in sisal fibre loadings decreased the tensile strength and modulus of hybrid composite materials. It was also observed that the evaluated tensile modulus, by using ROM, followed similar trend as experimental results. As stated earlier, ROM predicts the elastic modulus of continuous well-aligned fibres hybrid composites. Nevertheless, this model does not predict the elastic modulus of hybrid composite reinforced with discontinuous fibres and small particles. (Essabir et al. 2016) applied Tsai-Pagano model to predict the elastic modulus of poly-propylene hybrid composites reinforced with core fibres and core shell particles. Observed from ROM, Tsai-Pagano theory assumes that there is a good dispersion, distribution and alignment of fibres, interfacial adhesion between reinforcements and polymer matrix. The author (Essabir et al. 2016), reported that the best fit was obtained when a force of 5000 MPa for the core shell particles was employed. It was also observed that the predicted elastic modulus was comparable with the experimental elastic modulus. For the case of the tensile strength (σ) of the hybrid composite prediction, it was by the application of an equilibrium force (Fhc) on the hybrid composite cross-sectional area (A) seen in (Kureemun et al. 2018). Similarly to tensile modulus, the predicted tensile strength by ROM was in agreement with experimental tensile strength from ((Kureemun et al. 2018), and (Yusoff et al. 2016)). For instance, (Yusoff et al. 2016) developed a PLA hybrid by the incorporation of two and three fibre systems. They observed that the experimental tensile strength of the hybrid composites, reinforced with bamboo and coir fibres. Matched perfectly well with the predicted tensile strength by ROM, whereas kenaf, coir fibre reinforced hybrid composites and kenaf, bamboo and coir fibre reinforced hybrid composites, were slightly different, by 9 to 15 % higher, respectively than those predicted by using ROM. (Naito and Oguma, 2017) predicted the tensile strength of the hybrid composites reinforced with natural fibres. The authors reported that the estimated tensile strength was in agreement with the experimental strength data. The prediction models of strength properties provide numerous advantages e.g., reduction of cost and time consuming minimization for the design of the new product for certain application as these models can be employed to predict the resulting strength properties of the hybrid composite which are closely comparable to the experimental results. It is noteworthy to mention that some models which account for other variables which affect the strength properties of the resulting composite materials can be modified for hybrid composite as reported in ((Battegazzore et al. 2016), (Ezeokpube et al. 2021), and (Madu et al. 2019)). For examples, Pukanszky's model, which is often applied for quasi-spherical filler, could be used to describe the effects of filler volume fraction, and interface interactions on the strength properties.

For automotive industrial body parts, domestic furniture, food packaging, agricultural, biomedical building and residential applications, polymer composites reinforced with natural fibres have shown a great potential as seen from (Okoronkwo et al. 2016). To form a hybrid composite, natural fibres can be mixed with other natural fibres before incorporating into polymer matrix. This improves the performances and properties of the resultant polymer composite material while balancing the natural fibres cost reported by (Edhirej et al. 2017). (Edhirej et al. 2017) reported that at high strain the optimum tensile strength of a natural-natural fibre reinforced hybrid can be obtained. As suitable alternatives to synthetic fibres, like carbon and glass fibres, researchers are currently focusing on natural-natural fibres reinforced hybrid composites. Numerous researchers have studied the strength properties of natural-natural fibres reinforced hybrid composites like ((Maslinda et al. 2017), (Fragassa et al. 2018), (Das, 2017), ((Akash et al. 2018), and (Naidu et al. 2018)). Amongst these researchers, (Das, 2017) developed polyester hybrid composites reinforced with woven jute fabric and waste paper and studied their strength properties with the strength properties of the individual composites. He observed that from the results, polyester composites-reinforced with woven jute fabric showed high tensile and flexural properties, followed by hybrids and then polyester composites reinforced with waste paper (i.e. polyester composites-reinforced with woven jute fabric > hybrids > polyester composites reinforced with waste paper, in terms of their tensile and flexural properties). As a result of the waste paper consisting of short fibres, tensile and flexural properties of the hybrid composites were observed to decrease which contributed to the decrease in tensile properties of the materials. He also observed that these results were in agreement with the inter-laminar shear strength (ILSS) properties. Similarly, the tensile and flexural properties results reported by (Fragassa et al. 2018), followed a similar behaviour presented in the observations reported by (Das, 2017). For (Fragassa et al. 2018) data, vinyl-ester composites reinforced with basalt fibre showed high tensile and flexural properties; basalt-flax fibres reinforced vinyl-ester hybrid followed and then vinyl-ester composites reinforced with flax fibres. Conversely, vinyl-ester composites reinforced with flax fibres had higher energy absorbed, followed by the hybrid and then vinyl-ester composites reinforced with basalt fibre. (Maslinda et al. 2017) reported contrary findings. In their study, they reported that kenaf-jute fibres and kenaf-hemp fibres reinforced hybrids showed high flexural and tensile properties when compared to the individual composites at dry and saturated states. Recent investigations on the strength properties (viz. tensile, compressive, hardness and impact strength) of woven banana fibre and groundnut shell ash reinforced epoxy hybrid composite was reported in (Naidu et al. 2018). They observed that hybrid composite composed of 82 % epoxy, 1.5 % banana fibre and 3 % groundnut shell ash exhibited good strength properties when compared to other composites with the exception impact strengths. A tensile strength of 12.02 MPa, hardness of 37.3, impact strength of 0.340 J/mm2 and compressive strength of 24.4 MPa were observed, whereas composite composed of 85 % epoxy and 15 % banana exhibited tensile strength of 10.21 MPa, hardness of 35.6, impact strength of 0.252 J/mm2 and compressive strength of 20.7 MPa, respectively. An optimum impact strength (0.65 J/mm2) was obtained for hybrid composite composed of 77.5 % epoxy, 15 % banana and 7.5 % groundnut shell ash. Recently, the development of biodegradable hybrids after the end of their service lives has been a research hotspot. A biodegradable hybrid must consist of biodegradable polymer matrix and natural fibres. For example, (Sarasini et al. 2017) developed biodegradable poly-caprolactone (PCL)-based hybrid reinforced with ramie and borassus fibres. They observed that the inclusion of ramie fibres in PCL matrix resulted in increases tensile strength and modulus. Further increases in the tensile strength and modulus of the developed biodegradable hybrid composite were observed when the content of ramie fibres was increased. They also observed that the addition of borassus fibres in the system did not improve the tensile strength and modulus, irrespective of its fibre content. In addition, the addition of the fibres did not also improve the hardness of the hybrid to a great extent. (Jumaidin et al. 2017) and (Edhirej et al. 2017) developed hybrid composites by utilizing starch matrix reinforced with seaweed and sugar palm fibres (SPF), cassava and SPF, respectively. For (Jumaidin et al. 2017) work, the results demonstrated that hybrid exhibited higher tensile and flexural strength when compared to the individual composites. They observed an increase of SPF content from 25 to 50 % led to improvements in the tensile and flexural strengths. They also obtained optimum tensile (17.74 MPa) and flexural strength (31.24 MPa) for hybrid composite with 50:50 ratio of seaweed/SPF due to good compatibility amongst seaweed, SPF and the matrix. Contrally, the impact strength decreased with increase in SPF content by 1.2, 8.4 and 7.3 % for 75:25, 50:50 and 25:75 ratio of seaweed/SPF. Due to increased rigidity of the hybrid composite material reinforced SPF. Additionally, the hybridization of seaweed and SPF, led to slower biodegradation activities.

In the present study, unsaturated polyester polymer was used as binder in the production of hybrid ramie-isora fibres polyester polymer composite. The strength properties and material characteristics of hybrid ramie-isora fibres polyester polymer composite containing various hybrid ramie-isora fibre NaOH treatment concentrations and hybrid ramie-isora fibre NaOH treatment durations were conducted.

The aim of this study was to study application of ANN and RSM on strength properties of alkali mercerized hybrid ramie -isora fibre reinforced biodegradable polymer composites were carried out.

The novelty of this research cuts across the introduction of a new hybrid plant fibres and a new hybrid natural fibres biodegradable polymer composite material with a new locally sourced hybrid plant stem fibres possessing dual functions (i.e., functions as both hybrid reinforcement/hybrid filler materials for the bio-medicals, composite industries and fabrics for the textile industries) to structural and material engineers and the general public as a whole. Thereby reducing the undesirable costs and fatigues associated with the quest for a hybrid reinforcement/hybrid doping/hybrid filler material that must increases the strength properties of the hybrid ramie-isora fibre biodegradable polyester polymer composite (RIHFBPPC) under investigation. By this research also the indigenous people of Nekede in Imo State, Nigeria, from where the hybrid reinforcements were sourced from and the world as well will be exposed to a new hybrid and advanced but highly economical engineered hybrid natural fibre reinforced biodegradable polyester polymer composite (i.e., RIHFBPPC). That will provide jobs to them, revenue to both Imo State and Nigerian governments, entire Nigerian populace in general and the world at large.

