Evaluation of Mechanical and Microstructural Performance of Jute Fiber Reinforced Composites

Prashant Kumar Pandey[1], Rajeev Rathi[1], Vishaldeep Singh[1]

[1] *School of Mechanical Engineering, Lovely Professional University, Punjab, India*

Abstract

The improvement of composites derived from sustainable assets and natural fibers has pulled in analysts lately. Most non-industrial countries are especially wealthy in farming and regular filaments. India alone makes an overabundance of 400 million tons of agrarian waste yearly. It conveys a gigantic division of the world's rice husk, jute, tail, bagasse, and coconut fiber. These natural fibers filaments have great physical and mechanical properties and can be utilized even more satisfactorily in the improvement of composite materials for various applications.

Keywords: Natural fibers, Jute fiber-reinforced composite, Mechanical and microstructural properties

1. Introduction

Industry's new accentuation is on eco-accommodating materials and advances have been encouraged by government guidelines, buyer inclinations, and now and again, budgetary investment funds that can be acknowledged from the appropriation of these materials and innovations. Natural fibers have been appeared to consolidate minimal effort with great mechanical properties. Polymeric materials could be classified according to behavior with rising temperature (thermosets, thermoplastics, and elastomers), the attention has been paid to elastomer (rubber) in this study

The rubbers (elastomeric materials) can be classified into two major categories according to the common use i.e. natural rubber and synthetic rubber. Natural rubber (NR) displays many outstanding properties, that include better resilience, elasticity, resistance to abrasion, impact resistance, low cost, and efficient heat dispersion which allow it to be ideal for use in medical and other applications. The natural rubber is a product of latex that bleeds from the wounding in plants [1-3]. The drop in regular rubber items can be ascribed to the revelation of raw petroleum, uneconomic size of farmer's property, mature age of plantations, minimal horticultural contribution like compost, pesticides, etc. The deficiency of labor and the significant expense of work in rubber-producing territories was also among the reasons. Synthetic rubber is a type that is artificially made by man from a petrochemical feedstock or polymer material and is typically acquired by emulsion expansion polymerization and buildup polymerization, which goes about as an elastomer [4].

A diverse variety of particulate fillers such as carbon black, silica, alumina, and clay are used in the rubber industry for various purpose including reinforcement, a drop in material costs, perfections in processing, and to improve the mechanical, electrical and fracture properties of rubbers, for examples, increase the strength of rubber, increase the hardness, stiffness, tensile modulus, abrasion resistance, tear-resistance and increase frictional coefficient, reduced the rebound or resilience. Other fillers, the plasticizers are also necessarily added to compounding rubber. A great industrial development in the transportation field attracted many kinds of research that have been made to improve the rubber product that used for the car tires and sport utilities. During the years 1914 to 1940 natural rubber demand had risen from 0.12 tonnes to 1.13 million tonnes for the car tire industry. The expected production capacity of rubber in 2020 is about 680,000 tons. In 1980, the supply of natural rubber from Asia was over 90% and which was the world's major natural rubber manufacturer. The main reason was claimed to be the easy availability of land and labor [5-7].

1.1. History of Rubber Production

The history of rubber has been marked back to 1525 and the first known elastomer was natural rubber (NR), used as rubber balls and mortar. In 1615, the first practical use of rubber is claimed in the waterproofing footwear, when peoples of South America extracted this substance from trees often called "Hevea Brasiliensis" and "Para Rubber" trees, meaning "weeping wood". These trees represent sources of natural rubber, that begin grew in the Amazon forests in 1873. At that time the natural rubber became the first demand for a product in the world that lead to Amazon being the economic heart of Brazil. During the middle of the 18th century to about the end of the 20th century, the rubber industry experienced significant steps of development. At that time most rubber tree plantation grew in British and British Colonies in South and Southeast Asia particularly in Thailand, Malaysia, India, China, and Indonesia. Today rubber trees are grown in Africa such as Nigeria, which became important producers of natural rubber. The existence of natural rubber in European countries began in the late 19th century when the demand for natural rubber was considerably increased. The rubber studies concluded the development of condensed resinous oil and recommended that rubber could be used to develop flexible tubes. In 1820, British entrepreneurs formed rubber and endeavored to utilize them in clothing. The first bicycle tire product was made in 1830, while in 1832, the first factory was set up for rubber products. After some time America started using rubber in all sectors particularly in automobiles, electric light, waterproof footwear, and snow-boots. Charles Goodyear (in England) and Hancock (in America) simultaneously discovered the vulcanization procedure about 1839 by accident, which was the revolution for the rubber industry. In 1845, R.W. Thomson developed the pneumatic tire and the inner tube, and in 1869 made the solid rubber balls and hollow rubber balls for the golf and tennis, and again in 1888, the rubber is used to form rain jackets. The Russians and the Germans have made efforts to synthesize rubber, which can compete with natural rubber [8].

