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AN EXPERIMENTAL STUDY ON THE PERFORMANCE AND MECHANICAL PROPERTIES OF NATURAL RUBBER COMPOSITE REINFORCED WITH 40% V/V SISAL FIBER SUBJECTED TO DIFFERENT SURFACE MODIFICATIONS

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ABSTRACT

In the era of environmental consciousness, the relevance of naturally occurring materials are gaining more and more importance in the development of new material for engineering applications. In this context a natural fiber like sisal has a lot potential as reinforcement in engineering composites as an alternative to harmful, expensive synthetic fibers. The objective of this work is to develop elastomeric composite using only naturally occurring materials. A Natural Rubber-40% v/v sisal fiber composites with the sisal fiber given four surface modifications were made & two additional samples with addition of 10% w/w activated coconut shell powder is also made for evaluating the influence of filler powder in the composites. A total of six samples were made and are evaluated for their mechanical properties like Tensile strength& tear strength. An increase of 73% tensile strength obtained for alkalized impregnated sisal fiber composite with respect to Natural Rubber. Tear strength showed exceptional increase up to 246% for alkalized impregnated sisal fiber. Hardness values increased to 200-228% range for the composites. The best abrasion resistance is shown by alkalized impregnated fiber. Compressive strength is maximum for raw fiber and coconut shell powder filled rubber composite.

Keywords: natural rubber, rubber composites, sisal fiber, mechanical properties, ecofriendly materials, tensile strength, tear strength.

1. INTRODUCTION AND LITERATURE REVIEW

Natural fiber extracted from the stem, seeds and leaves of nature plants were used from the historic periods itself for making twains, threads, as clothing materials, as reinforcement in walls, roofs, potteries and vessels etc. [1]. The advantage with these fibers is that most of them can be obtained as an agricultural byproduct or can be cultivated easily. They are also inexpensive and economical biodegradable.

Most of the developed countries have imposed limited or complete ban on plastic and plastic commodities. All these situations demand the development of a natural and ecofriendly materials for the development of new material and new products. This also helps to generate a lot of rural employment and an additional income to the existing farmers.

Composites with coconut and rubber are widely used in automobile products [2]. Sisal is a leaf fiber and run through lengthwise of the leaves. Examples for leaf fibers are sisal, henequen, abaca, pineapple etc. [3, 4].

Sisal fibers

The main content of natural fibers is cellulose. They are basically lignocellulosic with helical wound cellulose microfibril in an amorphous matrix of lignin and hemicellulose. These fibers consist of several fibril running along the fiber length. In addition to cellulose, a lesser quantity of hemicelluloses and lignin will be present in the fibers. Lignin is the cementing material for the cellulose fibril and it gives the strength to the fibers [5].

The fiber properties are dependent on its chemical composition and internal fiber structure, which varies along the different sections of the same plant and also between different plants [6, 7]. The major sisal species available in India is Agave Sisalana. Annual Sisal production & cost--India- 3000 tons, world- 600,000 tons, cost- 0.05$ /kg.

Figure-1. Sisal fiber bundle.

Table-1. Mechanical properties of Sisal fiber [22].

Diameter (μm)	**50-200**
Density (g/mm³)	1.45
Moisture content %	11
Ultimate Tensile strength (MPa)	568-640
Modulus	9.4-15.8

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Table-2. Chemical composition of Sisal fibers (Wt. %).

Cellulose	**43-56**
Hemicellulose	21-24
Lignin	7-9
Ash	0.6-11
Pectin& Waxes.	1

Natural rubber

Natural rubber is a polymer cic-1, 4 poly-isoprene. It is an elastomer and a thermoplastic. Rubber when vulcanized turns into Thermoset.

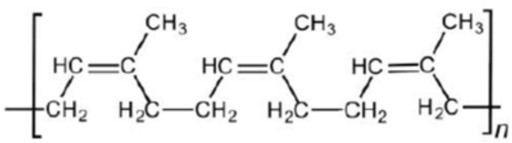

Figure-2. Chemical structure of natural rubber.

2. MATERIALS AND METHODS

2.1. Materials

Natural rubber or india rubber grade ISNR20, natural fiber-Sisal and the chemicals needed for the fiber surface modification-Sodium Hydroxide, Toluene etc. supplied by vendors at Coimbatore, India.