The structure of this paper is as follows: in section II, the raw materials are presented. Next, mixture design and preparation of samples followed by response surface methodology, artificial neural network, experimental design, statistical analysis and mathematical model development to ascertain the needed regression models with number of hybrid ramie-isora fibre biodegradable polyester polymer composite samples with respect to estimated responses and independent variables, their trainings and analysis of variance. Then, experimental methods to determine young's modulus, yield strengths and ultimate strengths. In section III, presentations of the results obtained are provided. Next, regression models employed to train and model the experimental results obtained were presented as experimentally validated. While discussions of the results obtained are provided in section IV. An artificial neural network model and response methodology model of the hybrid ramie-isora fibre biodegradable polyester polymer composite proposed and established in the previous sections were employed and results presented in section III were discussed. The training plots, Outputs vs. targets, optimum conditions, surface plots and response functions obtained from the proposed models are compared and, subsequently, experimentally validated. Section IV contains the final conclusions that summarize the most important achievements of this article.

II. MATERIALS AND METHODS

A. MATERIALS

These were as depicted below:

Ramie and isora fibres with different lengths were obtained from ramie and isora stems extracted from the ramie and isora plants obtained from local forest in Nekede, Owerri, Imo State, Ngeria. Catalyst, hardener and unsaturated polyester resin with density 1.40 g/cc, were supplied by Nycil Company Limited, Nigeria.

In the current research ramie and isora fibres were the reinforcements, unsaturated polyester resin the matrix material, cobalt nephthanate the curing agent and the catalyst was methyl ethyl ketone peroxide. Unsaturated polyester resins are always unsaturated synthetic polymers produced when polyhydric alcohols comes in contact with dibasic organic acids. The most common employed raw material is maleic anhydride possessing di-acid functional group. Unsaturated polyester the outcome of condensation polymers produced when polyhydric alcohols, reacts with organic compounds with multiple hydroxyl functional groups producing saturated or unsaturated dibasic acids. The properties of ramie, isora and unsaturated polyester resin are depicted in Tables 1 and 2, respectively.

Table 1: Physical and strength properties of hybrid reinforcements

Fibre 1	Diameter (μm)	Density (g/cc)	Tensile modulus (GPa)	Tensile strength (MPa)	Elongation at yield (%)
Ramie	100.00-300.00	1.20	5.00	175.00	15.00
Fibre 2	Diameter (μm)	Density (g/cm^2)	Tensile strength (MPa)	Micro-fibrillar angle(degrees)	Cellulose/Lignin contents (%)
Isora	10.00-20.00	1.35	500.00-600.00	2.00-25.00	75.00/23.00

Table 2: Physical and strength properties of unsaturated polyester resin

Matrix	Melt flow index (g/10 min)	Density (g/cc)	Tensile modulus (GPa)	Tensile strength (MPa)	Elongation at yield (%)
UPR	11.00	1.40	1.47	36.00	10.00

(a)

(b)

(c)

Fig. 1: Images of the (a) Ramie and isora fibres samples for hybrid polyester composite materials; (b) unsaturated polyester resin; (c) Initiator/Accelerator and Catalyst;

B. Response Surface Methodology, Artificial Neural Network, Experimental Design, Statistical Analytic Techniques and Mathematical Model Development.

Response surface methodology (RSM) and artificial neural network (ANN) two of the most accepted optimization techniques for optimizing, training and fitting the variable conditions before and after the production of the hybrid fibre unsaturated polyester polymer composites. The experimental design was conducted by the use of MATLAB R2007b (Math Works, Inc.). By the application of central composite design (CCD), two independent variables were considered in three steps: conducting the test designed properly, predicting the mathematical model coefficients, and examining the model validation. Below is the depicted mathematical model:

$$Y = f(X_1, X_2, X_3, \ldots\ldots X_n) + \varepsilon \tag{2.1}$$

where Y represents responses, X represents dependent variables, n represent variables number under investigation, while error is donated by ε. A second order can depict the effect of parameters in linear, quadratic, and cross product terms. The variables used were hybrid fibre NaOH treatment concentrations (x_1) and hybrid fibre NaOH treatment durations (x_2). Certain numbers of tests are required to be conducted according to CCD: $2n$ axial experiments, 2^n at the centre, and n_c replicates in centre point. The response functions measured were young's modulus, yield strengths and ultimate strengths. An n^{th}-order polynomial model can study the influence of parameters under linear, quadratic, and cross product conditions, being the function of variable x, was plotted for each variable as shown below (Madu et al. 2018):

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i<j}^{n} \sum_{j}^{n} \beta_{ij} x_i x_j + \varepsilon \tag{2.2}$$

where Y is the estimated responses; β_0, a_i, β_{ii}, β_{ij} and ε are constants (β_0 is constant term, β_i are the constant coefficients of linear terms, β_{ii} are the constant coefficients of quadratic terms, while β_{ij} is the constant coefficients of interactive terms) and ε is the constant error components; and x_1, and x_2 are the coded values of the regressor variables representing hybrid fibre NaOH treatment concentrations and hybrid fibre NaOH treatment durations, respectively. In each factor was the variance divided into say linear, quadratic, and interaction terms. The suitability of the n^{th}-order polynomial model and the significance of these variables were determined with lack-of-fit and error components.

The effects of the considerable parameters on the process were determined by ANOVA. To check further for parameters significance P and F values were used. As a lower P value affects the process enormously the P (probability) value comes in when data samples were subjected to null hypothesis. On the opposite, null hypothesis are rejected by data samples with large F values but samples with higher F values are expected to be significant.

Levels of process variables were obtained with CCD model. Two-process variable 2^2 CCD model was developed as seen earlier (Madu et al. 2018). This model contained 9 sets of experiments as seen in equation (2.3)

$$N = 2^n + 2n + n_c = 2^2 + 2 * 2 + 1 = 9 \tag{2.3}$$

C. METHODS

This section covers methods of research.

a. Experimental production of hybrid ramie-isora-biodegradable-polyester composite materials

The composites were reinforced with hybrid ramie-isora fibres reinforcement in UPR matrix material. The uniformly agitated hybrid fibres with unsaturated polyester resin were emptied in the mould and placed in compression moulding machine. Manufacturing of samples were performed by utilizing manually operated and temperature regulated compression moulding machine. The knotted hybrid fibres were obtained from ramie and isora plants and were cleaned up. These hybrid fibres were passed through a Knot Separating Machine to evacuate the bunch and to separate individual hybrid fibres. The hybrid fibres acquired from bunch isolating machine wre dried in daylight for a time period of 48 hrs to remove the moisture. Hybrid fibres were cut to different lengths (10 mm – 50 mm) with 0.6 mm diameter to be utilized for randomly oriented hybrid fibre mats. In this process, the spacers were utilized for casting composite boards of size 300 mm x 300 mm x 4 mm thicknesses. These were placed on the base plate and a thick mylar (a non sticky) sheet is placed in between spacers and base plate for the easy removal of composite samples after curing (Madu et al. 2018).

Polymer (unsaturated polyester), catalyst (methyl ethyl ketone peroxide) and hardener (cobalt naphthanate) were mixed in a proportion of 50:1:1 i.e., 1000 ml: 20 ml: 20 ml in ratio and stirred to uniform compositions. Different lengths of hybrid ramie and isora fibres of different required hybrid fibre NaOH treatment durations (i.e., 3 Hrs, 6 Hrs and 9 Hrs for 5 %; 3 Hrs, 6 Hrs and 9 Hrs for 10 %; 3 Hrs, 6 Hrs and 9 Hrs for 15 %, respectively) were weighed and distributed uniformly at the bottom of the mould inside the spacers. Compression load was then applied for 15 minutes on mould containing the hybrid fibres. Resin was then applied uniformly on hybrid fibres. Another releasing mylar sheet is spread over at the top surface with a steel plate and then the sample was compressed for one hour for uniform distribution of matrix and elimination of entrapped air bubble if any. Here the temperatures of both base plates were maintained at ambient conditions. The composite samples were cut from the casted composite panels. The tensile tests of every sample in the current study was determined according to ASTM D638 for tensile test on which young's modulus, yield strengths and ultimate strengths tests standards were performed. The sizes of testing samples were considered as 100 mm x 20 mm x 't', where 't' is the thickness of samples kept constant at 3.2 mm, with Table 3 indicating the hybrid proportion of the ramie and isora reinforcements of the polyester composite materials.

