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Influence of fibre loading and surface treatment on the impact strength of coir polyester composites

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ABSTRACT

Purpose: In this work, coir fibre with varying fibre content was selected as reinforcements to prepare polymer-based matrices and the problem of reduced fibre-matrix interfacial bond strength has been diluted by chemical treatment of coir fibres with alkali solution.

Design/methodology/approach: The effect of fibre loading, solution concentration and soaking time on the impact strength of the composites were analyzed using statistical techniques. Response Surface Methodology (RSM) approach was used to model and optimize the impact properties of coir-polyester composites.

Findings: The impact strength of coir fibre reinforced polyester composite depends mainly on the fabrication parameters such as fibre-polyester content, soaking time, concentration of soaking agent and adhesive interaction between the fibre and reinforcement.

Research limitations/implications: The mechanical properties of any coir polyester composite depend on the nature bonding between the fibre and reinforcement. The presence of cellulose, lignin on the periphery of any natural fibre reduces the bonding strength of the composite. This limitation is overcome by fibre treatment over sodium hydroxide to have better impact properties.

Practical implications: Now days, natural fibre reinforced composites are capable of replacing automotive parts, subjected to static loads such as engine Guard, light doom, name plate, tool box and front panels etc. These materials can withstand any static load due to its higher strength to weight ratios.

Originality/value: The effect of fibre loading, solution concentration and soaking time on the impact strength of the composites were analyzed using statistical techniques. Response Surface Methodology (RSM) approach was used to model and optimize the impact properties of coir-polyester composites. The impact strength of NaOH impregnated coir fibre reinforced polyester composites was evaluated.

Keywords: Coir fibre, Polymer composites, Impact strength, Response surface methodology

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PROPERTIES

1. Introduction

To meet basic requirements, natural fibres have been traditionally in use across the world, in particular, the south asian region and in the Indian subcontinent, the avalibility of such resourses are enormous. It mainly constitutes fibres such as jute, coir, sisal, pineapple, ramie, bamboo, banana etc., has focused towards the development of natural fibre composites primarily to explore value-added application avenues [1-5]. These composite materials are best alternatives of steel and wood in housing and & construction sector. Coir composites are widely used in roofing where it would consume less cement and would be cheaper by more than 40% than asbestos. In addition to that, it have been in used for constructing walls and partitions, flooring with signigicantly meadium density. These green composites were widely acknowledged material in order to reduce the overall construction cost af any structures. Panels for windows, doors, furnitures and other house hold appliances have also been designed and modeled with this green bio-composites at low cost.

Added to coir composites, other natural fibres such as sisal, hemp, banana, jute are also used to make hybrid composites for improvement in strength to weight ration. However poor mechanical properties of natural fibre composites caused due to poor interfacial bonding between fibre and matrix restrict their use in engineering application [6-9]. In near recent times, natural fibre composites are binded with non bio degradable materials such as glass in order improve the bindibility and strength [10-12]. Aprat from adding non bio degradable materials, many scientific researchs are going on side by side to improve the bindability between fibres and matrix through alkali treatment [13,14]. This work in aimed at identifying the suitable treatment parameters and fibre loading condition for better impact properties of coir fibre reinforced polyester composites.

2. Experimental procedure

2.1. Materials

In the present study, the commercially available coir fibre was procured in dry condition and its subjected to surface treatment for removing the lignin content [15-17]. Surface modification was done by impregnating the coir fibre in sodium hydroxide for stupilated period of time [18-21]. The matrix material used in this investigation was commercially available unsaturated polyester resin. The hand lay-up process was followed for fabricating composites as per design matrix.

2.2. Fabrication and testing of composites

The raw coir fibres were soaked in a solution of sodium hydroxide of varying concentration and soaking time [22-25]. The fibres were then washed to neutral pH and dried at room temperature, 23 ± 2°C, and for 2-3 days. The coir composites were prepared as per 3 Level full factorial designs (Tab. 1) with the fabrication parameters namely; fibre content (10%, 25% and 40%), soaking time (24 hrs, 48 hrs and 72 hrs) and solution concentration (2%, 4% and 6%). After fabrication, the test specimens were subjected to Impact test as per ASTM D256 standard [26,27].

