Research Article

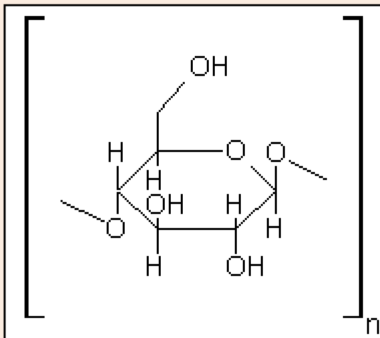
Tensile Behaviour of the Natural Areca Fiber Reinforced Rubber Composites

Dhanalakshmi Sampathkumar[1,2], Ramadevi Punyamurthy[1,2], Raghu Patel G. Ranganagowda[3], Pramod B. Badyankal[3], and Basavaraju Bennehalli[3,*]

[1]Research Scholar, Department of Chemistry, Jawaharlal Nehru Technological University, Hyderabad-500085, Telangana, India
[2]Department of Chemistry, KLE Society's BVB College of Engineering & Technology, Hubli-580031, Karnataka, India
[3]Alva's Institute of Engineering and Technology, Mijar-574225, Moodbidri, Karnataka, India

Abstract

The aim of the present work was to investigate the effect of compounding temperature and fiber loading on the tensile strength of areca fiber reinforced natural rubber composites. Composite boards were fabricated by using a heat press machine. Composites reinforced with 60% fiber loading at different compounding temperature, 130, 140, 150 and 160 °C; and composites with 40, 50, 60 and 70% fiber loading at 130 °C were fabricated and analysed for tensile strength according to ASTM standards. Areca fiber reinforced natural rubber composites with 60% fiber loading at 130 °C showed maximum tensile strength. The effect of compounding temperature on tensile strength of composites was insignificant.



Fiber cellulose

Keywords: Areca fibers, Natural rubber, Tensile strength, Compounding temperature, Compression moulding

***Correspondence**
Basavaraju Bennehalli,
Email: basavaraju_b@yahoo.co.in

Introduction

Environmental hazards of non biodegradable products and climate change aroused need for the researchers to develop new class of environmental friendly materials with superior properties. In the recent decades, natural fiber reinforced polymer composites are considered as most promising materials in structural applications especially in automobile industry due to its superior properties, environmental friendly nature and economic advantage.

In the area of research and development, natural fiber reinforced natural rubber composites find tremendous importance in its end-use applications, since these composites exhibit the combined behaviour of the soft, elastic rubber matrix and the stiff, strong fibrous reinforcement. The development of natural fiber reinforced natural rubber composites has resulted in the production of most promising materials that are harder than aluminum and stiffer than steel.

Natural rubber is one of the most versatile materials widely used in many applications. The main producers of natural rubber are Thailand, Indonesia, Malaysia, and China. Natural rubber has several advantages such as low cost, low hysteresis, high resilience, excellent dynamic properties and fatigue resistance [1]. Natural rubber is having, high tear and tensile properties. Toughness of rubber can change the mechanical and physical properties. However, raw natural rubber has poor mechanical properties. To improve its mechanical properties, ingredients such as accelerators, activators, cross linking agents, and fillers are commonly mixed into rubber to obtain suitable properties

[2]. In particular, the incorporation of fillers in natural rubber matrix leads to significant improvement in mechanical properties of the natural rubber composites [3].

The properties of short fiber reinforced rubber composites depend on several factors such as the aspect ratio of fiber, fiber length, fiber content, fiber orientation and dispersion, and fiber-rubber adhesion [4]. However, the main problem in natural fiber filled rubber is incompatibility between the hydrophilic nature of fiber and hydrophobic nature of rubber, and as a result, it merely possesses adhesion, leading to poor properties of composites [5].

Various rubber products have been developed using coir pith as filler. At the end user applications, the coir pith–rubber composite was satisfying all the essential properties needed for the product application. The coir pith can be used as low cost filler for rubber composite preparation along with other conventional fillers for making end use application products, with a view of cost reduction. Dynamic mechanical behaviour of short coir fiber natural rubber composites was revealed. Short fiber reinforced rubber composites can be used in vibration dampers, tyres etc. So, the study on dynamic mechanical properties is of great interest [6].