Table 3. Hybrid Proportion of the ramie and isora reinforcements

Sample No	NaOH Treatment Duration (Hrs)	NaOH Concentration (%)	Hybrid Fiber Proportion
1	3	5	3 Ramie – 1 Isora
2	3	10	2 Ramie – 2 Isora
3	3	15	1 Ramie – 3 Isora
4	6	5	3 Ramie – 1 Isora
5	6	10	2 Ramie – 2 Isora
6	6	15	1 Ramie – 3 Isora
7	9	5	3 Ramie – 1 Isora
8	9	10	2 Ramie – 2 Isora
9	9	15	1 Ramie – 3 Isora

b. Casted ramie-isora-biodegradable-polyester composite strength properties characterization

This section covers the sub-topics as follows.

a. Tensile test

Tensile tests were performed on casted samples according to ASTM test standard according to D 638-76 with the help of Instron machine. The samples specifications as per standard and actual samples configurations were followed. The ultimate strength was determined as the quotient of the maximum tensile force with the cross-sectional area of the sample according to the equation (2.4) (Okoronkwo et al. 2016):

$$R_t = \frac{F_{tmax}}{A} \quad (2.4)$$

where: R_t – Ultimate strength [N/mm^2], F_{tmax} – maximal tensile force [N], A – the sample's cross-sectional area [mm^2].

Fig.2: Hybrid fibre biodegradable composite sample subjected to tensile test

III. RESULTS AND DISCUSSIONS

This section presents the results and discussion.

Table 4. Strength properties table for hybrid ramie-isora biodegradable polyester composite mixtures

Hybrid ramie-isora polyester composite strength properties	Run number	Residuals	Studentized residuals	Predicted values (MPa)	Actual values (MPa)	Percentage increase (%)
Young's modulus	1	0.0000	0.0000	0.00	155.65	0.00
	2	-0.772	-0.6525	257.02	256.25	64.63
	3	0.0761	0.1637	263.77	263.85	69.52
	4	0.2011	0.2902	282.16	282.36	81.41
	5	0.0178	0.0251	253.90	253.92	63.14
	6	0.6711	1.2792	257.86	258.53	66.09
	7	-0.6889	-1.3429	279.93	279.24	79.40
	8	0.2594	0.6027	246.58	246.84	58.59
	9	0.6128	3.4697	249.97	250.58	60.99
	10	-0.8722	-25174	270.28	269.41	73.09
Yield strength	1	0.0000	0.0000	0.00	1.20	0.00
	2	-0.1244	-1.2982	1.71	1.59	32.50
	3	0.2422	1.6713	1.41	1.65	37.50
	4	-0.1178	-1.2286	2.49	2.37	97.50
	5	0.0956	0.6593	1.61	1.71	42.50
	6	-0.1778	-1.2267	2.07	1.89	57.50
	7	0.0822	0.5673	1.84	1.92	60.00
	8	-0.0644	-0.4447	1.38	1.32	10.00
	9	0.0356	0.3709	1.74	1.78	48.33
	10	0.0289	0.3014	1.81	1.84	53.33
Ultimate strength	1	0.0000	0.0000	0.00	2.36	0.00
	2	0.0733	-1.2982	3.49	3.56	50.85
	3	-0.1200	1.6713	4.10	3.98	68.64
	4	0.0408	-1.2286	4.52	4.56	93.22
	5	0.0792	-1.2267	3.28	3.36	42.37
	6	-0.0033	0.5673	3.77	3.77	59.75
	7	-0.0700	0.6593	4.50	4.43	87.71
	8	-0.1142	0.3709	3.39	3.28	38.98
	9	-0.0758	0.3014	3.53	3.45	46.19
	10	0.1900	-0.4447	4.43	4.62	53.39

Table 5: Analysis of variance table for hybrid ramie-isora biodegradable polyester composite strength properties

Hybrid ramie-isora polyester composite strength properties	Source	Sum Sq.	d. f.	Mean Sq.	F	Prob>F
Young's modulus	X1 X2 Error Total	222.61 1011.13 5.98 1239.72	2 2 4 8	11.306 505.567 1.494	74.49 338.35	0.0007 0
Yield strength	X1 X2 Error Total	0.08816 0.35509 0.20938 0.65262	2 2 4 8	0.04408 0.17754 0.05234	0.84 3.39	0.4952 0.1376
Ultimate strength	X1 X2 Error Total	0.998 2.04847 0.10313 2.2514	2 2 4 8	0.0499 1.02423 0.02578	1.94 39.72	0.2583 0.0023

Table 6. Response Surface Model based on hybrid ramie-isora biodegradable polyester composite strength properties

Hybrid ramie-isora polyester composite strength properties	VARIABLES	Coefficients	Std. Error	t-stat	P-value	F-stat
Young's modulus	Constant X1 X2 X1 * X2 X1.^2 X2.^2	202.2000 0.5083 16.6890 0.0643 -0.2609 -0.8803 R^2 = 0.9982	3.5253 0.8744 0.5246 0.0289 0.0681 0.0245 Adj. R^2= 0.9952	57.3560 0.5814 31.8110 2.2276 -3.8332 -35.9240 mse = 0.7506	1.1675e-005 0.6018 6.8265e-005 0.1123 0.0313 4.7436e-005	sse = 2.2519 dfe = 3 dfr = 5 ssr = 1237.5 f = 329.71 pval = 0.00026243
Yield strength	Constant X1 X2 X1 * X2 X1.^2 X2.^2	0.1211 0.1583 0.3420 -0.0087 -0.0091 -0.0155 R^2 = 0.7828	0.8846 0.2194 0.1316 0.0073 0.0171 0.0062 Adj. R^2= 0.4207	0.1369 0.7217 2.5980 -1.1960 -0.5313 -2.5154 mse = 0.0473	0.8998 0.5227 0.0805 0.3176 0.6321 0.0865	sse = 0.14178 dfe = 3 dfr = 5 ssr = 0.51084 f = 2.1619 pval = 0.27926
Ultimate strength	Constant X1 X2 X1 * X2 X1.^2 X2.^2	1.6733 -0.1567 0.7177 0.0042 0.0061 -0.0388 R^2 = 0.9611	0.6949 0.1724 0.1034 0.0057 0.0134 0.0048 Adj. R^2= 0.8964	2.4079 -0.9089 6.9394 0.7319 0.4554 -8.032 mse = 0.0292	0.0952 0.4304 0.0061 0.5172 0.6798 0.0040	sse = 0.087508 dfe = 3 dfr = 5 ssr = 2.1639 f = 14.837 pval = 0.025114

a. Hybrid ramie-isora fibre biodegradable polyester composite young's modulus

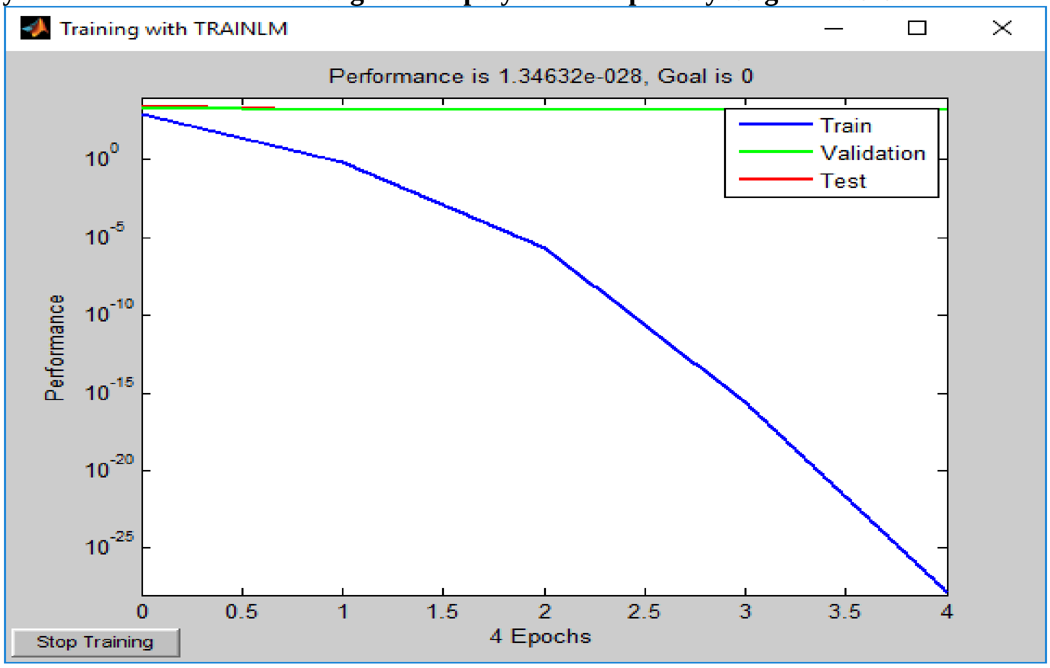

Fig. 3: Training plot of hybrid ramie-isora biodegradable composite young's modulus

