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Comparative Analysis of Polypropylene Composites, Reinforced By Sisal and Hemp.

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Abstract: *Polypropylene of grade H110MA (homopolymer) was reinforced by two different fibres individually. The process taken into consideration was compression moulding technique in which the compounding temperature and compression temperature was set at 190° C and the compression pressure was ranged from 180-200 kgf/cm². The fibres considered were short fibres of sisal and hemp of fibre length of about 30-40 mm. The pattern of fibre orientation was in a discontinuous and random manner. In this experiment the polymer (PP) is reinforced using Sisal and Hemp individually and certain tests were conducted on the samples to compare the properties between them. The tests that were conducted were tensile strength, compressive strength, elongation, tensile modulus. FESEM tests were also done on these samples to check their structural behaviour after testing. Sisal reinforced composites showed better and improved mechanical properties than the hemp reinforced composites. Although the enhancement in the tensile strength is more in case of hemp reinforced composites but overall the enhancement in properties is better in case of sisal reinforced composites. Thus it can be concluded that the sisal reinforced polymer composites should be preferred over hemp reinforced composites. The results are discussed later and it concludes.*

1. INTRODUCTION

We now live in a world that is varying and rising at persistent rate. Each new day we are presented with modern inventions which are two steps advance than the previous. Feasibility and effective techniques are the major keywords. Ideas of new minds has directed to the progress of newest and wanted technologies in the world of manufacturing.

Concentrated efforts are being made by researchers and scientists in both research and educational organisations to manufacture polymer composites based on renewable means, such as plant seed oils and natural fibers, to improve their physical, structural, and
mechanical properties. There are various continuing research projects targeting to manufacture composites with natural fibers as reinforcements and polymers from renewable resources as matrices. There is a developing market for bio based polymers, which is predictable to rise significantly in the future. Natural fibers, such as flax, jute, sisal, hemp, and ramie, are presently being used as reinforcements in composite manufacturing. The composite has greater strength and rigidity compared to neat polymer which is due to the high strength and modulus of fiber. These natural fibers are based on cellulose and are eye-catching because of their biodegradability, light weight, low combustibility, nontoxicity, nonabrasive nature, and low cost.

Current development in compounding technology progresses their competitiveness compared to conventional reinforcing means such as glass fibers and mineral particles. Compounding hemp/sisal together with polypropylene can afford an attractive combination of high definite stiffness and strength, less abrasion during processing, low density, and low price. An important feature of the compounding procedures is the addition of compatibilizers, which are essential to overcome incompatibility between the natural fibre and the polymer. Inadequate compatibility frequently is accompanied by significantly reduced impact and tensile strength.

Substantial developments in mechanical properties have also been accomplished by the reinforcing efficiency of fibers coupled with improvement through chemical modification to encourage bonding at the fiber–matrix interface. Natural fibers have a benefit over glass fibers in that they are cheap and richly accessible from renewable resources and have a high precise strength. For certain applications, the mechanical properties of natural-fiber composites, such as those made from flax or hemp fiber, are not satisfactory because of the low strength of these fibers. However, combining natural fibers with stronger synthetic fibers, such as glass, could offer an optimal equilibrium between performance and cost. The interfacial adhesion of the fiber and matrix are of greatest importance to the mechanical properties of composite materials, and one way to mechanically progress the interface is to attain effective chemical bonding between the polymer matrix and the fiber.

Chemical bonding can usually be enhanced by fiber surface treatment, the coating of the fiber, or the addition of a coupling agent. Certain drawbacks of natural fibers are their moisture uptake, quality variation, low thermal stability, and poor wettability.

1.1. FIBRE TO MATRIX INTERFACES IN NATURAL FIBRE

The performance and stability of fibre-reinforced composite materials depends on the growth of coherent interfacial bonding between fibre and matrix. In natural fibre-reinforced composites there is a deficiency of good interfacial adhesion between the hydrophilic cellulose fibres and the hydrophobic resins due to their inherent incompatibility. Short, cellulose-based fibres will also tend to agglomerate making their use in reinforced composites less attractive. The existence of waxy elements on fibre surface contributes massively to ineffective fibre to resin bonding and poor surface wetting is witnessed. Also the existence of free water and hydroxyl groups, specifically in the amorphous regions, worsens the skill of plant fibres to grow adhesive characteristics with most binder materials. High water and moisture absorption of the cellulose fibres reasons swelling and plasticising effect resulting in dimensional instability and poor mechanical properties. Plant fibres are also prone to micro - biological attack leading to weak fibres and decrease in their life period (Bisanda and Ansell, 1992).