Table 1.
Design factorial levels

Parameters	Low	Intermediate	High
Fibre loading, %	10	25	40
Solution concentration, %	2	4	6
Soaking time, Hrs	24	48	72

2.3. Modelling and optimization using RSM

On successful fabrication of coir polyester composites, the impact strength of all the fabricated specimes were obtained [28,29]. The impact properties obtained through experimental investigation were used to formulate regression model. The regression model were done between the fabrication parameters and impact properties. An empirical model has been developed in this investigation between the output (impact strength) and independent variables (fibre content, soaking time and solution concentration) using Response surface methodology technique [30-32]. Design Expert V8, a statistical software is used here and the developed mathematical model using this software was justified with the help of three dimensional response surface plots and the value of coefficient of correleation. Thus the developed model was optimized in order to improve the impact strength of coir polyester composites.

3. Results and discussion

3.1. Effect of fibre loading and surface treatment on impact properties of composites

The chemical treatment using sodium hydroxide solution has removed the excess lignin content present over the fibre surface. The presence of a rougher fibre surface has promoted a mechanical interlock between the fibres and the resin matrix. The impact strength was found to be better with

the composite fabricated with 25% of fibre loading, the increase or decrease in fibre loading beyond this level resulted with poor impact properties.

The effect of fibre loading and surface treatment on impact properties of composites is shown in the Figure 1. The fibres soaked in 4% solution concentration for 48 hrs resulted in better impact strength. The increase in solution concentration beyond this level resulted in excess leaching of fibres which in turn diminished the mechanical properties of the fibre. Hence it can be stated that fibre treated with 4% solution concentration for 48 hrs can improve the adhesion between fibre surface and polyester matrix and fibre loading of 25% may yield better impact properties to the composites.

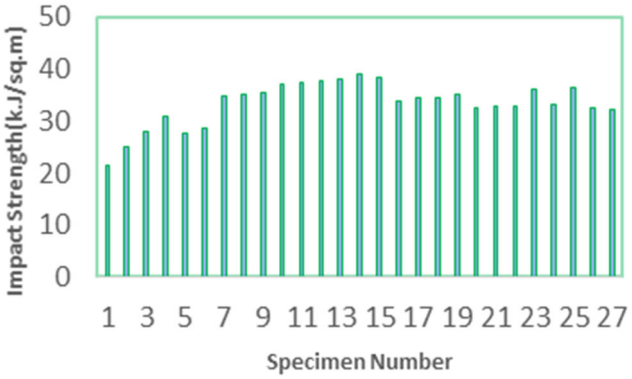

Fig. 1. Effect of fibre loading and surface treatment on impact properties of composites

3.2. Regression model

The regression model for impact strength of treated coir fibre reinforced polyester composites was developed using Response surface Methodology (RSM). The 3D response plot for the impact strength obtained from statistical tool is shown in the Figure 2a. The plot indicated the interaction effect of fibre loading vs solution concentration, solution concentration vs soaking time and soaking time vs fibre loading on the impact strength of the composites. The coefficient of correlation (R^2) obtained for impact strength of the composite was 0.82.The significance of the developed model using RSM is justified with the value of R^2. The nearer the valur of R^2 towards 1 here shows the significance of model [31].

The impact strength of the composites exhibited a quadratic behavior as shown below

$$i_s = -29.34923+3.89578f_1+2.88051f_2-0.20522f_3-0.22086f_1f_2+ +0.00001f_1f_3-0.031375f_2f_3-0.049832f_1^2+0.58489f_2^2+ +0.069222f_3^2 \quad (1)$$

a)

b)

c)