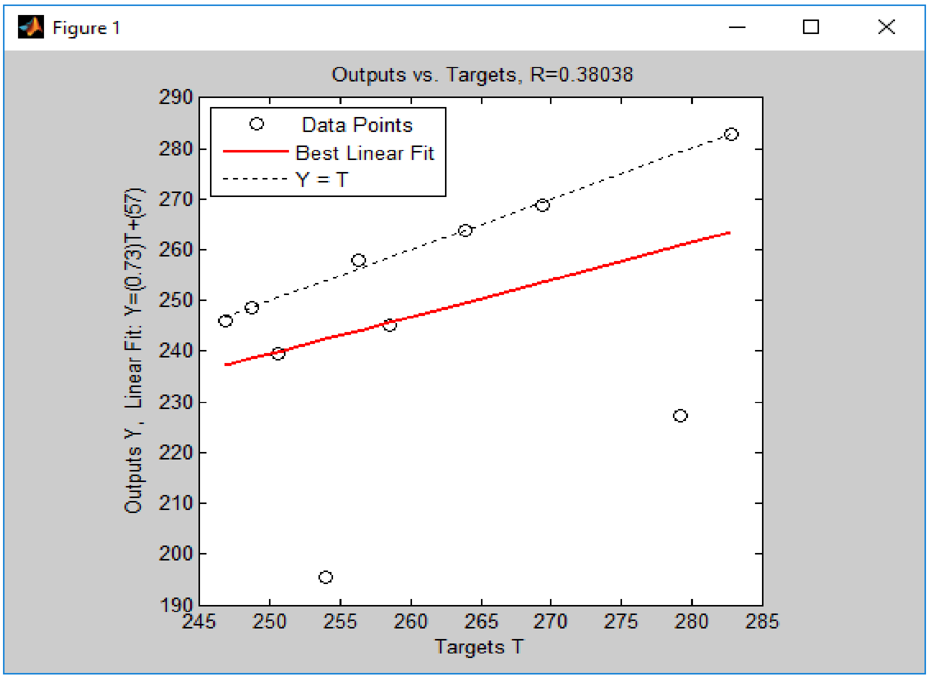

Fig. 4: Outputs vs. targets plot of hybrid ramie-isora biodegradable composite young's modulus

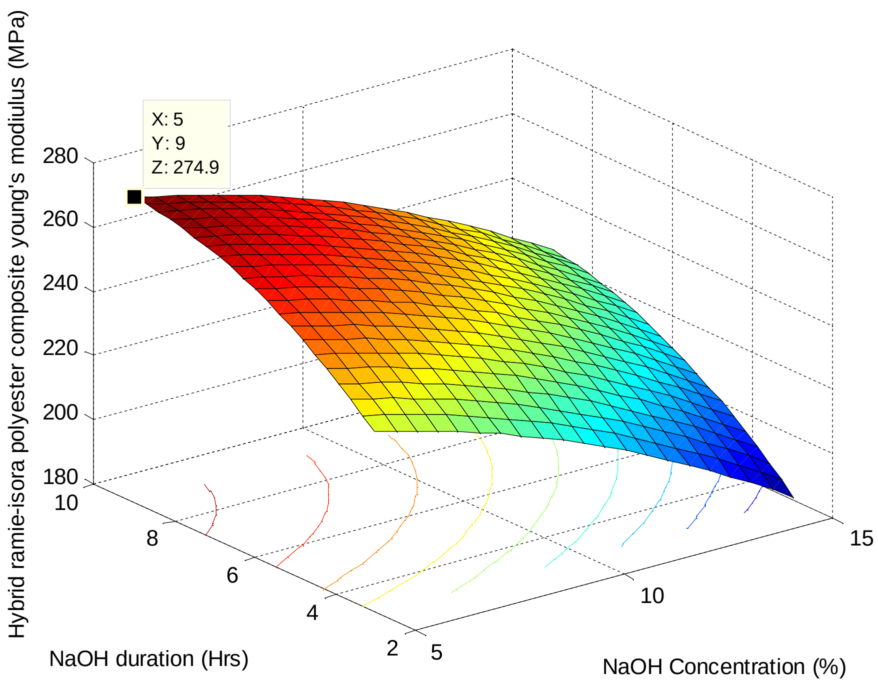

Fig. 5: Surface plot of hybrid ramie-isora biodegradable composite young's modulus

b. Optimization of hybrid ramie-isora biodegradable composite young's modulus

Optimization terminated: first-order optimality measure less than options. TolFun and maximum constraint violation is less than options. TolCon.
Active inequalities (to within options. TolCon = 1e-006):

```
 lower     upper    ineqlin   ineqnonlin
     1           2
x =     5     9
fval = -274.9244
```


c. **Hybrid ramie-isora fibre biodegradable polyester composite yield strength**

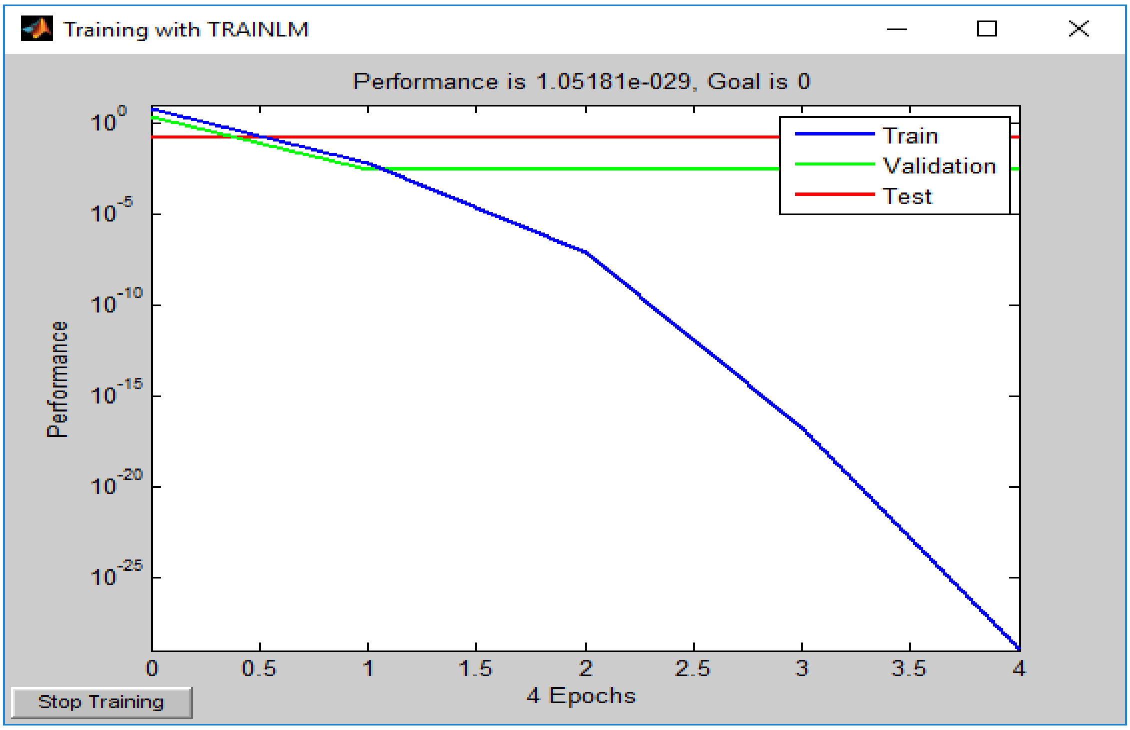

Fig. 6: Training plot of hybrid ramie-isora biodegradable composite yield strength

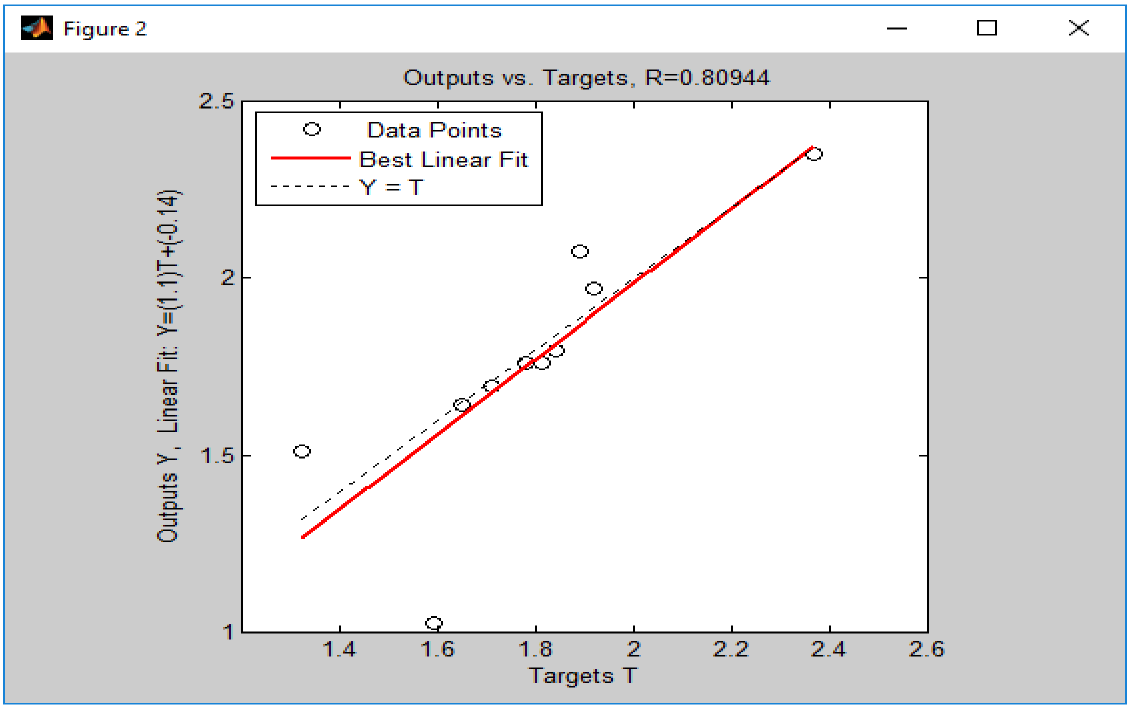

Fig. 7: Outputs vs. targets plot of hybrid ramie-isora biodegradable composite yield strength