2.2. Experimental methods

2.2.1. Fiber surface modifications

A total of four types of Sisal fibers are used as reinforcement in the fabrication of Rubber composites-Sisal Raw Rubber, Alkalized fiber, rubber pre-impregnated fiber and rubber pre-impregnated alkalized fiber.

The process of alkalization involves immersion of chopped 10mm long fibers in a 2% w/w sodium hydroxide solution in water for one hour. The above concentration and time were found by experimenting the fibers with different sodium hydroxide concentrations-treatment time combinations and analyzing the treated fiber weights and strengths. The fibers are then washed thoroughly with fresh water, till all the alkalinity is removed from the fiber surface. A few drops of acetic acid added to the solution to neutralize the alkali. The fibers are then dried at 32 °C for 48 Hrs.

For the fiber pre-impregnation with natural rubber, first a 4%w/w rubber-toluene solution is prepared by adding the rubber particles in a heated (80 °C) toluene solvent. The chopped fibers are then added to the solution and kept for one hr. The solution is continuously stirred for the complete rubber-fiber penetration of all the fibers. The toluene solution is then drained and the fibers are then separated and the fibers then separated and kept at room temperature 32 °C for 72 Hrs, for the complete evaporation of the solvent.

The rubber-impregnated alkalized fibers are also made in the same manner. Instead of raw fibers, alkalized sisal fibers are used for the impregnation process.

2.2.2. Composites molding

The treated fibers are mixed with the natural rubber in a two roll mill for about 30 minutes. The roll gap is maintained at 2 mm. The compounded sheets are then compression molded into sheets of 2 mm thickness. Molding is done in a 2 Ton compression molding machine at 180 °C. The specimens for the tensile tests and tear tests were cut from these sheets using ASTM standard dies.

3. RESULTS AND DISCUSSIONS

Table-3. Samples details.

S. No.	Samples	Description.
1	NR	Natural Rubber
2	SRa-NR	Raw Sisal fiber-NR
3	SNa-NR	Alkalised Sisal fiber-NR
4	SRaI-NR	Pre-Impregnated Raw Sisal fiber-NR
5	SNaI-NR	Pre-Impregnated Alkalised Sisal fiber-NR
6	SRa-NR-Cs.	Raw Sisal fiber-Coconut Shell Powder-NR
7	SRaI-NR-Cs.	Pre-Impregnated Raw Sisal fiber-Coconut Shell Powder-NR

Table-4. Results.

S. No.	Specimens.	Tensile strength (MPa)	Tear strength N/mm.
1	NR	4	14.47
2	SRa-NR	4.27	36.59
3	SNa-NR	4.39	33.37
4	SRaI-NR	4.34	32.38
5	SNaI-NR	6.92	50.08
6	SRa-NR-Cs.	4.26	31.89
7	SRaI-NR-Cs.	6.13	38.94

3.1. Tensile strength

The tensile tests are done on an Instron UTM. The variation of tensile strengths of rubber-sisal composite with the sisal fiber subjected to various surface modifications is shown in Figure-3. The maximum tensile strength is obtained for the composite with rubber impregnated alkalized sisal (SNaI-NR). A value of 6.92 MPa, an increase of 73% over rubber specimen. This is due to the better interfacial bonding between the sisal fiber surface and the rubber matrix. The alkalization of the fibers removed the wax, dirt and the hydroxyl groups from the fiber surface making it clean and more hydrophobic.

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This facilitated the rubber to impregnate deep into the fiber surface and voids during the pre-impregnation process. This rubber pre-impregnated fiber when mixed with the matrix rubber made a strong interfacial bonding and a homogeneous interphase between them. This bonding led to a better load transfer to the fibers during the tensile tests. SEM images (Figures 6-4) shows that the material failure occurred due to fiber breakage than the matrix failure.