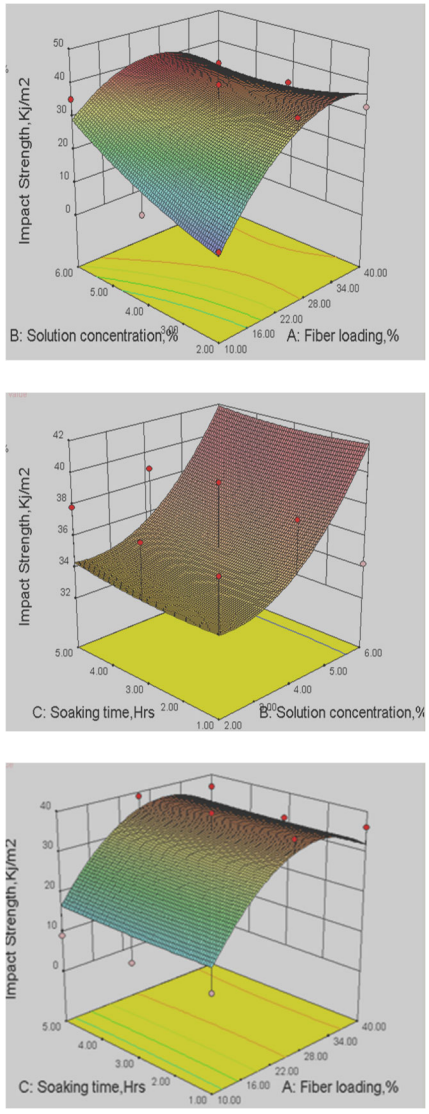

Fig. 2. Contour and 3D surface plot for the impact strength model

3.3. Optimization using RSM

Based on the mathematical equations formed by Response Surface methodology technique, the fibre parameters were optimized and the optimal parameters to maximize impact strength were obtained using Response Surface methodology (RSM). The maximum value of impact strength of 41.18 kJ/m² was predicted at the fibre loading of 28% and with the fibres treated in 5% concentration solution for 45 hrs. The experiment value was found to be very closer to the predicted (Tab. 2) which witnessed the effective prediction of PSO technique.

Table 2.
Confirmation Test on impact strength of the composites

Mechanical property	Impact strength
Fibre Loading, %	28
Solution Concentration, %	6
Soaking Time, Hrs	5
Experimental/Prediction Values, kJ/sq.m	42.15/41.18
% Error	2.35

4. Conclusions

The mechanical strength of treated coir fibre reinforced polyester composites was evaluated in this investigation as per ASTM D256, standard. The fabrication parameters namely fibre content, soaking time and solution concentration were found to play prominent role in the impact strength of the composites. The mathematical equation for predicting impact strength over the wide range of conditions was formulated and optimized using RSM technique. The prediction model was found to be significant and the optimum value was found to be very closer to the experimental value. This specific investigation has paid way for the possible development of engineering application-based coir reinforced polyester composite applications.

References

[1] R. Gallego, C.C. Piras, L.A.J. Rutgeerts, S. Fernandez-Prieto, W.M. De Borggraeve, J.M. Franco, J. Smets, Green approach for the activation and functionalization of jute fibers through ball milling, Cellulose 27/2 (2020) 643-656. DOI: https://doi.org/10.1007/s10570-019-02831-0

[2] J.-Z. Liang, Predictions of tensile strength of short inorganic fibre reinforced polymer composites, Polymer Testing 30/7 (2011) 749-752. DOI: https://doi.org/10.1016/j.polymertesting.2011.06.001

[3] D. Senthilnathan, A. Gnanavel Babu, G.B. Bhaskar, K.G.S. Gopinath, Characterization of glass fibre–coconut coir–human hair hybrid composites, International Journal of Engineering and Technology 6/1 (2014) 75-82.