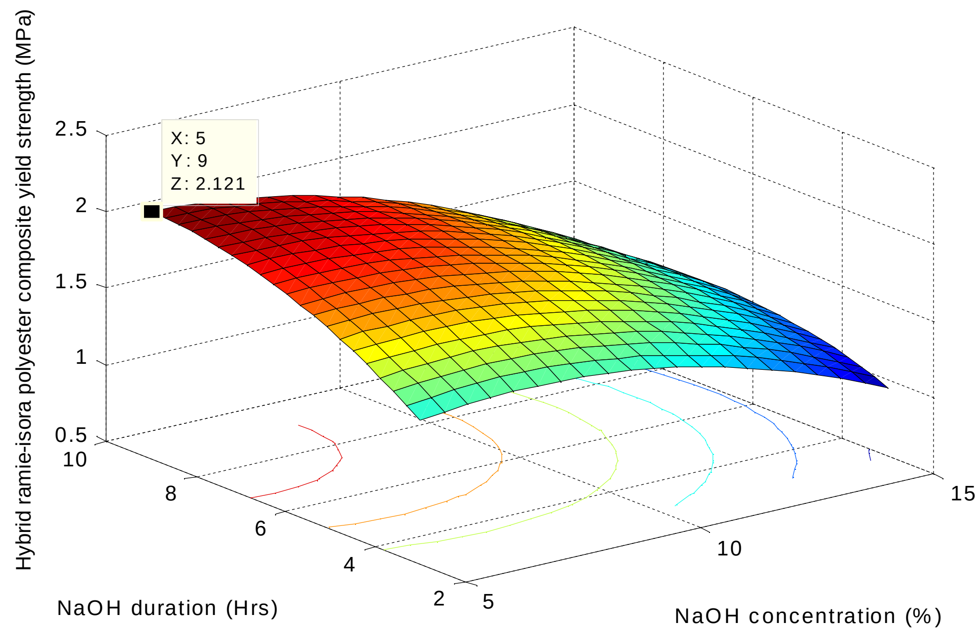

Fig. 8: Surface plot of hybrid ramie-isora biodegradable composite yield strength

d. Optimization of hybrid ramie-isora biodegradable composite yield strength

Optimization terminated: first-order optimality measure less than options. TolFun and maximum constraint violation is less than options. TolCon.

Active inequalities (to within options. TolCon = 1e-006):

lower	upper	ineqlin	ineqnonlin
1	2		

x = 5 9

fval = -2.1211

e. Hybrid ramie-isora fibre biodegradable polyester composite ultimate strength

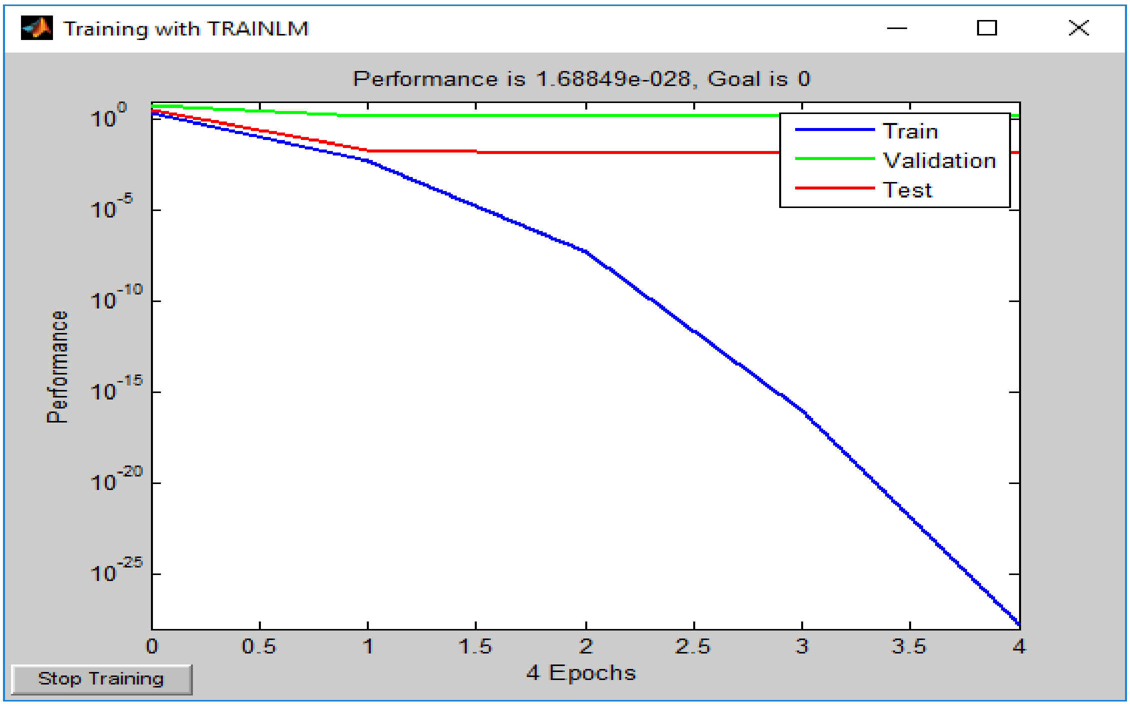

Fig. 9: Training plot of hybrid ramie-isora biodegradable composite ultimate strength

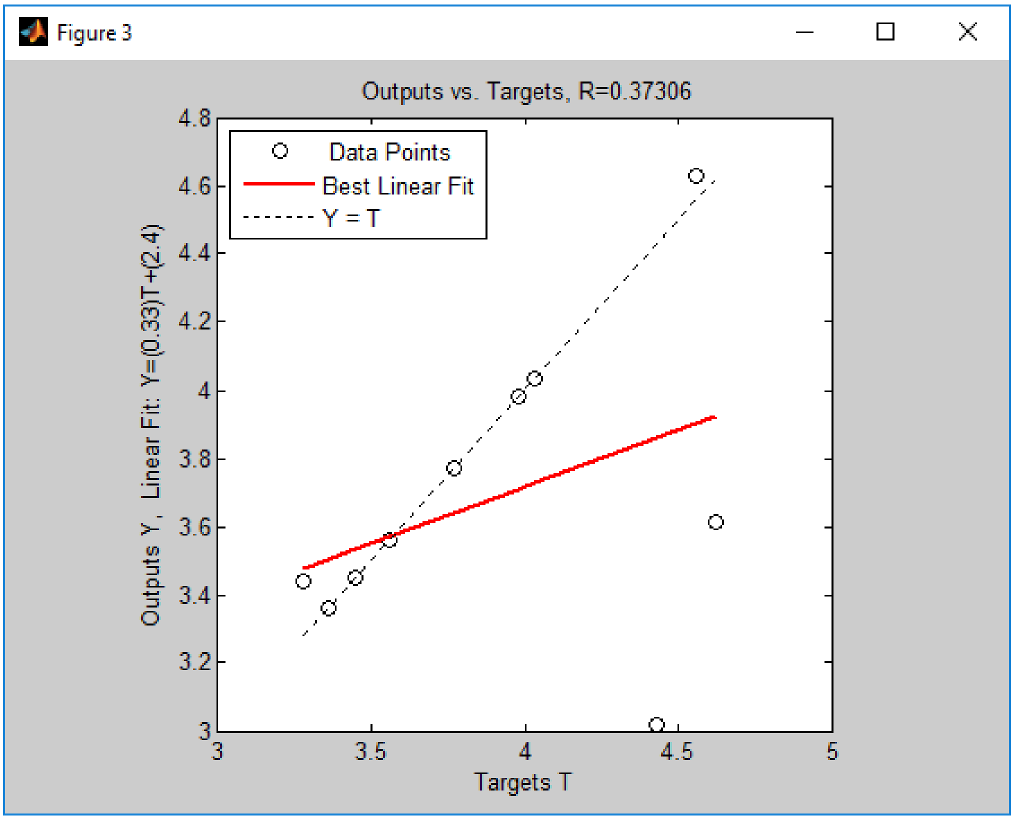

Fig. 10: Outputs vs. targets plot of hybrid ramie-isora biodegradable composite ultimate strength