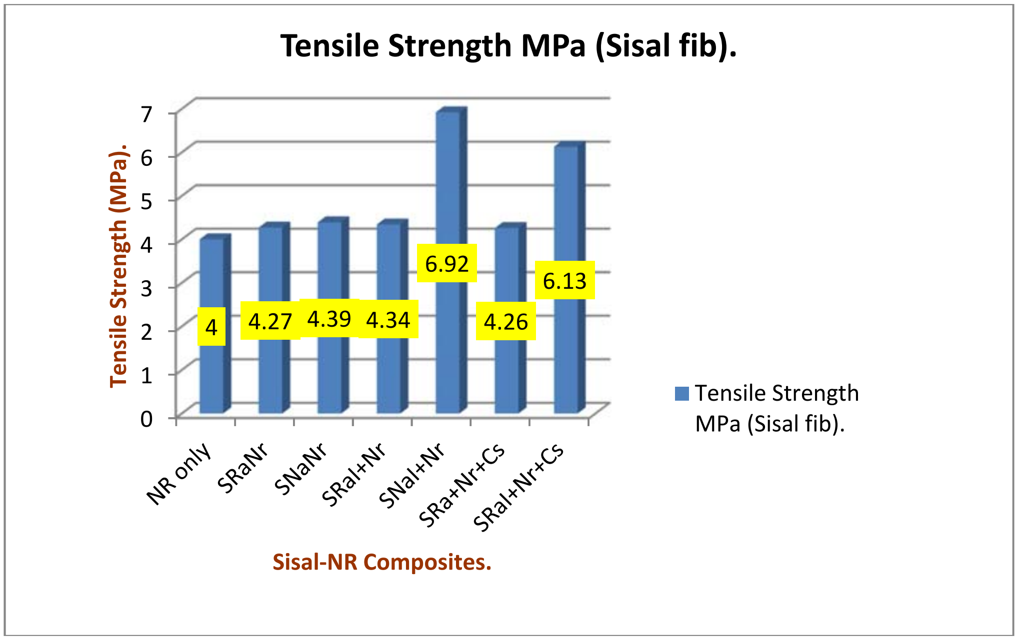

Figure-3. Tensile strength-sisal fiber.

Figure-4. UTM for tests.

Figure-5. Tensile specimen after test.

The second best tensile value

Obtained for rubber composite with rubber pre-impregnated raw sisal fiber (SRaI-CsNR). In this case the coarse and rough fiber surface facilitated a good rubber penetration and interlocking with the fiber surface during the rubber pre impregnation process (Ref. fig.6-3 SEM image) This rubber impregnated fiber made an excellent interfacial bonding with the matrix rubber during the compounding process. The specimen exhibited a tensile value of 6.13MPa an increase of 53.3% compared to rubber without any reinforcement.

The remaining four samples showed a marginal increase in tensile strengths, an average of 8% increase over rubber.