[4] C. Jayasekara, N. Amarasinghe, Coir–Coconut Cultivation, Extraction and Processing of Coir, in: J. Müssig (ed.), Industrial Applications of Natural Fibres: Structure, Properties and Technical Applications, John Wiley & Sons, Ltd, 2010, 197-217. DOI: https://doi.org/10.1002/9780470660324.ch9

[5] S. Sathees Kumar, Dataset on mechanical properties of natural fiber reinforced polyester composites for engineering applications, Data in Brief 28 (2020) 105054. DOI: https://doi.org/10.1016/j.dib.2019.105054

[6] V.G. Geethamma, G. Kalaprasad, G. Groeninckx, S. Thomas, Dynamic mechanical behavior of short coir fiber reinforced natural rubber composites, Composites Part A: Applied Science and Manufacturing 36/11 (2005) 1499-1506. DOI: https://doi.org/10.1016/j.compositesa.2005.03.004

[7] G.L. Easwara Prasad, B.S. Keerthi Gowda, R. Velmurugan, A study on impact strength characteristics of coir polyester composites, Procedia Engineering 173 (2017) 771-777. DOI: https://doi.org/10.1016/j.proeng.2016.12.091

[8] K.G. Satyanarayana, C.K.S. Pillai, K. Sukumaran, S.G.K. Pillai, P.K. Rohatgi, K. Vijayan, Structure property studies of fibres from various parts of the coconut tree, Journal of Materials Science 17/8 (1982) 2453-2462. DOI: https://doi.org/10.1007/BF00543759

[9] D. Nagesh Kumar, M. Janga Reddy, Multipurpose reservoir operation using particle swarm optimization, Journal of Water Resources Planning and Management 133/3 (2007) 192-201. DOI: https://doi.org/10.1061/(ASCE)0733-9496(2007)133:3(192)

[10] G. Wróbel, S. Pawlak, Ultrasonic evaluation of the fibre content in glass/epoxy composites, Journal of Achievements in Materials and Manufacturing Engineering 18/1-2 (2006) 187-190.

[11] J. Stabik, A. Dybowska, M. Chomiak, Polymer composites filled with powders as polymer graded materials, Journal of Achievements in Materials and Manufacturing Engineering 43/1 (2010) 153-161.

[12] G. Wróbel, S. Pawlak, The effect of fiber content on the ultrasonic wave velocity in glass/polyester composites, Journal of Achievements in Materials and Manufacturing Engineering 20/1-2 (2007) 295-298.

[13] V. Calado, D.W. Barreto, J.R.M. d'Almeida, The effect of a chemical treatment on the structure and morphology of coir fibers, Journal of Materials Science Letters 19/23 (2000) 2151-2153. DOI: https://doi.org/10.1023/A:1026743314291

[14] N. Venkateshwaran, A. Elayaperumal, G.K. Sathiya, Prediction of tensile properties of hybrid-natural fiber composites, Composites Part B: Engineering 43/2 (2012) 793-796. DOI: https://doi.org/10.1016/j.compositesb.2011.08.023