2. Literature review

Literature shows that fiber-reinforced composites can be set up with jute strands of fiber length 5-6 mm. The resins that help are polyester and epoxy. Once, the composites formed were blended at 18:82 fiber-resin the mechanical test result shows that jute- reinforced epoxy composite displayed preferred mechanical properties over Jute-polyester composite. The jute-reinforced epoxy composite additionally shows better flexural quality with transverse fiber appropriation in the composites. Scanning electron microscopic coordinates that morphological changes occurred relying upon the fiber direction in epoxy composites. It has likewise been seen from the thermogravimetric investigation that jute fiber epoxy composites would be advised to exhibit better thermal properties [9].

The wide assortment of biocomposite handling systems just as the variables, for example, dampness content, fiber type, and content, and their impact on composites properties have also been debated in various research works. The accumulation of nano clay to the jute fiber-reinforced composites showed critical improvement in the mechanical properties at a lower cost and hence can be utilized as a substitute to glass and engineered strands [10].

Further, studies that mainly focuses on Natural Fiber Reinforced Polymer Composite (NFPC) demonstrate the impacts of different chemical treatments on the thermal and mechanical properties of natural fibers reinforcements thermosetting and thermoplastics composites. Numerous disadvantages of NFPCs like substandard imperviousness to fire, higher water assimilation, and lower mechanical properties inhibited its applications [11].

3. Experimental Work

3.1 Preparation of Natural Rubber

Rubber tapping - The smooth white fluid latex is gathered with the rubber trees and then eroded, sifted and responded with chemicals to coagulate the rubber elements.

Mastication-The rubber acquired from the tapping procedure is as yet not fit to be utilized. At the point when it is cold it is exceptionally fragile and when heated up it turns out to be extremely gluey. To expel the weak nature and solid smell of the elastic, it is permitted to go through the rollers and is squeezed to make it gentler and adaptable to work.

Calendering – It is a procedure, which is essentially achieved to give shapes to rubber by utilizing rollers and appropriate blending of the chemical constituents.

Vulcanization –Significantly in the wake of playing out every one of these means the rubber isn't a lot stiffer and tougher so that it can be utilized in different things alike vehicle tires and hardware. To upgrade every one of these properties, sulfur is added to the rubber and then heated up to a temperature covering 373 k to 415 k. This procedure is acknowledged as vulcanization.

(a)

(b)

Figure 1: (a) Natural Rubber and (b) Vulcanized Rubber

3.2 Preparation of jute fiber

Initially, jute fiber of different orientations is selected for the process. These jute fibers are dipped into NaOh solution which is prepared in 9 gm of Na mixed with 100 mL of water. This jute fiber is then dipped into the NaOh solution for 4 hours. Then further dried out with the help of drier or oven. The aim to dry the jute fiber is to prevent moisture which is not required in jute fiber because it reduces the mechanical properties and adhesive strength.

Figure 2: Modified jute fiber

3.2 Preparation of composite rubber

To prepare a sample, firstly need a mould that is kept into the furnace at high temperature. After preparing a mould, a high vacuum silicone gel is applied on the surface of the mould so rubber should not stick to the surface of the mould. These high vacuum silicone gel should withstand high temperature because the vulcanization process should be done on the 160-degree celsius. 100 ml of natural rubber taken out and mixed with 30 gm of sulfur (S) which is used as a rubber hardener and 15 gm of zinc oxide (ZnO) which is used as an accelerator which helps to cure the rubber faster and also help to enhance the mechanical properties of natural rubber. The mixing of natural rubber with sulfur and zinc oxide carefully because during the mixing natural rubber reacts with the environment which produces some kind oxidation process that weakens the natural composite. After mixing natural rubber with sulfur and zinc oxide, as much as possible mould should be kept into the furnace, so no further oxidation occurs. The temperature of the furnace is set on 145 degrees Celsius and mould are kept into the furnace for 1 hour. After a 1-hour mould is taken out from the furnace and applied load on mould with the help of universal testing to avoid the bubble formation in composite rubber up to 5 minutes. Then composite rubber is kept in an open environment for cooling for a few minutes and then rubber composite is taken out from the mould.

4.Mechanical testing of the composite rubber and results

4.1 Tensile test

Tensile strength was conducted beneath ambient environments, using the composite universal material testing machine as per ASTM standard to find the modulus of elasticity, and percentage elongation at breaking point. All tests were completed with alternate gauge lengths.

