

VALORIZING DARBHA GRASS FIBRE TO DEVELOP ECO-FRIENDLY BIO-NANO COMPOSITE BASED ON PP / EPDM FOR IMPACT-RESISTANT APPLICATION

Project Report submitted to

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

In partial fulfilment of the requirements for the award of the degree of

**BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING**

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(Validity June 2019 to June 2022)

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JUNE 2022**

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CERTIFICATE

This is to certify that the report entitled “Valorizing darbha grass fibre to develop eco-friendly bio-nano composite based on PP / EPDM for impact-resistant application” is a bonafide record of project presentation done by AKHIL K (MUT18ME008), BHARATH P B(MUT18ME022), JONATHAN REGGIE EBENEZER (MUT18ME038), SAI NIVED M V (MUT18ME055) during the year 2021-2022. This report is submitted to APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering.

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ACKNOWLEDGEMENT

First of all, we thank God Almighty for helping us to successfully start our final year project.

We express our sincere thanks to **Dr. Manoj Kumar K**, Head of the Department, Mechanical Engineering, for his whole-hearted support and guidance in initiating the project.

We express our sincere gratitude to **Dr. Praveen K M**, Assistant Professor, Dept. of Mechanical Engineering, and **Prof. Rony Thomas Murickan**, Assistant Professor, Dept. of Mechanical Engineering who were our guides for the final year project for their valuable contributions, suggestions, and guidance without which this project would not have happened. We thank all the staff members of the Mechanical Department and my friends for all help and coordination extended in bringing out this project with a valuable team.

We express our sincere gratitude to our external guide **Dr. Neetha John** (Central Institute of Petrochemicals Engineering & Technology) for her valuable contributions, suggestions and guidance for the project. We also thank all the staff members of CIPET for helping us with our experiments and using the facilities.

We will be failing in duty if we do not acknowledge with grateful thanks to the authors of the references and other literature referred to start the project work.

Last but not the least, we express my sincere thanks to all those who directly or indirectly supported me in all stages of the course of the initiation of the project.

ABSTRACT

Nowadays, the automotive industry is under increasing pressure to fulfil environmental and performance demands and higher fuel efficiency at competitive costs. Automakers recognize the potential in biocomposites if these materials can offer the same performance as traditional composites but with a lower weight. Additionally, they exhibit non-brittle fracture on impact, which is another significant requirement for the automotive sector. Other drivers that score for use of natural fibres reinforced polymer composites (NFRPC) in automotive applications imply reduced waste disposal, reduction of greenhouse gas emission, and Life Cycle Consideration.

Synthetic fibre reinforced polymeric composites are inappropriate for various applications due to their high cost and lack of recoverability. On the other hand, natural fibre-based polymer composites are partially biodegradable and have significantly lower pricing than most regularly used synthetic fibres, especially in composite manufacture. Darbha fibre is a well-known natural fibre with a low density and has a lot of promise for usage as composite reinforcement. The growing demand for natural fibre-reinforced composites, as well as the unique qualities of Darbha fibres highlight the need to investigate the mechanical properties of darbha fibre based composites. Polypropylene in its pure form does not possess much impact strength, So it has to be toughened for impact-resistant applications, this can be achieved by the addition of an elastomer. The composite was prepared by blending PP, EPDM & Dharba fibres using twin-screw extruder, and samples were prepared using injection moulding . The PP/EPDM percentage is kept constant at 100/25 (wt percentage) and the fibre percentage is varied. Samples with 5%,10%,15%, and 20% fibre are made and tensile, flexural, impact, hardness, FTIR, and DSC tests are conducted.