[15] G. Dorez, L. Ferry, R. Sonnier, A. Taguet, J.M. Lopez-Cuesta, Effect of cellulose, hemicellulose and lignin contents on pyrolysis and combustion of natural fibers, Journal of Analytical and Applied Pyrolysis 107 (2014) 323-331. DOI: https://doi.org/10.1016/j.jaap.2014.03.017
[16] F. Serra-Parareda, Q. Tarrés, F.X. Espinach, F. Vilaseca, P. Mutjé, M. Delgado-Aguilar, Influence of lignin content on the intrinsic modulus of natural fibers and on the stiffness of composite materials, International Journal of Biological Macromolecules 155 (2020) 81-90. DOI: https://doi.org/10.1016/j.ijbiomac.2020.03.160
[17] A. Komuraiah, N.S. Kumar, B.D. Prasad, Chemical composition of natural fibers and its influence on their mechanical properties, Mechanics of Composite Materials 50/3 (2014) 359-376. DOI: https://doi.org/10.1007/s11029-014-9422-2
[18] S. Kalyana Sundaram, S. Jayabal, Mechanical properties of potassium hydroxide-pretreated Christmas palm fiber-reinforced polyester composites: characterization study, modeling and optimization, Journal of Polymer Engineering 34/9 (2014) 839-849. DOI: https://doi.org/10.1515/polyeng-2014-0084
[19] S. Kalia, B.S. Kaith, I. Kaur, Pretreatments of natural fibers and their application as reinforcing material in polymer composites – a review, Polymer Engineering and Science 49/7 (2009) 1253-1272. DOI: https://doi.org/10.1002/pen.21328
[20] A. Benyahia, A. Merrouche, M. Rokbi, Z. Kouadri, Study the effect of alkali treatment of natural fibers on the mechanical behavior of the composite unsaturated Polyester-fiber Alfa, Proceedings of the 21st Congres Mechanics French, Bordeaux, 2013, 1-6.
[21] T.H. Nam, S. Ogihara, N.H. Tung, S. Kobayashi, Effect of alkali treatment on interfacial and mechanical properties of coir fiber reinforced poly (butylene succinate) biodegradable composites, Composites Part B: Engineering 42/6 (2011) 1648-1656. DOI: https://doi.org/10.1016/j.compositesb.2011.04.001
[22] J. Myalski, J. Śleziona, Influence of preparing of GFR recyclates on the properties of polyester matrix compsites, Journal of Achievements in Materials and Manufacturing Engineering 18/1-2 (2006) 163-166.
[23] D. Priselac, T. Tomašegović, S. Mahović Poljaček, T. Cigula, M. Leskovac, Thermal, surface and mechanical properties of PCL/PLA composites with coconut fibres as an alternative material to photopolymer printing plates, Tehnički Glasnik 11/3 (2017) 111-116.
[24] S. Wu, Impact fracture mechanisms in polymer blends: Rubber-toughened nylon, Journal of Polymer Science: Polymer Physics Edition 21/5 (1983) 699-716. DOI: https://doi.org/10.1002/pol.1983.180210503
[25] N. Mohd Nurazzi, A. Khalina, M. Chandrasekar, H.A. Aisyah, S. Ayu Rafiqah, R.A. Ilyas, Z.M. Hanafee, Effect of fiber orientation and fiber loading on the mechanical and thermal properties of sugar palm yarn fiber reinforced unsaturated polyester resin composites, Polimers 65/2 (2020) 115-124. DOI: https://doi.org/10.14314/polimery.2020.2.5
[26] S. Jayabal, U. Natarajan, U. Sekar, Regression modeling and optimization of machinability behavior of glass-coir-polyester hybrid composite using factorial design methodology, The International Journal of Advanced Manufacturing Technology 55/1 (2011) 263-273. DOI: https://doi.org/10.1007/s00170-010-3030-7
[27] M.N. Obaid, S.H. Radhi, Enhancement of tribological properties and characteristic of polymer matrix composite (UHMWPE reinforced with short fibres of polyester) for Total Disc Replacement (TDR), Journal of Achievements in Materials and Manufacturing Engineering 102/2 (2020) 55-65. DOI: https://doi.org/10.5604/01.3001.0014.6775
[28] L.A. Dobrzański, B. Ziębowicz, M. Drak, Mechanical properties and the structure of magnetic composite materials, Journal of Achievements in Materials and Manufacturing Engineering 18/1-2 (2006) 79-82.
[29] L.A. Dobrzański, A. Tomiczek, B. Tomiczek, A. Sława-Waniewska, O. Iesenchuk, Polymer matrix composite materials reinforced by $Tb_{0.3}Dy_{0.7}Fe_{1.9}$ magnetostrictive particles, Journal of Achievements in Materials and Manufacturing Engineering 37/1 (2009) 16-23.
[30] K.R. Sumesh, K. Kanthavel, Optimizing various parameters influencing mechanical properties of banana/coir natural fiber composites using grey relational analysis and artificial neural network models, Journal of Industrial Textiles (2020) (onlineFirst). DOI: https://doi.org/10.1177/1528083720930304
[31] G.E. Box, N.R. Draper, Empirical model-building and response surfaces, Vol. 424, Wiley, New York, 1987.
[32] R.H. Myers, D.C. Montgomery, C. M. Anderson-Cook, Response surface methodology: process and product optimization using designed experiments, John Wiley & Sons, 2016.