Table 1: Tensile Test results

Sample	Tensile strength (MPa)	Elongation at breaking point (%)	Modulus of elasticity(MPa)
Vulcanized natural rubber	1.682	32.35	39.932
Rubber composite with jute fiber	10.3	143.1	21.56

4.2 X-Ray Diffraction (XRD)

Name and formula

Reference code:	98-062-5090
Compound name:	Cobalt Titanium Silicide (16/6/7)
Common name:	Cobalt Titanium Silicide (16/6/7)
Chemical formula:	$Co_{16}Si_7Ti_6$

Crystallographic parameters

Crystal system:	Cubic
Space group:	F m -3 m
Space group number:	225
a (Å):	11.2010
b (Å):	11.2010
c (Å):	11.2010
Alpha (°):	90.0000
Beta (°):	90.0000
Gamma (°):	90.0000

Calculated density (g/cm^3):	6.74
The volume of the cell (10^6 pm^3):	1405.30
Z:	4.00
RIR:	3.33

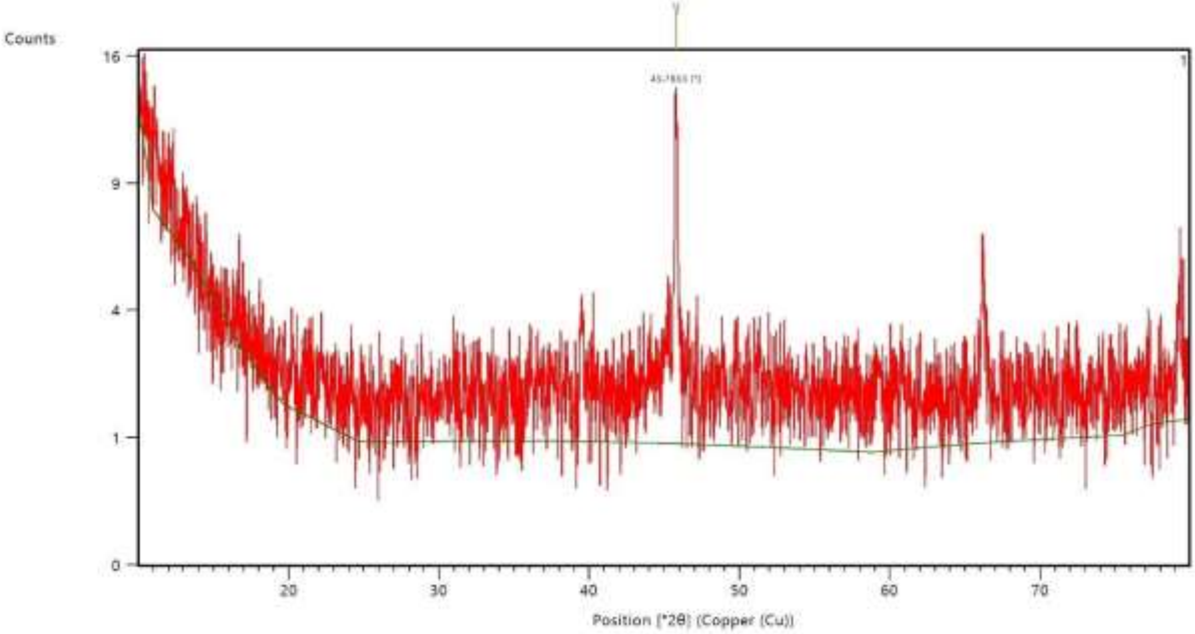

Figure 3: XRD Test Result Graph

4.1 Scanning Electron Microscope

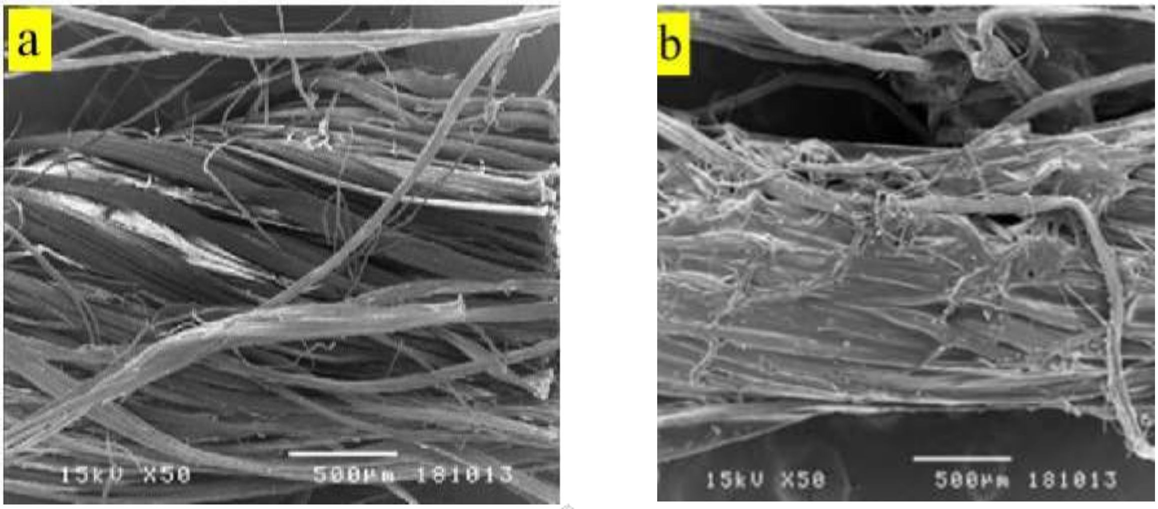

Figure 4: The microstructure of Composite

Conclusion

The mechanical properties of natural rubber composite have been deliberated in this experiment and observed that adding jute fiber with natural rubber enhances the properties of natural rubber. The tensile strength of the rubber is increased by 1.5% when rubber is mixed with jute fiber.

Relating to the mechanical properties, an ultimate modulus improved with including sulfur and zinc oxide with natural rubber and jute fiber. It is inferred that even though the mechanical properties of natural rubber composite don't have qualities and moduli as good as those of ordinary composites, but they possess improved qualities than wood composites and a few plastics. Subsequently, these composites could be considered for future materials use, since the material is eco-accommodating, non-harmful, non-wellbeing risky, low in cost and effectively accessible when contrasted with customary filaments like glass, Kevlar, asbestos and so on.

For the idea of business applications, the composites arranged with the jute fibers gives great harmony among cost and properties. Composites show fragile nature and most reduced disintegration rate contrasted with different composites, because of their chemical structure and closeness.

References