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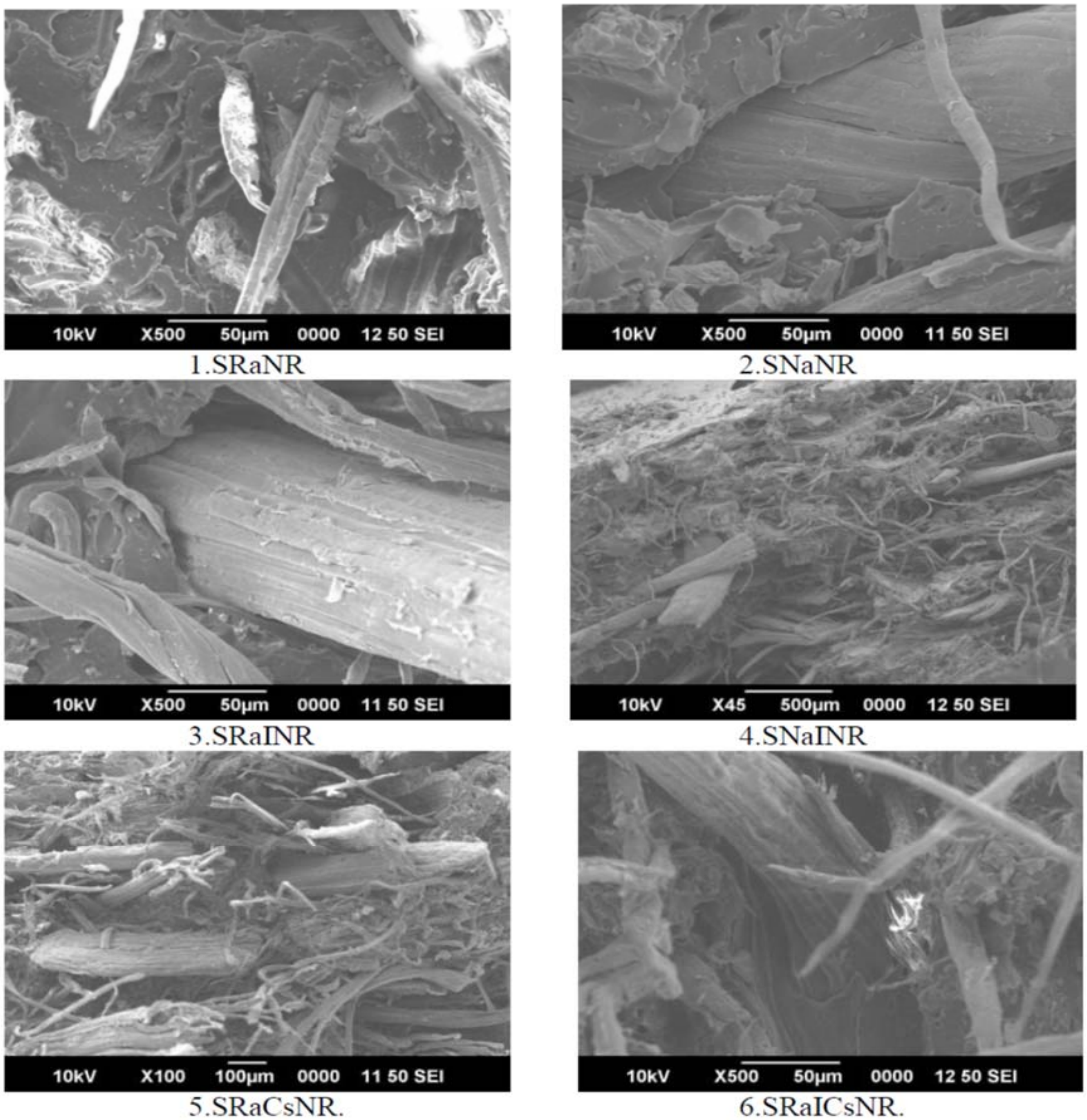

Figure-6. SEM of tensile failure edges: 1.SRaNR, 2.SNaNR, 3.SRaINR, 4.SNaINR, 5.SRaCsNR, 6.SRaCsNR.

3.2. Tear strength

The Tear strength of the fabricated composite specimens showed a significant and useful increase in property (Figure-8). The maximum tear strength is noted for rubber pre-impregnated alkalized sisal-rubber composite (SNaI-NR), a value of 50.08 N/mm, an increase of 246.1% compared to natural rubber. This achievement is due to the improved interfacial bonding and a better interphase between the fiber and rubber. This is because alkalization helped to remove the dirt and grease from fiber surface and made the fiber hydrophobic by the removal of hydroxyl groups. The rubber pre-impregnation process further added to better the fiber matrix bonding. This led to a homogeneous material structure.

The remaining samples also exhibited improved tear strengths (31.89-38.94 N/mm) an average increase of 139.4% compared to natural rubber.

Figure-7. Tear specimen after test.

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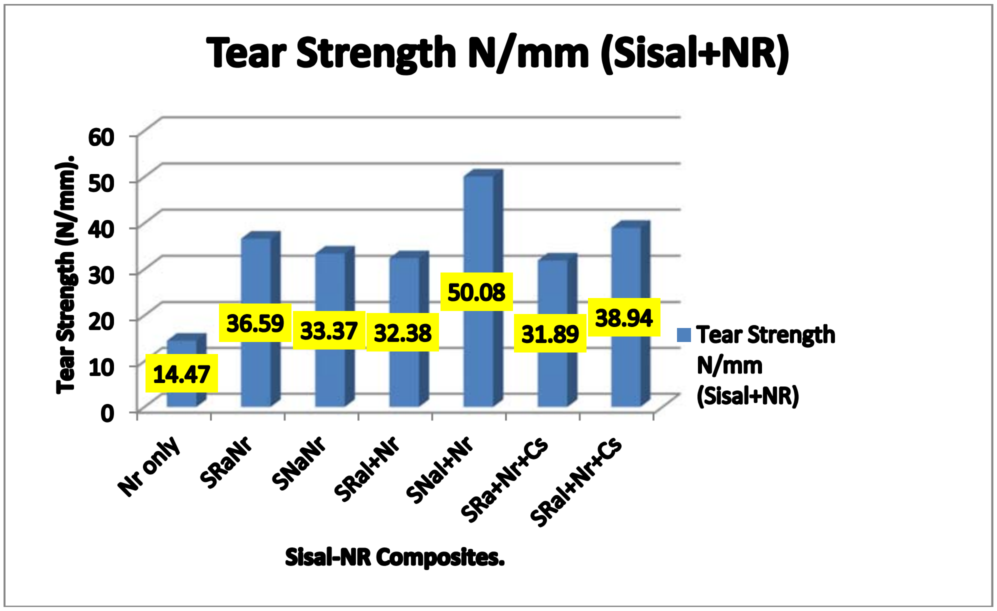