Fibres with high cellulose content have also been found to have high crystallite content. These are the sums of cellulose blocks held together narrowly by the strong intra-molecular hydrogen bonds which large molecules, for example dyes, are not capable to breach if the cell wall is swollen. Fibres are, therefore, generally exposed to treatment such as mercerisation and acetylation, with or without heat, to first bulk or swell the cell wall to permit large chemical molecules to enter the crystalline regions.

1.2. PLANT FIBRES AS REINFORCEMENTS FOR COMPOSITES

The upsurge in the application of plant fibres as reinforcement for polymeric substrates has been encouraged by the environmental cost of manufacturing energy-intensive, synthetic fibres such as glass, carbon and kevlar. However, whereas synthetic fibres can be manufactured with engineered properties to suit particular uses this is not the case with naturally occurring plant fibres. Properties of the cellulose fibres hinge mostly on the nature of the plant, vicinity in which it is developed, age of the plant and removal method used. For example, sisal is a hard leaf fibre but jute and hemp are both bast fibres and are generally referred to as 'soft' fibres to separate them from the hard leaf fibres. Both leaf and bast fibres are multi-cellular with very small separate cells bonded together.

The mechanical properties of plant fibres are largely connected to the amount of cellulose, which is closely linked with the crystallinity of the fibre and the micro-fibril angle with respect to the main fibre axis. Fibres with high crystallinity and/or cellulose content have been found to keep higher mechanical properties. Sisal fibres with a cellulose content of 67% and micro-fibril angle of 10-22° have a tensile strength and modulus of elasticity of 530 MPa and 9-22 GPa respectively. On the other hand, coir fibre with a cellulose content of 43% and micro-fibril angle of 3049° is described to have a tensile strength and modulus of elasticity of 106 MPa and 3 GPa respectively. This dissimilarity in the mechanical properties with enlarged microfibril angle displays an important role in defining the mechanical properties of fibre reinforced composites. In addition it is essential to optimise fibre alignment parallel with the direction of applied force to optimize tensile properties.

1.3. COMPRESSION MOULDING

Compression moulding technique has been taken into consideration for manufacturing plastics and polymer composite products. Numerous products can be formed with the help of compression moulding technique fluctuating from simpler structures such as fuse box, pot handles, automotive parts, aircraft parts etc. The machining cost of compression moulding is very fewer in comparison to injection moulding and transfer moulding. In a compression moulding the plastic is in a liquified state which is forced into the mould by high pressure and heated to change to the wanted shape.

Working Principle

In a compression moulding the obligatory quantity of plastic is heated primarily and kept in the bottom half of the heated mould before pressing it into the mould. Then the moulding unit is enclosed with the upper half of the mould and consequently high pressure is applied to pressurise the polymer material into the mould and henceforth the polymer is in the shape of the wanted mould. The temperature of the mould differs from 135-205°C and pressure applied by the mould is about 7-25

MPa, in many cases 180-200 MPa. Now the mould is kept aside for quenching and after that the mould is undone and the quenched plastic is taken out using ejector pins to acquire the desired shape.

2. EXPERIMENTAL SETUP

The raw materials and the gadgets crucial for carrying on the research are as follows:

- Sisal fiber
- Hemp fiber
- Polypropylene (H110MA)
- Weighing machine
- A Two Roll Mill
- A Compression Molding Machine
- Vernier Calliper
- Silicon Spray

The parameters that were considered were:

Sisal percentage considered

- 5%
- 10%
- 15%

Hemp percentage considered

- 5%
- 10%
- 15%

Compression temperature and compounding temperature considered:

- 190 °C

Compression pressure considered

- 50 kgf/cm² (Breathing Pressure)
- 180-200 kgf/cm² (Compression pressure)

1.A two-roll mill- The necessity of the two roll mill is to carry out the compounding technique in which a rounded bulk of polymer composite is accomplished. The specifications of the two- roll mill are as mentioned below:

Table 1: Specification of two roll mill

Temperature range	50°C-300°C
Time range	0-99.9min
Thickness variation	0.5 -5mm

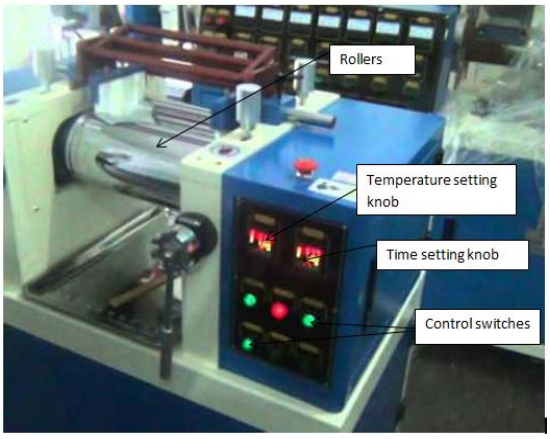

Fig 1.A Two Roll Mill

2. Compression moulding machine- This is the process in which the compounded bulk of composite is put into a certain mould to get a unvarying shaped composite which can be used for auxiliary testing. The compression moulding machine that was used in the experiment was a hand compression moulding machine with the specification mentioned below:

Table 2: Specification of Compression moulding machine

Compression capacity	30 Ton
Pressure range-	0-300 kgf/cm²
Heating capacity	50°C-300°C
Mold dimension	175X175X3.5 mm
Mold platen dimension	300X300 mm

Fig 2.A Compression Moulding Machine

<u>The Experiment Procedure carried out for compression moulding technique-</u>

Steps 1- Firstly the balls of PP were spread over the two roll mill where the phase change of PP takes place. The PP liquefies as the rolls get heated.

In this research the melting temperature taken was 190°C and roll speed was set at 40 rpm.

Step 2- Now in the molten PP the needed masses of fibre (in this case 5%, 10% and 15 % of sisal/hemp) are spread from the top to get a proper bonding among the plastic and the sisal/hemp fibre. Now the sample is left to cool. By this technique the mixture achieved is a rounded bulk of the composite which should to be compacted further for conducting several tests.

Step 3- The overhead practice is recognised as compounding method and each compounding method consumes about 10-25 minutes reliant on the sample to be prepared.

Step 4- After achieving the rounded bulks of polymer fibre composite of different fibre configuration these masses are conceded forward for compression technique to carry on. For this research a hand compression moulding machine was considered.

Step 5- In the compression moulding procedure there are two metal square plates which is used as concealment from the above and bottom of the mould in which silicon spray is applied for better ejection of the sample from the mould.

Step 6- Now the mass of composites accomplished from compounding procedure are kept into the mould and is compressed at a pressure of 50kgf/cm² and at a temperature set at 190°C for 30 seconds. This is familiar as the breathing pressure which is required to evacuate the air from the mould to prevent blow holes. After the breathing pressure the actual compression pressure is applied which ranges from 180-200 kgf/cm². The compression pressure is applied for at least 10 minutes for proper curing of the composites.

Step 7- After completion of 10 mins the compression pressure is liberated and the mould is left for air quenching. After cooling the sample is ejected out of the mould. This is the final sample achieved.

3. RESULTS AND DISCUSSION

The actual tensile strength of polypropylene is- **36MPa**

The actual compressive strength of polypropylene is- **29MPa**

The actual tensile modulus of PP is- **100 MPa**

The actual elongation of PP is- **1.9%**

Table 3.Mechanical properties of Sisal/PP composites

Produced by compression moulding

Test parameters (595 Watt)	5% sisal	10% sisal	15% Sisal
Tensile strength	55.80	59.50	62.70
Compressive strength	73	82.50	84.8
Elongation (%)	4.18	4.39	4.51
Tensile Modulus (MPa)	427	401	397

Table 4.Mechanical properties of Hemp/PP composites produced by compression moulding

Test parameters Compression moulding	5% hemp	10% hemp	15% Hemp
Tensile strength	55.4	61.2	67.7
Compressive strength	74.9	75.8	79.3
Elongation (%)	3.55	3.79	3.90
Tensile Modulus (MPa)	392	319	301