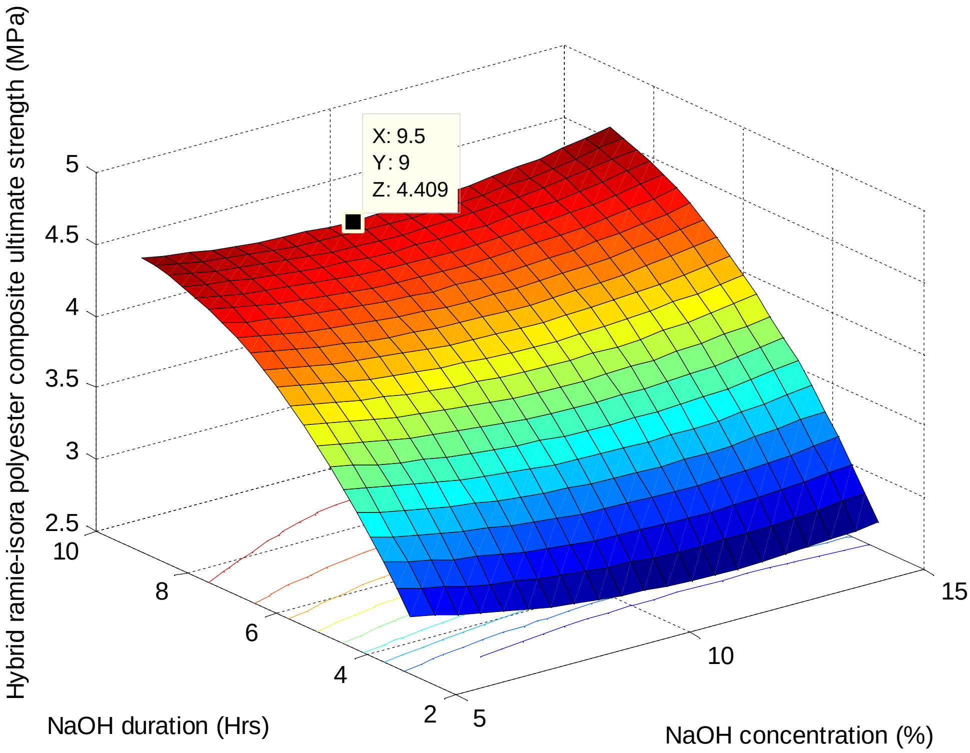

Fig. 11: Surface plot of hybrid ramie-isora biodegradable composite ultimate strength

f. Optimization of hybrid ramie-isora biodegradable composite ultimate strength

Optimization terminated: magnitude of directional derivative in search direction less than 2*options.TolFun and maximum constraint violation is less than options. TolCon.
Active inequalities (to within options. TolCon = 1e-006):
lower upper ineqlin ineqnonlin
2
x = 9.7499 9.0000
fval = -4.4086

g. Regression models

Linear regression analyses in the form of models depicted in table 7 were employed to train and model the experimental results obtained.

Table 7: Individual hybrid ramie-isora biodegradable polyester composite strength properties linear regression analysis objective functions

Hybrid ramie-isora polyester composite strength properties	Regression models	R^2 %
Young's modulus, ANN	$Y = (0.73)\,T + (57)$	38.04
Yield strength, ANN	$Y = (1.1)\,T + (-\ 0.14)$	80.94
Ultimate strength, ANN	$Y = (0.33)T + (2.4)$	37.31
Young's modulus, RSM	$Y = 202.20 + 0.51 * (x_1) + 16.69 * (x_2) + 0.06 * (x_1x_2) - 0.26 * (x_1^2) - 0.88 * (x_2^2)$	99.82
Yield strength, RSM	$Y = 0.12 + 0.16 * (x_1) + 0.34 * (x_2) - 0.009 * (x_1x_2) - 0.009 * (x_1^2) - 0.02 * (x_2^2)$	78.28
Ultimate strength, RSM	$Y = 1.67 - 0.16 * (x_1) + 0.72 * (x_2) + 0.004 * (x_1x_2) + 0.006 * (x_1^2) - 0.04 * (x_2^2)$	96.11

where Y is predicted young's modulus, predicted yield strength and predicted ultimate strength.

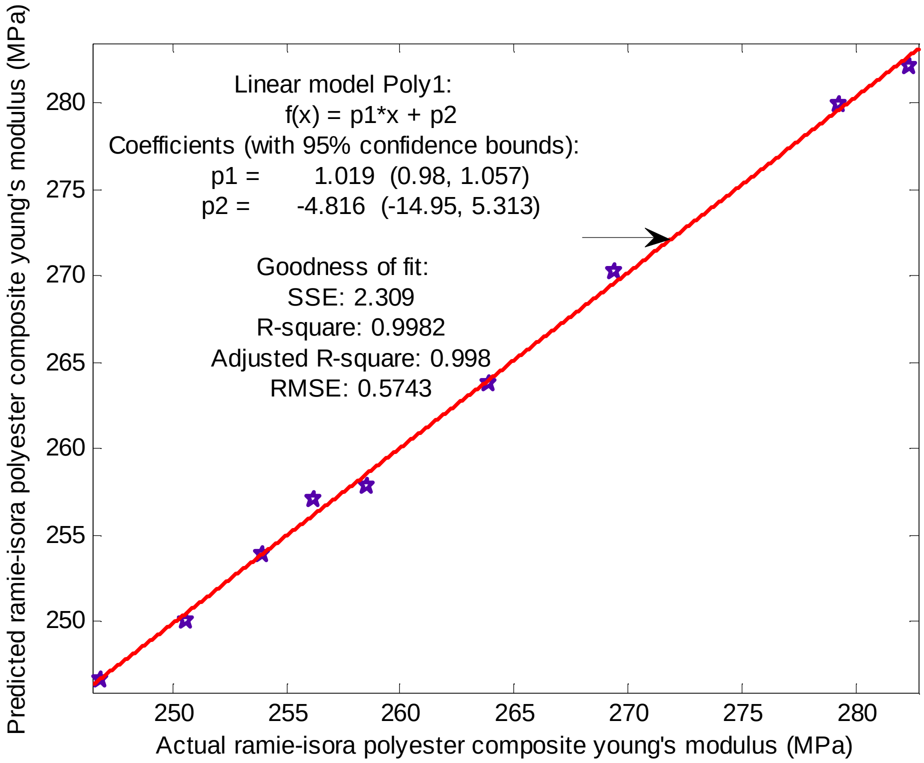

Fig. 12: Fit for predicted vs. actual responses of biodegradable composite young's modulus

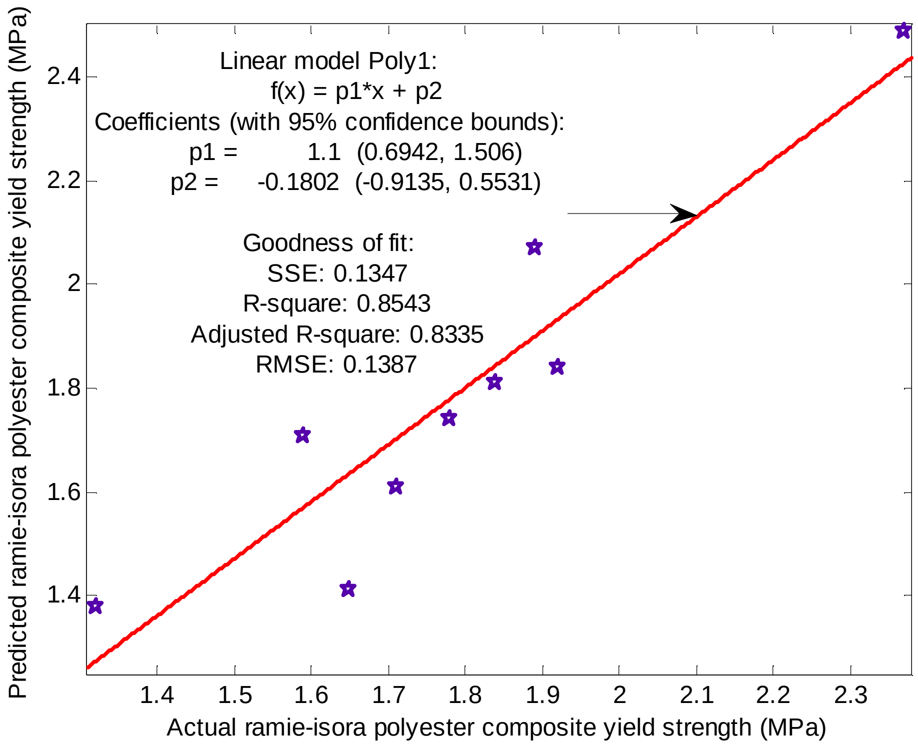

Fig. 13: Fit for predicted vs. actual responses of biodegradable composite yield strength