Among the many natural fibers, areca fiber has a great potential in the composite field. Karnataka is India's largest areca nut producing state which has a share of around 50% areca productions in the country. Dakshina Kannada is a coastal district situated in the western part of Karnataka. This district is in the tropical region having a hot and humid climate and is highly suitable for cultivation of areca nut crops. In Dakshina Kannada, areca is one of the major crops and is cultivated in 27,600 hectares with an annual production of about 40,000 tonnes. Hence, enormous quantity of unmanaged areca husk is available for further processing. The areca husk is a hard fibrous material covering the endosperm and constitutes about 60-80% of the total weight and volume of the areca fruit.

The husk fiber is composed of cellulose with varying proportions of hemicelluloses (35–64.8%), lignin (13.0–26.0%), pectin and protopectin [7-9]. Few investigators studied the mechanical behaviour of areca composites with 60% fiber loading and found to have a good flexural strength and tensile properties [10-12]. However, no literature is available on the effect of fiber loading on tensile strength of areca fiber reinforced natural rubber composites. Presently, this highly cellulosic material is being used as a fuel in areca nut process. Thus the use of this husk fiber as structural material requires a detailed study on physical, chemical and mechanical characteristics. The objective of this paper is to study the tensile behaviour of areca fibers reinforced natural rubber composites so as to establish their usefulness or otherwise as composite reinforcing materials.

Experimental

Fiber Extraction

The dried areca empty fruits were soaked in de-ionized water for about five days. This process is called retting; allowing the fiber to be removed from the fruit easily. Areca fibers were removed from the fruit and separated into an individual state. The resulting fibers were treated in the condition (temperature 30 °C, RH 70%) for 72 h.

Composite Fabrication

The fabrication of composite plates was carried out by compression moulding technique. The areca fiber is used as reinforcement material and natural rubber granules were taken as matrix material. The natural rubber granules used in this experiment was supplied by Akolite Synthetic Resins, Mangalore. The weight fraction, 40, 50, 60 and 70% of areca fiber was carefully controlled during the mixing of two ingredients. The resulting material was compression moulded to the dimension of 300 x 300 x 5.0 mm^3. The composite preparation process was performed in the following order. First, the heat press was pre-heated to 60 °C. Then the pressure was set as 0 MPa and the temperature raised to 100 °C. After that the pressure was raised to 5 MPa and temperature was raised to certain degree (130, 140, 150 or 160 °C) respectively. Further, raised the pressure to 15 MPa, maintained the pressure and temperature for 30 min. Finally, lowered the pressure to 0 MPa, lowered the temperature to 30 °C and composite plate was removed from the heat press. The specimens were post cured for 48 h before the test.

Tensile Strength of Composites

Specimens prepared for the tensile strength test were cut and the measurement was carried out according to ASTM D3039 standards. A rectangular shape specimen with the total length of 250 mm, gauge length of 150 mm, width of 50 mm and a uniform thickness of 5.0 mm is considered for the test. The specimen was loaded in the universal testing machine until the failure of the specimen occurs.

Results and Discussion

The ability of a material to resist breaking under tensile stress is one of the most important and widely measured properties of composite materials used in structural applications. The force per unit area (N/mm^2 or MPa) required to break composite material is the ultimate tensile strength or tensile strength at break. It has been reported that the modulus of natural rubber decreases with increasing temperature in the range 130-210 °C [13]. The higher compounding temperatures induce higher rubber fluidity, which would lead to a better dispersion of the liquid rubber among the areca fibers, resulting in a better integration between the fiber and matrix. To study the effect of compounding temperature on tensile strength of composites, the composites reinforced with 60% fiber loading at different temperature, 130, 140, 150 and 160 °C were prepared for the measurements. Each piece of the fabricated areca composite plate was cut into five specimens. Each result is an average of five measurements and is presented in **Table 1**.

Table 1 Effect of moulding temperature on tensile strength

Moulding Temperature (°C)	Tensile Strength (MPa)	Elongation at Break (%)
130	126.02	15.48
140	130.25	17.42
150	125.24	18.48
160	127.68	16.94

Table 2 Effect of fiber loading on tensile strength

Volume Fraction of Fiber (%)	Tensile Strength (MPa)	Elongation at Break (%)
40	87.24	23.26
50	112.28	18.62
60	126.48	15.68
70	108.32	10.88

The tensile strength results show that there is no considerable difference among the four samples. The reason may contribute to the limited temperature difference among the four groups. Hence, compounding temperature, 130 °C would be recommended for economical consideration. Composites with 40, 50, 60 and 70% fiber loading were fabricated according to the procedure described and the temperature used for the fabrication was 130 °C. From the prepared composites, test specimens were cut to size according to ASTM standards and were evaluated for tensile properties. The variation of tensile strength with different fiber loadings are presented in Table 2. Each result in the table is an average of five determinations.

