Application of Optimization Techniques in the Fabrication of Coir Fibre Reinforced Composites: A Review

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***Abstract*— The growing demand for the materials accelerated the research in natural fibre reinforced composites. Coir fibre emerged as an important option due to its abundant availability, bio sustainability and mechanical properties. This review paper investigates about the improvement of manufacturing process of coir fiber reinforcement composites by using optimization techniques. It connects the gap between advanced manufacturing and material science. By carefully reviewing various optimization methodologies this paper explores how processing methods and the way fibers interact with the fiber matrix. Further this paper identifies important gaps in the research done so far. It suggests and highlights the new paths for future studies. The findings in this paper aim to study the unexplored arears.**

Keywords*— *Coir fibre, MCDM, Particle swarm, Soft Computing methods, Bio sustainable composites

I. Introduction

Composites play a major part in sectors like aerospace, construction, architecture because of their high specific mass, corrosion resistance and flexibility in design. But due to difficulty in disposal of the composites made from synthetic reinforcements modern researchers are concentrated on natural fiber reinforced composites (NFRC) made from various natural resources. Among the NFRC, the coir fiber reinforced composites (CFRC) play a key role in composites because of its lignin dense content which enhances the durability of the composites and good insulation properties. Applying optimization for various parameters like composition of fiber, stirring speed, stirring time etc., will improve the performance of the composite by predicting and analyzing the best parameters and conditions required for the desired application and solves complex problems which are difficult to solve using hard computing techniques. [1]. The coir fibers were also undergone through the surface treatment by various reagents to improve specific properties like resistance towards moisture. [2] Coir fibers at different stages of the coconut are being investigated to get the better yield of the composites. Researches are being carried out by hybridizing the coir fiber with several other synthetic and natural fibers to improve the desired properties of the CFRF.

A. Motivation

The main motivation of the current work is to produce a detailed account of the literary works performed by researchers with regard to coir fibres and their extraction process. Further the process of incorporating coir fibre reinforcements (short fibre, micro fibre and nano fibre) in NFRC has become the need of the hour owing to their exceptional bio sustainability and easy availability although the mechanical and thermal properties are in close proximity with some other natural fibres. The use of CFRC will aid in green manufacturing by replacing the costly and non-bio degradable synthetic fibre reinforced composites.

B. *Flow of events*

The article presents the study in a systematic manner. Section 2 provides a brief over view on coir fibre and types along with the comparison between them. Section 3 briefs us about the methods used for manufacturing of CFRC. In section 4 optimization techniques used in processing of the coir fibre has been illustrated. Section 5 discusses the key findings and research gaps found through this article. Section 6 portrays the conclusion the article.

II. COIR FIBRE

Coir Fiber is among the most abundant renewable sources among the natural fibres for fabrication of NFRC. The moisture resistance is property which makes CFRC unique among all the NFRC. Moreover, coir fibres are abundant and exhibit the characteristics comparable to synthetic fibres. The afore discussed properties attract the researchers to investigate of various properties and parameters in the fabrication coir Fiber reinforced composites. The general characteristics of coir fibres are discussed by Walte et al are presented in Table I. [3] Among various lengths coir fibres investigated, composites with a fibre content of 5wt% and a fibre length of 3mm exhibit the lowest water absorption.[4]. The Coir fibres can be obtained from coconuts at various stages which will alter the characteristics of the composite depend on the type of coir fibre used, which can be classified as either brown coir or white coir.

TABLE I. PROPERTIES OF A TYPICAL COIR FIBER [3]. Reproduced with the permission from Elsevier

Properties of Coir	**Values**
Density (g/m3)	1.25-1.5
Tensile Strength (MPa)	105-175
Youngs Modulus (GPa)	4-6
Elongation at break (%)	17-47
Moisture	10

A. *Brown Coir Fiber*

Brown coir fibres are generally extracted from the matured coconut shells. Brown fibre is predominantly used in most coir-reinforced composites because it offers superior flexural strength, tensile strength, hardness, and impact strength compared to white coir fibres. Brown coir fibres are more durable when compared to others. The typical brown and white coir fibres are shown in Fig. 1 [5] .The tensile behaviour of brown coir fibres and related composited was studied by Gu. [6].