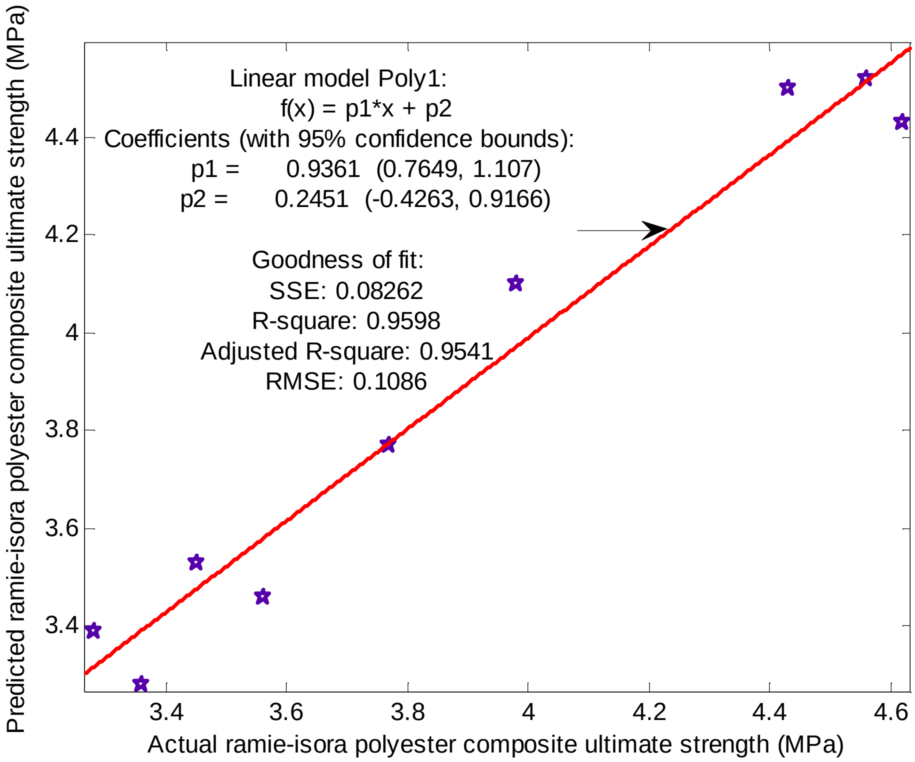

Fig. 14: Fit for predicted vs. actual responses of biodegradable composite ultimate strength

B. DISCUSSIONS

a. Fibre NaOH treatment concentration for the hybrid biodegradable composite strength models

As observed from Table 6, the linear co-efficient of fibre sodium hydroxide treatment concentrations for those of young's modulus model, yield strength model, ultimate strength model were not significant at 95 % significant confidence intervals but were significant below 95 % significant confidence intervals. As their individual magnitudes are not two and above weather negative or positive but are blow two and above weather negative or positive at 95 % significant confidence intervals. Their individual probability values $(pval)$ shows that they are not also significant at 95 % confidence intervals because $pval > 0.05$.

Also observed from Table 6, the quadratic co-efficient of fibre sodium hydroxide treatment concentrations for those of young's modulus model, yield strength model and ultimate strength model are not significant at 95 % confidence intervals but are significant below 95 % significant confidence intervals. As their individual magnitudes were not two and above weather negative or positive at 95 % significant confidence intervals but are blow two and above weather negative or positive at 95 % significant confidence intervals. Their individual probability values $(pval)$ shows that young's modulus model, yield strength model and ultimate strength model are also not significant at 95 % intervals because $pval > 0.05$.

b. Fibre NaOH treatment duration for the hybrid biodegradable composite strength models

As observed from Table 6, the linear co-efficient of fibre sodium hydroxide treatment durations for those of young's modulus model and ultimate strength model are significant at 95 % confidence intervals with exception of yield strength model which is slightly significant at 95 % significant intervals. As their individual magnitudes were two and above weather negative or positive at 95 % confidence intervals. Their individual probability values $(pval)$ shows that young's modulus model and ultimate strength model are also significant at 95 % intervals because $pval \leq 0.05$. Again with exception of yield strength model which is slightly significant at 95 % significant confidence intervals with it's $pval$ sligthly greater than 0.05.

Also observed from Table 6, the quadratic co-efficient of fibre sodium hydroxide treatment durations for those of young's modulus model and ultimate strength model are significant at 95 % confidence intervals with exception of yield strength model which is slightly significant at 95 % significant intervals. As their individual magnitudes were two and above weather negative or positive at 95 % confidence intervals. Their individual probability values ($pval$) shows that young's modulus model and ultimate strength model are also significant at 95 % intervals because $pval \leq 0.05$. Again with exception of yield strength model which is slightly significant at 95 % significant confidence intervals with it's $pval$ sligthly greater than 0.05.

c. Young's modulus for the ramie-isora hybrid biodegradable composite strength models

As can be seen in Fig.3, the training of the hybrid ramie-isora polyester composite young's modulus ANN model was completed at 4 epochs with 1.34632e-028 performance giving goal is 0 as desired for the validation of its tested values. Hybrid ramie-isora polyester composite young's modulus ANN model output-target fit with the model of the form $y = aT + b$ has 38.04 % accuracy as observed from Figure 4 compared to RSM model possessing 99.82 % accuracy also seen in Table 3. Hence, RSM model computational techniques present a better study and results judging from the accuracy of the models.

It was observed from Table 4 that the control composite mixture and composite reinforced with hybrid ramie-isora fibres with various NaOH treatment concentrations and NaOH treatment durations were depicted by the strength study in it. The control polyester composite material young's modulus is 155.65 MPa. The hybrid ramie-isora fibre NaOH treatment concentrations of 5 %, 10 % and 15 % possess young's modulus of 256.25 MPa, 253.92 MPa and 269.41 MPa, respectively. Also depicted were the different mixture values of the hybrid ramie-isora composite samples. Young's modulus improved by 63.14 to 81.41 % as observed in Table 4 for hybrid ramie-isora fibre reinforced with polyester polymer.

It was observed from Table 6 that the constant term, the linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations, the interaction of both linear co-efficient of both hybrid ramie-isora fibre sodium hydroxide treatment concentrations and durations, and square of linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations all contributed to the changes at 95 % significant confidence intervals in hybrid ramie-isora polyester composite young's modulus from the composite strength models. The accuracy of the model is 99.82 % at 95 % significant confidence interval with 274.9 MPa optimum hybrid ramie-isora composite young's modulus, 5 % optimum hybrid ramie-isora fibre NaOH treatment concentrations and 9 Hrs optimum ramie-isora fibre NaOH treatment durations as were observed from Figure 5 validated with those of the optimized parameters. Hence, the model was adequate at 95 % significant confidence bounds for both hybrid ramie-isora fibre NaOH treatment concentrations and durations. Judging from probability values of ANOVA and F-stat in Tables 2 and 3 which were able to explain 99.82 % varabilities in its modelled variables with the reduced form as: $y = \beta_0 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_1^2 + \beta_5 x_2^2$.

It was observed from optimization of hybrid ramie-isora fibre reinforced polyester polymer composite young's modulus at 95 % significant confidence interval. That optimum hybrid fibre polyester polymer composite young's modulus was 274.92 MPa (i.e., fval is the optimum response variable in this case hybrid fibre polyester polymer composite young's modulus), optimum hybrid fibre NaOH treatment concentrations as 5 % and optimum ramie-isora fibre NaOH treatment durations was also 9 Hrs (i.e., x is the optimum regressor variables, here were hybrid ramie-isora fibre NaOH treatment concentrations and durations).

As can be seen also from the output diagnostic messages, the feasibility of the solutions measured were active absolute measures judging from constraint tolerance (TolCon) which is an upper bound for the constraint violation compared to the relative max (maximum constraint violation). Then, it depicted that x0 satisfies the constraints.

d. Yield strength for the ramie-isora hybrid biodegradable composite strength models

As can be seen in Fig. 6, the training of the hybrid ramie-isora polyester composite yield strength ANN model was completed at 4 epochs with 1.05181e-029 performance giving goal is 0 as desired for the validation of its tested values. Hybrid ramie-isora polyester composite young's modulus ANN model output-target fit with the model of the form $y = aT + b$ has 80.94 % accuracy as observed from Fig.7 compared to RSM model possessing 78.28 % accuracy also seen in Table 6. Hence, ANN model computational techniques present a better study and results judging from the accuracy of the models.