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LIST OF ABBREVIATIONS

PP	Polypropylene
TPE	Thermoplastic elastomer
FTIR	Fourier Transform Infrared
ASTM	American Society for Testing Materials
EPDM	Ethylene propylene diene monomer
SRT	Scrap rubber tyres
UTM	Universal testing machine
SEM	Scanning Electron Microscopy
NFRPC	Natural Fibre Reinforced Polymer Composites

CHAPTER 1

INTRODUCTION

Thermoplastic elastomers are thermoplastic polymers that are either amorphous or semi-crystalline with rubbery characteristics. That is, they are processed using standard plastics machinery such as injection moulders, blow moulders, sheet and profile extruders, and so on, but once chilled, they take on their final rubber-like qualities. Traditional rubbers, on the other hand, need to be vulcanised before they can be used. This is a delayed and irreversible process caused by heat. The change from a processible melt to a solid rubber-like item in thermoplastic elastomers, on the other hand, is quick, reversible, and occurs during cooling. Several thermoplastic elastomers may be dissolved in ordinary solvents and then re-evaporated to restore their characteristics.

TPEs are gaining appeal among designers as a consequence of the cost reductions that may be realised by processing them with plastics technology. For natural or synthetic rubber, vulcanization, a chemical cross-linking process that happens during moulding or extrusion, is necessary. The time it takes for the vulcanization reaction to finish varies depending on a variety of conditions, although it can take anywhere from one minute to many hours. TPEs, on the other hand, are manufactured using thermoplastic moulding and extrusion procedures that do not need cross-linking and can result in short cycle times.

Elastomers are amorphous polymers with a high degree of flexibility and deformability. They are made up of polymeric chains that are joined in a network structure. Elastomers are good for energy dissipation since they have excellent damping properties. Elastomers are used in a range of applications, including car tyres and conveyor belts, adhesives, and the aerospace industry, to name a few. Elastomers must be crosslinked to obtain rubber elasticity, and certain elastomers have hyperplastic characteristics and behave like thermoplastics. Due to the poor tracking and erosion resistance of pure elastomers (rubbers and thermoplastic elastomers),

numerous elastomer properties need to be changed to increase service life and impact. Elastomer fillers can enhance some properties while cutting expenses.

In recent years, there has been an upsurge in demand for items created from non-petroleum-based renewable and sustainable resources. Natural fibres are employed in biocomposites in a number of ways instead of synthetic and glass fibres. Darbha fibre is the fibre of choice for our research. The strength of these fibres is not investigated. Although these green composites do not have the same mechanical properties as glass fibre reinforced composites, they are suitable for use in housing, secondary and tertiary structures, automotive, textiles, packing materials, and entertainment accessories due to their low mechanical properties and biodegradability. Natural fibres are less costly, have a higher stiffness per unit weight, and have a lower impact on the environment. In the transportation industry, natural fibre-reinforced polymer (NFRP) composites are gaining traction as a replacement for metals and synthetic fibre composites. The need to build lightweight and fuel-efficient cars has sparked a greater interest. Furthermore, stronger rules and increased environmental awareness are driving the transportation industry to employ low-carbon products. NFRP composite materials are an ideal alternative in this case due to their inexpensive cost, limited environmental impact, and nearly equivalent attributes to metals and other composites.

Our study used polypropylene as the thermoplastic in its true form polypropylene does not possess much impact resistance or toughness properties. This can be improved by blending it with a suitable elastomer. The elastomer that we used in our study is EPDM which is extremely durable, hard, and flexible. A good PP/EPDM composite depends on the following factors: (i) The molecular property(configuration, constitution, molecular mass distribution, and molecular mass); (ii) The crystallisation, blending, and processing conditions. But in using EPDM the tensile properties of polypropylene decreases in order to improve tensile properties a ternary phase or fibre material is added. Darbha fibre is used for this.

CHAPTER 2

LITERATURE REVIEW

Polypropylene (PP) is a polyolefin polymer that is frequently used. In the field of PP resin modification, toughening has been one of the most active and significant themes. EPDM (ethylene-propylene-diene copolymer) is commonly used to toughen PP. Currently, adding elastomers to the modified resin can increase its impact strength by four times when compared to the matrix.