Fig. 1 brown & white coir fibres [5]. Reproduced with the permission from Elsevier

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B. White Coir Fiber

White coir fibers are generally drawn out from the immature coconut shells. The fibers find less applications compared to brown coir fibers due to their less strength in comparison. White coir fibers are more flexible, finer and elastic when compared to brown coir fibers which makes them to find their applications as a reinforcement in soft composite materials. Abhilash and Lenin Singaravelu conducted a comparative study on white and brown coir fibers as shown in Table II. [7]. Mechanical characteristics of white and brown coir fibers have been studied and discussed. [5]

TABLE V. COMPARISON BETWEEN WHITE AND BROWN COIR FIBRES[7]. Reproduced with the permission from Elsevier

Results	White coconut fibres	Brown coconut fibres
Total Intrusion Volume	0.6578mL/g	0.7645 mL/g
Total Pore Area	22.618 m2/g	14.373 m2/g
Median Pore Diameter (Volume)	555.4µm	751 µm
Median Pore Diameter (Area)	13.8nm	6.6nm
Average Pore Diameter (4V/A)	0,1163 µm	0.2128 µm
Bulk Density at 1.02 psia	0.709g/mL	0.664g/mL
Apparent (Skeletal) Density	1.3284 g/mL	1.3486g/mL
Porosity	46.64%	50.77%
Stem Volume Used	36%	38%

III. MANUFACTURING METHODS OF COIR FIBRE REINFORCED COMPOSITES

Numerous methods have been devised to manufacture the coir fibre reinforced composites base on the product to be manufactured. The manufacturing methods include Hand Lay-Up method, Compression Moulding, Rotational moulding, etc. Different phases in the fabrication of CFRC is depicted in Fig. 2. [8]

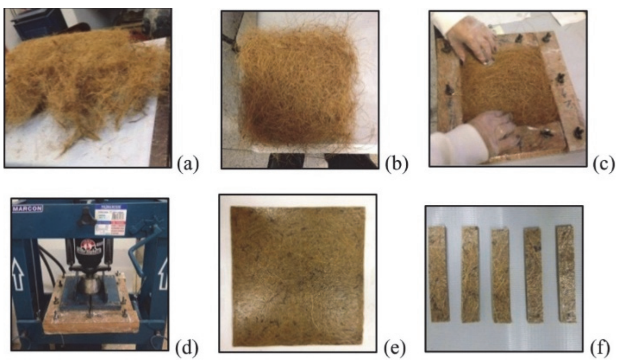

Fig. 2 (a) process of fabrication (b) Coir fibers in their natural state (c) random coir fibers fabric (d) arrangement of fabric inside mold (e) composite laminate (f) specimens for flexural testing [8]. Reproduced with the permission from SAGE publications

Hand lay-up method is one of the common methods use to fabricate the coir reinforced composites. In this method the coir fibres are manually laid on to a mould layer by layer. The resin is then applied to the fibres to consolidate the material. This technique is simple and can be used to fabricate only in small scale. This technique is more suited for complex structures. A detailed discussion has been done on hand lay-up technique. [9]. This method is used in fabrication and investigation of CFRC. [10], [11]. Compression moulding method the resin prototype and the coir fibre is placed on the heated mould and is compressed to form a mould. It has its significance mainly in production of high-volume parts with consistent quality. Fabrication of CFRC is done by compression moulding method. [12] . Kumar et. al discussed the behaviour of composites using compression moulding process [13]. In rotational moulding production of hallow parts is mainly done by rotational moulding technique. In this process the initially the coir fibres are treated and mixed with resin and then the

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mixture is placed on the heated mould and rotated. The composite is solidified by cooling the mould after the resin is melted. [7] used rotational moulding method to fabricate the composite.