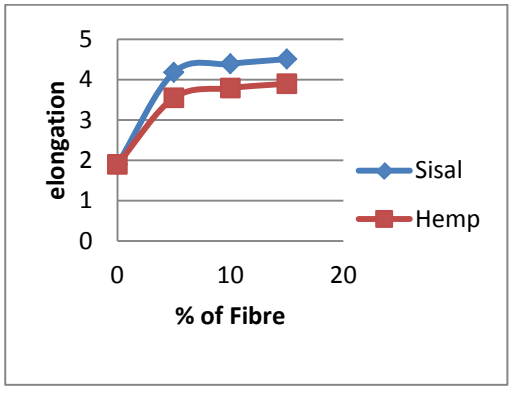

Fig 3.Comparison between sisal and hemp reinforced composites on the basis of elongation

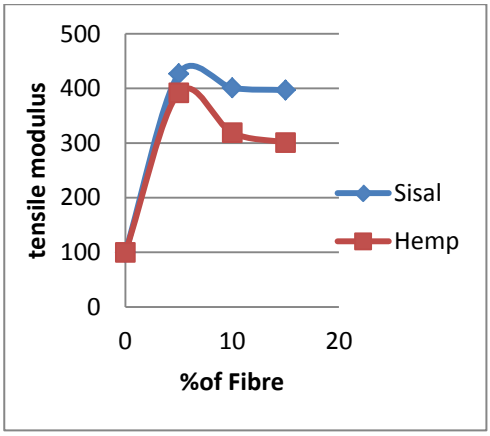

Fig 4.Comparison between sisal and hemp reinforced composites on the basis of tensile modulus

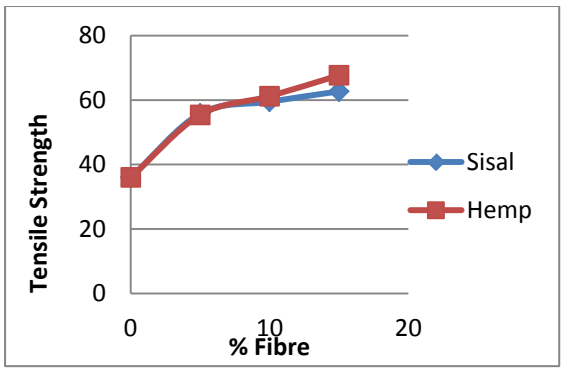

Fig 5.Comparison between sisal and hemp reinforced composites on the basis of tensile strength

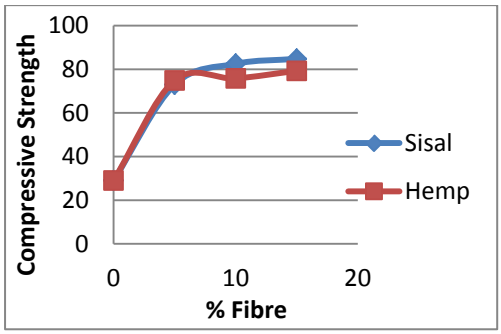

Fig 6.Comparison between sisal and hemp reinforced composites on the basis of compressive strength