The work carried out by Maddah et.al [1] examines polypropylene (PP) from a variety of perspectives. The goal of this research is to demonstrate that polypropylene is a promising plastic by demonstrating its excellent chemical, physical, and mechanical properties, by understanding and comparing PP types and thermoplastics to determine their advantages and disadvantages, by providing a comprehensive explanation of the Dow/UNIPOL PP technology process, and by including extensive reviews on an infinite number of PP applications. PP is discovered to be the most important propylene derivative, accounting for two-thirds of total consumption. With a density of 0.90 g/cm³, PP is the lightest form of plastic.

Shirvanimoghaddam et.al [2] studied the overview of Polypropylene's toughening mechanism as well as insights on several strategies for reaching the proper balance of strength and toughness in thermoplastic composites. The term "toughness" is used in this paper to refer to both macro and micro-level toughness, as well as structural toughness and composite impact behaviour. The parameters that affect the effectiveness of toughened polymer composites are thoroughly examined. The adoption of different tactics or combining a couple of strategies for boosting the fracture toughness of thermoplastic composites is promoted by addressing current issues and future directions in toughening mechanisms in thermoplastic composites.

Engineering plastics and metals have been substantially replaced by polypropylene (PP) based materials in vehicle parts to achieve weight reductions and cost benefits. PP compounds made from PP and other components are being explored intensively to achieve this. In this work, Sumitomo Kagaku et.al [3] looks at how compounding technology has progressed, as well as how mechanical qualities and functionalization

have improved. Injection moulding difficulties and remedies are also summarised. In addition, new material advancements for reducing environmental load are shown.

Mohammad Khoirul Huda et.al [4] focuses on the advancement of polymeric materials used in the automotive industry. Several top vehicle manufacturers have created and developed products using NFRP or recycled plastics with natural fibre reinforcement because they are reasonably cheap, lightweight, and capable of reducing exhaust emissions, according to a review of selected research. The huge potential of using NFRP materials and recycled plastics in the automobile industry poses a future concern, notably the long-term demand for natural fibre, which will undoubtedly have an impact on ecosystems and biodiversity.

Helson Moreira da Costa et.al [5] work to improve PP's impact toughness and extend its application range by using different methods of toughening and reinforcing PP. A single screw extruder was used to make mixtures of ground scrap rubber tyres (SRT) and polypropylene (PP); ethylene–propylene–diene terpolymer (EPDM) and PP; and ground SRT, PP, and EPDM. All formulations were tested for impact strength and thermal characteristics. With increasing SRT or EPDM loading, the crystallisation temperature (T_c), degree of crystallinity (X percent), and heat of crystallisation (DH_c) are all reduced. The thermal characteristics of PP/SRT/EPDM compositions showed the same or a similar effect depending on the amount of SRT/EPDM. Impact strength did not improve much with SRT; nevertheless, when combined with EPDM (PP/SRT/EPDM 50/30/20 percent w/w), PP impact strength increased unexpectedly.

A N Balaji et.al [6] goal of this study was to identify new natural cellulosic kusha fibres derived from kusha grass plants. The physical and chemical parameters of kusha fibres were determined, including cellulose content (70.58%), lignin (14.35%), wax content (1.52%), ash content (2.46%), moisture content (8.01%), and density (1.1025 g cc⁻¹). The presence of cellulose, with a crystalline index of 55.4 percent, is confirmed by X-ray diffraction of kusha fibres. To determine the confidence of employing them as reinforcement fibre, a Fourier transform infrared spectroscopic investigation was performed. Thermal stability is ensured by thermogravimetric analysis up to 357°C, which is within the polymerization process temperature range.