It was observed from Table 4 also that the yield strength of all studied composite sample mixtures was represented. Its control polyester composite material yield strength is 1.20 MPa. Hybrid ramie-isora fibre NaOH treatment of 5 %, 10 % and to 15 % possess yield strength of 1.59 MPa, 1.71 MPa and 1.84 MPa, respectively. Table 6 also depicts the percentage increase in yield strength values of ramie-isora fibre reinforced polyester composite with various NaOH treatment concentrations and there NaOH treatment durations. It is seen that yield strength of 10 to 97.50 % enhancements were obtained with ramie-isora fibre reinforced polyester polymer composite. To utilize 15 % ramie-isora fibre NaOH treatment concentrations seems to be promising as observed from Table 4.

It was observed from Table 6 that the linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations and square of linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations all contributed to the changes at 95 % significant intervals in composite yield strength from the composite strength models. The accuracy of the model is 78.28 % at 95 % significant confidence interval with 2.121 MPa optimum hybrid fibre composite yield strength, 5 % optimum hybrid fibre NaOH treatment concentrations and 9 Hrs optimum hybrid fibre NaOH treatment duration as were observed from Figure 8 validated with those of the optimized parameters. Hence, the model was not adequate at 95 % significant confidence bounds for both hybrid fibre NaOH treatment concentrations and NaOH treatment durations. Judging from probability values of ANOVA and F-stat in Tables 5 and 6 which were able to explain 78.28 % varabilities in its modelled variables with the reduced form as: $y = \beta_2 x_2 + \beta_5 x_2^2$.

It was observed from optimization of ramie-isora fibre reinforced polyester polymer yield strength at 95 % significant confidence interval. That optimum polyester polymer hybrid fibre composite yield strength was 2.121 MPa (i.e., fval is the optimum response variable in this case polyester polymer hybrid fibre composite yield strength), optimum hybrid fibre NaOH treatment concentrations as 5 % and optimum hybrid fibre NaOH treatment durations was also 9 Hrs (i.e., x is the optimum regressor variables, here were hybrid fibre NaOH treatment concentrations and NaOH treatment durations).

As can be seen also from the output diagnostic messages, the feasibility of the solutions measured were active absolute measures judging from constraint tolerance (TolCon = 1e-006) which is an upper bound for the constraint violation compared to the relative max (maximum constraint violation). Then, it depicted that x0 satisfies the constraints.

e Ultimate strength for the ramie-isora hybrid biodegradable composite strength models

As can be seen in Fig.9, the training of the hybrid ramie-isora polyester composite ultimate strength ANN model was completed at 4 epochs with 1.68849e-028 performance giving goal is 0 as desired for the validation of its tested values. Hybrid ramie-isora polyester composite young's modulus ANN model output-target fit with the model of the form $y = aT + b$ has 37.31 % accuracy as observed from Figure 10 compared to RSM model possessing 99.82 % accuracy also seen in Table 6. Hence, RSM model computational techniques present a better study and results judging from the accuracy of the models.

Ultimate strengths under current study were shown in Table 4 also. It is observed that its control composite ultimate strength is 2.36 MPa. Hybrid ramie-isora fibre with NaOH treatment of 5 %, 10 % and to 15 % possess ultimate strength of 3.56 MPa, 3.36 MPa and 4.62 MPa, respectively. Hybrid ramie-isora fibre addition increased ultimate strength by 38.98 to 93.22 % as seen in Table 4.

It was observed from Table 6 that the constant term, the linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations and square of linear co-efficient of hybrid ramie-isora fibre sodium hydroxide treatment durations all contributed to the changes at 95 % significant intervals in composite yield strength from the composite strength models. The accuracy of the model is 96.11 % at 95 % significant confidence interval with 94.409 MPa optimum hybrid fibre composite ultimate strength, 9.5 % optimum hybrid fibre NaOH treatment concentrations and 9 Hrs optimum hybrid fibre NaOH treatment duration as were observed from Fig.11 validated with those of the optimized parameters.. Hence, the model was adequate at 95 % significant confidence bounds for hybrid fibre NaOH treatment durations but was adequate below 95 % significant confidence bounds for hybrid fibre NaOH treatment concentrations. Judging from probability values of

ANOVA and F-stat in Tables 5 and 6 which were able to explain 96.11 % varabilities in its modelled variables with the reduced form as: $y = \beta_0 + \beta_2 x_2 + \beta_5 x_2^2$.

It was observed from optimization of hybrid ramie-isora fibre reinforced polyester polymer ultimate strength at 95 % significant confidence interval. That optimum polyester polymer hybrid fibre composite ultimate strength was 4.4086 MPa (i.e., fval is the optimum response variable in this case polyester polymer hybrid fibre composite ultimate strength), optimum hybrid fibre NaOH treatment concentrations 9.7499 % and optimum hybrid fibre NaOH treatment durations was also 9 Hrs (i.e., x is the optimum regressor variables, here were hybrid fibre NaOH treatment concentrations and NaOH treatment durations).

As can be seen also from the output diagnostic messages, the feasibility of the solutions measured were active absolute measures judging from constraint tolerance (TolCon) which is an upper bound for the constraint violation compared to the relative max (maximum constraint violation). Then, it depicted that x0 satisfies the constraints.

f. Regression model for the biodegradable composite strength models

Good associations between calculated/ experimental and predicted hybrid fibre polyester composite strength parameters were obtained as can be seen from Figs. 12, 13, and 14.

III. CONCLUSIONS

As can be seen in Figs. 3, 6 and 9 the training of the hybrid ramie-isora polyester composite young's modulus, yield strength and ultimate strength ANN models are completed at 4 epochs with 1.34632e-028, 1.05181e-029 and 1.68849e-028 performances giving goals are 0 as desired for the validation of its tested values. Hybrid ramie-isora polyester composite young's modulus, yield strength and ultimate strength ANN models output-target fits with the models of the form $y = aT + b$ have 38.04 %, 80.94 % and 37.31 % accuracies as observed from Figs. 4, 7 and 10 compared to RSM model possessing 99.82 %, 78.28 % and 99.82 % accuracies also seen in Tables 6,. Hence, RSM model computational techniques present a better study and results for young's modulus and ultimate strength judging from the accuracies of the models. While ANN model computational techniques present a better study and results for yield strength only judging from the accuracies of the models also.

It was observed from Table 4 that the control composite mixture and composite reinforced with hybrid ramie-isora fibre with various NaOH treatment concentrations and NaOH treatment durations depicted the strength study in it. The control polyester composite material young's modulus 155.65 MPa. The hybrid ramie-isora fibre NaOH treatment concentrations of 5 %, 10 % and 15 % possess young's modulus of 256.25 MPa, 253.92 MPa and 269.41 MPa, respectively. Also depicted were the different mixture values of the composite samples. Young's modulus improved by 63.14 to 81.41 % as observed in Table 4 for hybrid ramie-isora fibre reinforced with polyester polymer. Its control polyester composite material yield strength is 1.20 MPa. Hybrid ramie-isora fibre NaOH treatment of 5 %, 10 % and to 15 % possess yield strength of 1.59 MPa, 1.71 MPa and 1.84 MPa, respectively.

Table 6 also depicts the percentage increase in yield strength values of ramie-isora fibre reinforced polyester composite with various NaOH treatment concentrations and there NaOH treatment durations. It is seen that yield strength of 10 to 97.50 % enhancements were obtained with ramie-isora fibre reinforced polyester polymer composite. To utilize 15 % ramie-isora fibre NaOH treatment concentrations seems to be promising as observed from Table 4.

It is observed that its control composite ultimate strength is 2.36 MPa. Hybrid ramie-isora fibre with NaOH treatment of 5 %, 10 % and to 15 % possess ultimate strength of 3.56 MPa, 3.36 MPa and 4.62 MPa, respectively. Hybrid ramie-isora fibre addition increased ultimate strength by 38.98 to 93.22 % as seen in Table 4.

Also, from strength properties models it is found that the hybrid ramie-isora fibre polyester polymer composites has optimum yield strength of 2.121 MPa below 95 % adequacies with 5 % optimum hybrid ramie-isora fibre NaOH treatment concentrations and 9 Hrs optimum hybrid ramie-isora fibre NaOH treatment durations at

99.82 % accuracy all at 0.7506 mean square error. Then, 274.9 MPa and 94.409 MPa, optimum hybrid ramie-isora fibre polyester composite young's modulus and ultimate strength at 95 % adequacies with 5 % optimum hybrid ramie-isora fibre NaOH treatment concentrations, 9 Hrs and 9.5 Hrs optimum hybrid ramie-isora fibre NaOH treatment durations at 78.28 % and 96.11 % accuracies all at 0.0473 and 0.0292 mean square errors.

Development and analyzing of properties are done for the composite materials of hybrid ramie-isora fibre according to the need of the industries. The analysis concludes that at 9 hours durations of treatment or slightly above it say 9.5 hours with 5 % concentration of sodium hydroxide shows a better strength properties of the composites based on RSM model but with a slight difference in ANN model which implies that choosing this type of hybridization for any practical application of the composites is a better option to have high efficiency.

Conflict of interest
The authors declare that there is no conflicting interest in the publication of this paper.

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