To enhance the characteristics of CFRC, numerous advancements have been made, with hybridization playing a crucial role. This process involves combining two or more fibres, which can be either synthetic or natural. The characteristics of hybrid composites are still under investigation. Various combinations of fibers are hybridized. [1], [14], [15], [16]

IV. Optimization Techniques used in the processing of Coir Fibers

Optimization techniques are computational methods used to enhance composite properties by predicting the optimal values of various input parameters and conditions. These techniques are significant in producing cost-effective composites with improved properties tailored to specific applications. Various optimization methods exist, with some employing soft computing techniques and others utilizing MCDM techniques.

A. MCDM (Multi Criteria Decision Making techniques)

MCDM is an abbreviation for Multi Criteria Decision Making techniques. They have an added ability to make important decisions among the multiple conflicting criteria. They enhance the decision making by giving a structured approach to prioritize over different factors.. There are various MCDM techniques available among which most commonly used techniques are TOPSIS & VIKOR.

TOPSIS, or Technique for Order of Preference by Similarity to Ideal Solution, is significant for identifying the best alternative solutions from a given set. It is based on the idea that the best solution should be nearest to the ideal and most distanced from the worst. Verma et. al performed optimization on the process parameters for removal of lignin using TOPSIS technique [17]. Parameters of Coir Fiber for Alkali Pretreatment for Biomass Production have been optimized using TOPSIS[18]. VIKOR aims to identify the best possible results after evaluating all the options which aligns very closely with the ideal solution. VIKOR helps to achieve most appropriate and acceptable solution, even it isn't perfect. Exploring the advancement and mechanical profiling of innovative polymer-based flexible composites while optimizing stacking sequences through VIKOR and PSI methodologies reveals significant potential in enhancing material performance. [19]

B. Soft Computing Techniques

Flexible and efficient methods for solving complex problems are offered by soft computing techniques due to which they're mostly in use. Traditional hard computing methods requires precise models and solutions where as soft computing techniques have the ability to handle the imprecision and uncertainty which enables it to deal with practical problems where data may be insufficient. The most widely recognized soft computing techniques include genetic algorithms, artificial neural networks and many more.

Genetic algorithm's main objective is to figure out the optimal combination of variables and their values to obtain the best possible properties in composites. In genetic algorithm, variables are treated similar to chromosomes. Genetic algorithms are inspired from the principles of natural evolution and genetics. The detailed step by step procedure for performing genetic algorithm is discussed[20] . ANNs are made up of artificial neurons which receive, process and transmit signals to other neurons or nodes. These are inspired by brain's neurons, which are required for processing information. They have ability to recognize patterns within large datasets. ANNs excel at classifying data and predicting unknown outcomes. The characteristics of CFRC were forecasted by Prasad et al using ANN [10]. ANN were employed to fine-tune the parameters affecting the characteristics of banana/coir natural fibre composites, ensuring optimal performance [1].

V. UNEXPLORED AREAS AND MAJOR INSIGHTS

In most of the researches the work has been carried out on improving the characteristics of the coir fibre composites with limited study on manufacturing methods. So far research is done on white and brown coir fibre extensively, but there can be investigation done on using semi matured coir fibres by incorporating mechano-chemical treatment during the extraction of the fibres. Application of optimization techniques in the fabrication methods could find further exploration. The sufficient research has been done on different lengths of coir fibre. The scope of research can be extended to investigate the nano composites made from coir fibres. Adequate research has been done on optimizing the parameters influencing the properties of the composites. The implementation of multi objective optimization on two or more conflicting parameters improves the overall performance of the composites. A detailed investigation can be carried out on the fatigue resistance and durability of the composites through optimization.

VI. CONCLUSION

Coir fiber-reinforced composites (CFRCs) are gaining recognition for their sustainability and eco-friendliness as natural fiber composites. In the due course of time, major progress haven been made to improve the performance of CFRC, investigating the new methods and applications. It also examines the different fabrication techniques used in creating CFRCs. Additionally, this paper briefly discusses the over view of the optimization methods highlighting their importance in improving composite. Finally, the research identifies potential areas for further exploration, discussing key findings and existing research gaps. By identifying these research gaps, the paper encourages the future scope of improvement in developing CFRC.

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