The causes that prompted various automakers to do research on biocomposites were highlighted by J Agarwal et.al[7] , since they play a vital role in biodegradability and sustainability around the world. In particular, cellulose nanofiber-reinforced composites are the current research emphasis, as they may be used for a variety of automotive applications and offer several benefits and accessibility. Polypropylene (PP) is a developing polymer in the automobile industry, and many researchers are currently concentrating their efforts on PP-based composites, which might be a boon for a variety of current environmental issues. Natural fibre-reinforced composites are the excellent alternatives to the synthetic fibre-strengthened composites due to their attractive properties which includes low cost and density, weight reduction, design flexibility, and green conduct. Even though having those attractive properties, they have less durability, low modulus and are hydrophilic in nature.

Natural fibres as composite reinforcement is now being studied for its extraction process, physical qualities, chemical properties, and mechanical capabilities. Researchers are drawn to natural fibre because of its high specific strength, light density, low cost, good mechanical qualities, non abrasive nature, environmental friendliness, and biodegradability. A quick review was conducted by IP Lokantara et.al [8] for the use of Indonesia's plentiful natural fibres. Mendong grass, Snake grass, Kusha grass, Arundo donax L, Sansevieria ehrenbergii, Sansevieria cylindrica, Elephant grass, Napier grass, Sansevieria trifasciata, Broom grass, Sisal, Corn husks, and Belulang grass are all discussed in this study.

The influence of natural fibres derived for composite manufacture from milkweed, kusha grass, sisal, banana, and hay mixed with polypropylene 10:90 was investigated by K Hariprasad et.al [9]. ASTM standards were used to determine mechanical qualities such as tensile strength and hardness. Water absorption experiments have also been carried out to determine the water's ability to absorb. A thickness of 10 mm and 20 mm is used to characterise the acoustic properties of these natural reinforced fibre composites. Increased thickness is ineffective at higher sound absorption frequencies, according to the findings. Microstructures of milkweed fibre are examined using a scanning electron microscope. These findings point to materials that are suited for a variety of mechanical and automotive applications.

M S Fogorasi et.al [10] covers a wide range of topics, with a focus on fibre mechanical characteristics, interface adhesion, and NFRPC's environmental implications. The purpose of this discussion is to relate the chemical composition, microstructure, and mechanical properties of cellulosic/lignocellulosic fibres, as well as to understand their use and limitations as reinforcements in composite materials. atment on the mechanical properties of the resulting NFRPC is also reviewed.

CHAPTER 3

OBJECTIVES OF THE PROJECT

1. To develop an impact-resistant composite using polypropylene/EPDM/Darba fibre for automotive impact-resistant applications.
2. To analyse the different functional groups present in darbha fibre using Fourier Transform Infrared Spectroscopy(FTIR).
3. To analyse the mechanical properties (Impact, Tensile, Hardness, and flexural) of the developed composite.
4. To evaluate the fracture morphology of the developed composite.

CHAPTER 4

MATERIALS AND METHODOLOGY

Materials

Polypropylene

Polypropylene (PP) is a propylene monomer-based thermoplastic "addition polymer." It has a market share of 65-75%. PP has a crystallinity of 40-60%. It is a homo-polymer (PP with only propylene monomer in a semi-crystalline solid form) with a density of 0.90 g/cm³. It is the lightest type of plastic with high chemical and temperature resistance. It is created through a process of monomer connection called addition polymerization.

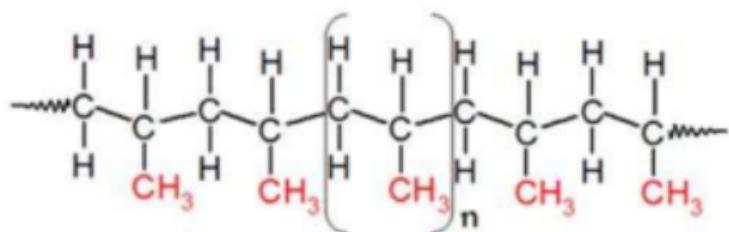


Fig 4.1 Polypropylene Structure

Polypropylene which is a low cost thermoplastic polymer, has three specific relatable configurations: atactic-irregular arrangement of methyl group, syndiotactic-methyl groups alternate on both sides, and isotactic-methyl groups on one side of polymer backbone.