Figure-8. Tear strength- Sisal fibers.

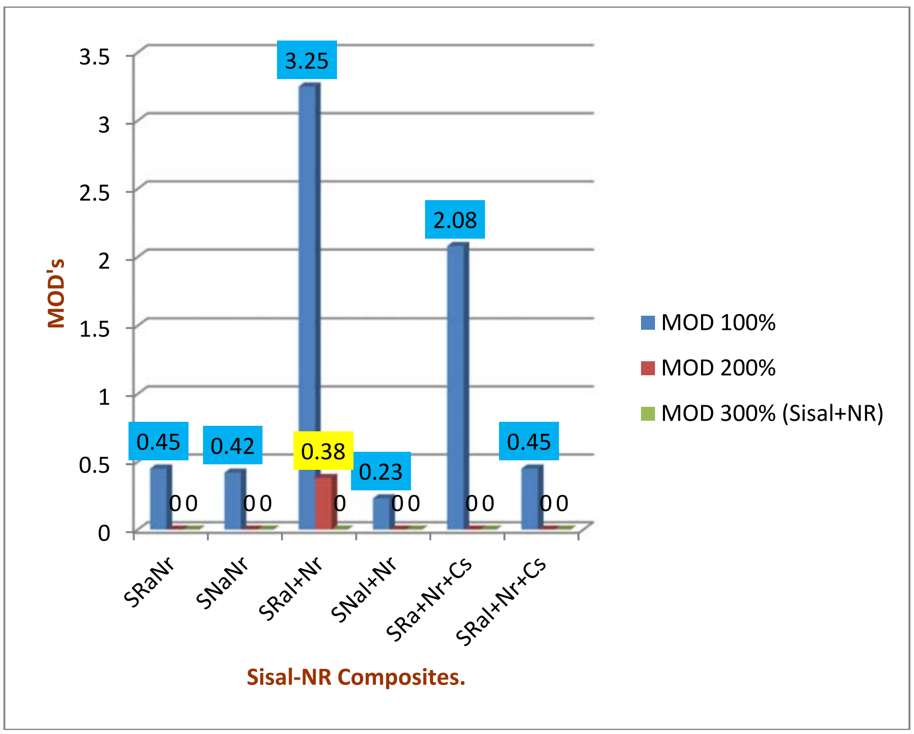

Figure-9. MOD 100%, 200%, 300%.

4. SOCIAL IMPLICATIONS

Natural rubber composites with natural fiber sisal as reinforcement find a lot of engineering and consumer applications and goods. Sisal has a high modulus and rigidity. When this fiber, subjected to various surface modifications is embedded into natural rubber matrix, a composite with better mechanical properties obtained. This material with improved tensile and tear strengths can be used in making of wear resistant and anti vibration pads, floor mats, door panels, load bearing bushes etc. These materials find applications in automobile parts, aerospace industry, machinery supports etc. to name a few.

5. CONCLUSIONS

A composite with better mechanical properties prepared using natural rubber and surface modified sisal fibers. The materials exhibited better tensile& tear strengths. A tensile strength improvement of 73% obtained

ARPN Journal of Engineering and Applied Sciences

for composite with alkalized impregnated fiber compared to rubber. Tear strengths showed an improvement of 246.1% for impregnated alkalized fiber-rubber composites.

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