The tensile strengths of composites with 40%, 50%, 60% and 70% fiber loadings are 87.24, 112.28, 126.48 and 108.32 MPa respectively. The tensile strength values found to increase with higher fiber loading. For 60% fiber loading, tensile strength increased by 44.97% compared to 40% fiber loading. This is because at 60% fiber loading, there is better fiber distribution in matrix, less fiber fractures and effective transfer of load from matrix to fibers. However, for 70% fiber loading, tensile strength decreased by 14.35% compared to 60% fiber loading. In this case, melted rubber could not reach each of the areca fibers surface because of the smaller amount of matrix material. The reduced tensile strength of composites is due to the ineffective transfer of stress from the matrix to reinforced fiber. From these results it is very clear that areca fiber reinforced natural rubber composites with 60% fiber loading showed maximum tensile strength. So, these composites are best for applications where high tensile strength is required. Further, in the cases of composites with 40 and 50% fiber loading, smaller areca fiber fraction is used and areca fibers serving as the primary reinforcement in the composites, the reduced fiber amount resulted in a significant decrease in tensile strength compared to composites with 60% fiber loading.

Conclusion

The natural areca fiber reinforced natural rubber composites with 60% fiber loading were fabricated by using hot compression moulding technique. The variation in compounding temperature from 130-160 °C has no significant influence on the tensile strength of composite. The lower or higher than 60% of the fiber loading may reduce the tensile strength of composites. Hence, composites with 60% fiber loading would be the better choice.

Acknowledgements

This work was supported by Vision Group on Science and Technology, Department of Information Technology, Biotechnology and Science & Technology, Government of Karnataka, India (grant number VGST/CISEE/2012-13/282 dated March 16, 2013). The first author would like to thank the Management of KLE Society's B.V.B. College of Engineering and Technology, Hubli, Karnataka, India for the kind encouragement and constant support provided. She sincerely thanks Dr. Ashok S. Shettar, Principal, K.L.E. Society's B.V.B. College of Engineering and Technology, Hubli, for his encouragement and support throughout this work.

References

[1] Teh PL, Mohd Ishak ZA, Hashim AS, Karger-Kocsis J, Ishiaku US, Eur Polym J **2004**, 40, 2513-2521.
[2] Ismail MN, Turky GM, Polym Plast Technol Eng **2001**, 40, 635-652.
[3] Dutta NK, Rubb Chem Technol **2001**, 74, 260-280.
[4] Jacob M, Thomas S, Varughese KT, J Appl Polym Sci **2004**, 93, 2305-2312.
[5] Ismail H, Rusli A, Rashid AA, Polym Test **2005**, 24, 856-866.
[6] Geethamma VJ, Thomas S, Kuriakose BJ, J App Polym Sci **1995**, 55, 583-594.
[7] Rajan A, Kurup JG, Abraham TE, Biochem Engg J **2005**, 25, 237-242.
[8] Dhanalakshmi S, Ramadevi P, Raghu Patel GR, Manikanta M, Jayaraj A, Jason M, Chethan GR, Basavaraju B, Ciencia e Technica Vitivinicola **2014**, 29, 99-114.
[9] Dhanalakshmi S, Basavaraju B, Ramadevi P, International Journal of Material Sciences and Manufacturing Engineering **2014**, 41, 1151-1156.

[10] Srinivasa CV, Basavaraju B, Mownesh GK, Raghu Patel GR, BioResources **2010**, 5, 1845-1858.
[11] Srinivasa CV, Arifulla A, Goutham N, Santhosh T, Jeethendra HJ, Ravikumar RB, Anil SC, Santoshkumar DG, Mater Des **2011**, 32, 2469-2475.
[12] Dhanalakshmi S, Ramadevi P, Srinivasa CV, Basavaraju B, Int J Agriculture Sci **2012**, 4, 227-229.
[13] Miwa M, Takeno A, Hara K, Watanabe A, Composites **1995**, 26, 371–377.

Publication History

Received	02nd	Oct 2014
Revised	16th	Oct 2014
Accepted	11th	Nov 2014
Online	30th	Nov 2014