This homopolymer has both crystalline and non-crystalline(amorphous) regions. The amorphous region has both isotactic PP and atactic PP. The isotactic PP crystallises over time. So this homopolymer mostly consists of an isotactic propylene unit that provides a definite structure to the overall PP. Therefore this PP at room temperature has high stiffness and high melting point, but lower transparency and lower impact strength.

Some of the properties of Polypropylene are: good flame resistance, good heat resistance, recyclability, dimensional stability, good electrical resistance, low water absorption, and high glass transition point.

It's used in consumer packaging, plastic parts for many industries, such as the car industry, and textiles, to name a few. Bumpers, chemical tanks, wire insulation, and gas cans are all made of PP in the automotive industry. Polypropylene is a common thermoplastic binder component in natural fibre composites. Just a few examples are door panels, consoles, seatbacks, trunk liners, and other vehicle applications. In recent studies it showed that due to the environmental adaptability of PP, its consumption rate will continue to drastically increase in the coming future.

The polymer matrix we used in our research was Repol H350FG. Polypropylene with a melt flow index of 38g/10 min(230/2.16 Kg) is available from Reliance Industries Ltd. in Mumbai, India.



Fig 4.2 PP H350FG

Ethylene Propylene Diene Monomer

EPDM is an unsaturated polyolefin rubber that has received a lot of attention for outdoor applications like automotive sealing systems, building profiles, electrical power cables, white side walls of tyres, roofing sheets, belting, and sporting goods, as well as ablative and insulator compounds used in solid propellant rocket motors. This is due to its exceptional capacity to tolerate high filler loadings as well as its excellent resistance to oxygen, ozone, UV, and heat.

The EPDM we used for our research purpose was Keltan 9565Q.