[1] Abdelwahab, N. A., Helaly, F. M. and Badran, A. S. (2008) ‘Effect of bagasse on the physicomechanical properties of natural and styrene-butadiene rubbers’, J Elastom Plast, 40, 347–363.

[2] Affonso, J. E. S. and Nunes, R. C. R. (1995) ‘Influence of the filler and monomer quantities in rheometrical behaviour and crosslink density of the NBR–cellulose II composites’, Polym Bull, 34, 669–675.

[3] Andrio, A., Compañ, V., Nunes, R. C. R., Lópes, M. L. and Riande, E. (2000) ‘Influence of cellulose reinforcers on gas transport through natural rubber’, J Membrane Sci, 178, 65–74.

[4] Arumugam, N., Selvy, K. T., Rao, K. V. and Rajalingam P. (1989) ‘Coconut-fiber- reinforced rubber composites’, J Appl Polym Sci, 37(9), 2645–2659.

[5] Bendahou, A., Kaddami, H. and Dufresne, A. (2010) ‘Investigation on the effect of cellulosic nanoparticles’ morphology on the properties of natural rubber based nanocomposites’, Eur Polym J, 46(4), 609–620.

[6] Kim, Yoong Ahm, Takuaya Hayashi, Morinobu Endo, Yasuo Gotoh, Noriaki Wada, and Junji Seiyama. "Fabrication of aligned carbon nanotube-filled rubber composite." *Scripta Materialia* 54, no. 1 (2006): 31-35.

[7] Wang, Zhi-Fen, Zheng Peng, Si-Dong Li, Hua Lin, Ke-Xi Zhang, Xiao-Dong She, and Xin Fu. "The impact of esterification on the properties of starch/natural rubber composite." *Composites Science and Technology* 69, no. 11-12 (2009): 1797-1803.

[8] Pantamanatsopa, Pruttipong, Warunee Ariyawiriyanan, Tawatchai Meekeaw, Rattiyakorn Suthamyong, Ketsara

Arrub, and Hiroyuki Hamada. "Effect of modified jute fiber on mechanical properties of green rubber composite." *Energy Procedia* 56 (2014): 641-647.

[9] Gopinath, Ajith, M. Senthil Kumar, and A. Elayaperumal. "Experimental investigations on mechanical properties of jute fiber reinforced composites with polyester and epoxy resin matrices." *Procedia Engineering* 97, no. 10.1016 (2014).

[10] Deepak, K., S. V. Prabhakar Vattikuti, and B. Venkatesh. "Experimental investigation of jute fiber reinforced nano clay composite." *Procedia Mater. Sci* 10 (2015): 238-242.

[11] Biswas, Subhankar, Sweety Shahinur, Mahbub Hasan, and Qumrul Ahsan. "Physical, mechanical and thermal properties of jute and bamboo fiber reinforced unidirectional epoxy composites." *Procedia Engineering* 105 (2015): 933-939