3.1 FESEM images for both compression molding composites

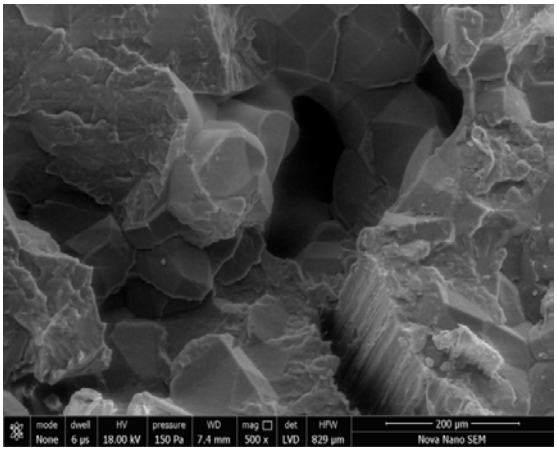

Fig 7.Pores in compression moulding of PP-hemp composites

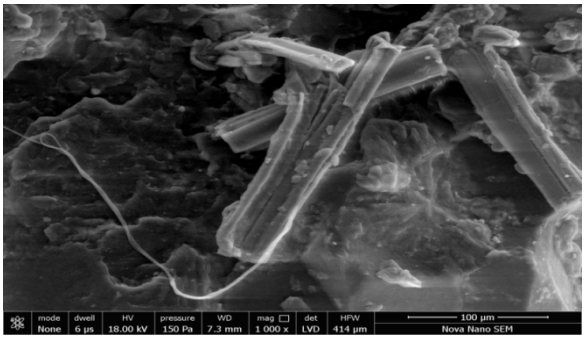

Fig 8.Hemp breakage in case of compression moulding

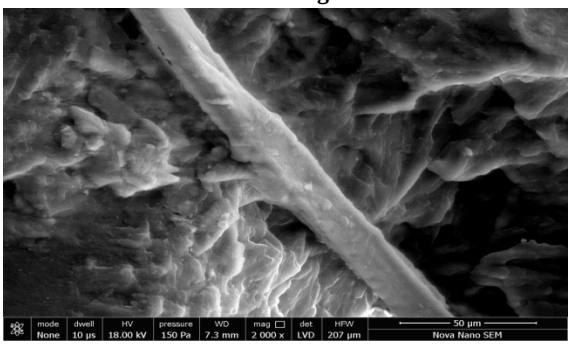

Fig 9.Proper Hemp-PP bonding in case of compression moulding

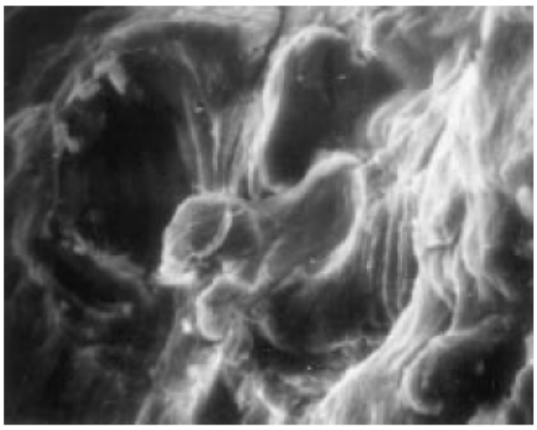

Fig 10.FESEM photograph showing tensile fracture surfaces of PP-Sisal composite

Fig 11.FESEM photographs showing sisal fiber splitting

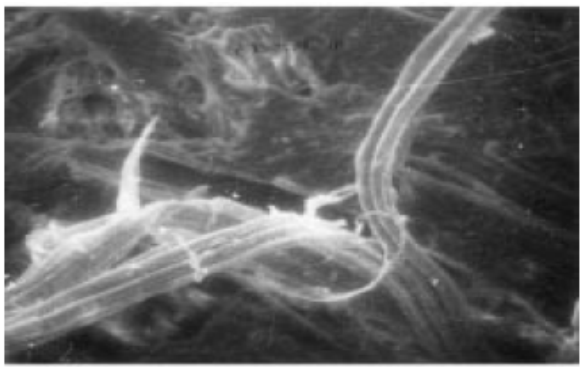

Fig 12.FESEM photographs showing peeling of sisal fibres

4. CONCLUSION

- It can be concluded that the tensile and compressive strength has increased from the parent polymer's strength on increasing the fiber content in case of both the fiber.
- The tensile strength of hemp reinforced composite is much more than the sisal reinforced composite. This is due to proper bonding of hemp with PP and also due to hemp's high individual tensile strength.
- The compressive strength of sisal reinforced composite is much more than the hemp reinforced composite. This is due to proper bonding of sisal with PP and also due to Sisal's high compression resistance property.
- The elongation of sisal reinforced composite has increased a lot than the hemp reinforced composite.
- The tensile modulus of sisal reinforced composite has also increased much more than the hemp reinforced composite.
- Thus we can conclude that sisal reinforced composite has shown much more improved mechanical properties than hemp reinforced composite.
- Hemp reinforced composite will cost less as the cost of hemp is much lesser the sisal and it has also shown improved properties than the base polymer matrix.

4.1. FUTURE SCOPE

- This reexamination can be passed on several fibers like Ramie, grewia optiva, coir, abaca, etc.
- Several measurements of fibres can be deliberated like short fibers, long fibers and mat-form fibers to compare with.
- Several other molding methods can be used like Injection molding, transfer molding, microwave for comparing with.

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