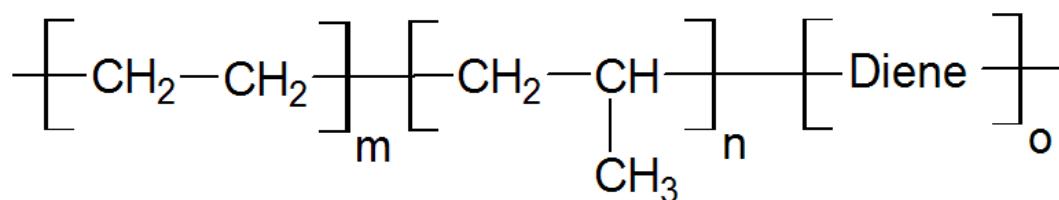


Fig 4.3 EPDM chemical structure

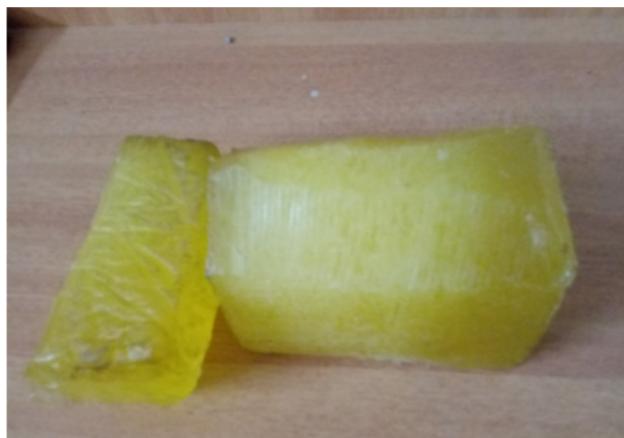


Fig 4.4 EPDM

Darbha fibres



Fig 4.5 Darbha grass

Darbha grass, which is scientifically called *Desmostachya bipinnata*, is in the family of Poaceae. In English, darbha is commonly known by the names Big cordgrass, Halfa grass, and Salt reed-grass. In India it is distributed in the hotter parts from Punjab to south-wards. This tropical grass which is considered a sacred material in Vedic scriptures is used to purify the offerings during rituals. Since darbha has the ability to prevent bacterial contamination, it is used in the traditional rituals for sacrificing offerings without any decay. The reduction of microbial accumulation in fermentable food or the disinfecting ability of Darbha is attributed mainly to the hierarchical micro/nano-features present on the grass surface. In recent research, Darbha has been observed to block X-Ray radiation, and no further studies have been conducted to prove this. It contains triterpenoids (arundoin, fernenon, Isoburneol, cylindrin, and simiarenol), which is an important agent for Anti-Cancer. In the medical domain, it is used for the treatment of nosebleeds, haematuria, diarrhoea, jaundice, haematemesis, oedema, also dysentery, and used as a diuretic (to promote the free flow of urine). Different studies have shown that Darbha fibre has an excellent electrochemical property that can be applied in supercapacitor applications, and also enhance the sound absorption properties.

The darbha fibres used in this study are collected from Ernakulam, Kerala ,India.

The constituents of Darbha fibre are given below in the following table.

Constituents	Composition
Cellulose content	70.58%
Lignin content	14.35%
Moisture content	8.01%

Table 4.1 Constituents of Darba fibre

The existence of cellulose, with a crystalline index of 55.4 percent, is confirmed by X-ray diffraction of darbha fibres. To determine the confidence of employing them as reinforcement fibre, Fourier transform infrared spectroscopy was used. Thermal stability is guaranteed up to 357°C, which is within the temperature range of the polymerization process.



Fig 4.6 Darbha fibre

METHODOLOGY

4.1 Preparation and characterization of darbha fibres

4.1.1 Water retting/Chemical retting

We begin by preparing the fibre that will be utilised as the ternary phase of the composite that will be developed. A method known as retting is used to separate the main elements contained in the fibre (such as cellulose and lignin). The retting procedure is divided into two categories: water retting and chemical retting. Water retting takes 6 months to separate the fibres, but chemical retting takes only 24 hours. We chose chemical retting for our research. Dharba grass is cut into 20cm lengths and a 10% NaOH solution is prepared by combining 1100g NaOH with 11000ml water. The Grass is then immersed in the solution for 24 hours before being removed.

After 24 hours, the cellulosic fibres are left behind, and many of the cellular tissues and gummy substances around the bast-fibre bundles are dissolved or decay away, allowing the fibre to be separated from the stem. To eliminate any contaminants or excess chemicals, the resulting fibres are carefully cleaned. To eliminate moisture, the washed fibres are sun-dried for 5 days.

Weighing of Darbha grass

The long darbha grass which is brought from the stores is shortened for the retting process. The Fibre was weighed in a weighing machine to obtain 500g which was then placed inside the plastic bowl.



Fig 4.7 Weighing of darbha grass

Preparation of NaOH solution

For chemical retting NaOH solution is used. NaOH solution (containing water with 10% NaOH) was created in a 4000 ml beaker. A total of 11000 ml of water with 1100 g of NaOH was prepared.



Fig 4.8 Preparation of NaOH solution

The NaOH solution prepared was poured in the plastic bowl containing the darbha grass and kept at optimum temperature for 24 hours.



Fig 4.9 Adding NaOH solution into darbha grass

Retting after 24 hours

After 24 hours NaOH solution turns to greenish-yellow which indicates that lignin and cellular tissues around the bast-fibre bundles are dissolved, allowing the fibre to be separated from the stem and only fibres are left behind.



Fig 4.10 Retted darbha grass

Cleaning process

The darbha fibre was initially separated from the NaOH solution. The separated darbha fibre is washed thoroughly to remove the remaining NaOH and Lignin content.



Fig 4.11 Cleaning of darbha fibre

Drying process

The washed darbha fibre is collected and dried at ambient temperature for 3 days.



Fig 4.12 Drying of darbha fibre

4.1.2 Fibre constituent testing

FTIR (Fourier Transform Infrared spectroscopy) is conducted to identify the changes in fibre after retting. After that, if the fibre doesn't meet up with the required properties like interfacial adhesion, percentage of moisture content, etc, then the fibre will have to be implemented with various surface treatment processes.

The FTIR testing machine is a Spectrum Two FTIR Spectrometer that has the standard ASTM E 1252, and ASTM D 5477. It has a testing wavelength range of 4000-450cm⁻¹. It is mainly used for the identification of oxidation, identification of

contamination, identification and characterization of unknown materials, identification of additives after extraction from the polymer matrix, and the decomposition of uncured monomers in failure analysis.

Fourier Transform Infrared Spectroscopy is a technique that is used to obtain transmission or absorption of Infrared (IR) Spectrum using the test sample. This helps in recognizing the occurrence of different functional groups present in the sample provided. The x-axis indicates the wavenumber that provides the frequency of transmission or absorption of the Infrared Spectrum which ranges from 450 on the right to 4000 on the far left. The y-axis indicates Transmittance which provides the intensity of transmission or absorption, and it ranges from 0 at the bottom to 100 at the top.

In the Infrared spectrum, we have various points that stand out called peaks, and to understand an IR spectrum, we need to actually know what each peak indicates. These peaks will help you find out what functional groups are present in the provided test sample. By making use of an Infrared Spectroscopy Table, we can tell which functional group is indicated on each peak based on their wave number.

The IR spectroscopy region is divided into two parts: the functional group region and the fingerprint region. The functional group region is from 4000 to 1500cm^{-1} and the fingerprint region is from 1500 to 450 cm^{-1} .

The IR radiation of about $10,000\text{--}100\text{ cm}^{-1}$ is sent through the test sample, and the part of the radiation is absorbed and travelled through the sample. The absorbed radiations in the test sample are converted into vibrational or rotational energy of the molecules. These absorbed energies are then converted to signals by the detector at the range of $4000\text{-}450\text{ cm}^{-1}$, which is used to represent the test sample molecules fingerprint.

The functional group regions contain fewer peaks due to the stretching vibration of the functional groups with a varying narrow range. Whereas the fingerprint region

consists of the bending vibrations of the molecules, which makes it too have a complicated pattern, thus making it difficult to identify individual peaks. However, the fingerprint region of a given compound is unique, and therefore can be used to distinguish between compounds.

Once an IR spectrum of an unknown compound is found, it is compared with the IR spectrum of the known samples of the compounds. If all the peaks of the fingerprint region are matched, the unknown compound is identified.

Since the test samples are quite difficult to analyse using the conventional FTIR spectroscopy method, the IR spectroscopy is combined with reflective theories to form the reflection IR spectroscopy. In this technique, the reflected light from the sample placed over a reflective surface is used for the extraction of the absorption properties of the sample. This technique compared to the conventional method requires less sample preparation and also collects the light reflected from the surface of the sample.

It is easy to use, powerful, compact, and robust. The Spectrum Two FTIR Spectrometer makes use of a high-performance DTGS (deuterated triglycine sulphate) MIR detector which is ideal for low light applications. The FTIR of the chemical-retted and water-retted darbha fibre along with the darbha grass is obtained under the operating range of 5 - 45 °C.



Fig 4.13 FTIR Spectrometer

4.2 Blend preparation

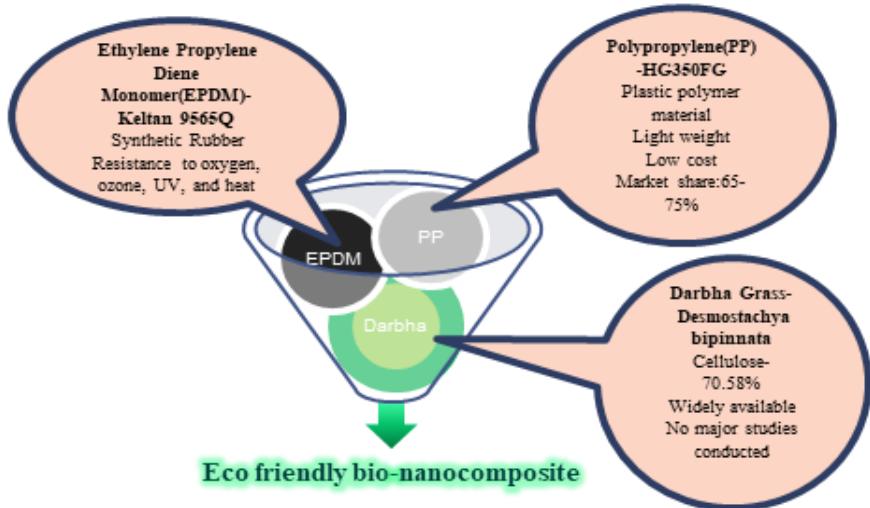


Fig 4.14 PP/EPDM/Darbha fiber composite

After the fibre extraction, the next step is blend preparation. Blend preparation is done thermally by using Twin-screw extruder. In impact-resistant applications, twin screw extruder is the most common method for the production of PP-based composites. Twin-screw extruder has high productivity as well as the ability to disperse the fibre and rubber phase properly within the matrix phase without any material degradation during manufacturing. Before feeding to the extruder, the EPDM block is first cut and rolled through a two roll mill into bands, these bands are then later manually cut into pellet size. The fibre is cut into its critical length which was found to be 20mm from the literature reference.

After preparing the materials, all the materials are carefully weighed according to the required compositions. The PP/EPDM composition is fixed to be 75/25 (weight percentage) and fibre percentage is varied, 5%, 10%, 15% & 20% fibre composition is made.

Sl No.	PP	EPDM	Darbha	Total
1	375g	125g	25g(5%)	525g
2	375g	125g	50g(10%)	550g
3	375g	125g	75g(15%)	575g
4	375g	125g	100g(20%)	600g

Table 4.2 PP/EPDM/Fibre composition

Each composition is properly mixed and fed manually into the extruder. The extruder consists of 4 zones and each zone has zonal temperatures as follows.

Zone	Temperature (degree celsius)
1	177
2	166
3	156
4	146

Table 4.3 Temperature zones of twin screw extruder



Fig 4.15 Twin screw extruder

The materials are thermally blended in a semi-solid state and noodle samples are produced. The obtained noodle sample is pelletized by using a scrap grinder. The scrap grinder is a Toshiba machine with a throat area of 200*150mm. It has three rotating blades and one fixed blade with a size of 195mm. The grinding output is 35-40 kg/hr which makes use of an electric motor of 1.5KW.



Fig 4.16 Scrap grinder

4.3 Injection moulding

Test samples must be made from the pelletized composite. Injection moulding is used to create dumbbell-shaped samples for our research.

One of the most extensively utilised manufacturing procedures is injection moulding. The material is delivered into the moulding machine's cylinder through a tiny aperture at the top of the cylinder, melted, and injected into the die under pressure during the injection moulding process. When the resin has hardened, the portion is evacuated after about one minute. We prepared a minimum of 15 test samples for each combination (fibre content: 5%, 10%, 15%, and 20%) of the PP/EPDM/Darbha composite required for testing.



Fig 4.17 Injection moulding machine

The injection moulding utilised is the OMEGA 80 WIDE model. It features a 1639 kg/cm² injection pressure and a 133 CC/sec injection rate. The nozzle and barrel temperatures were kept at 215°C and 220°C, respectively, throughout the operation.

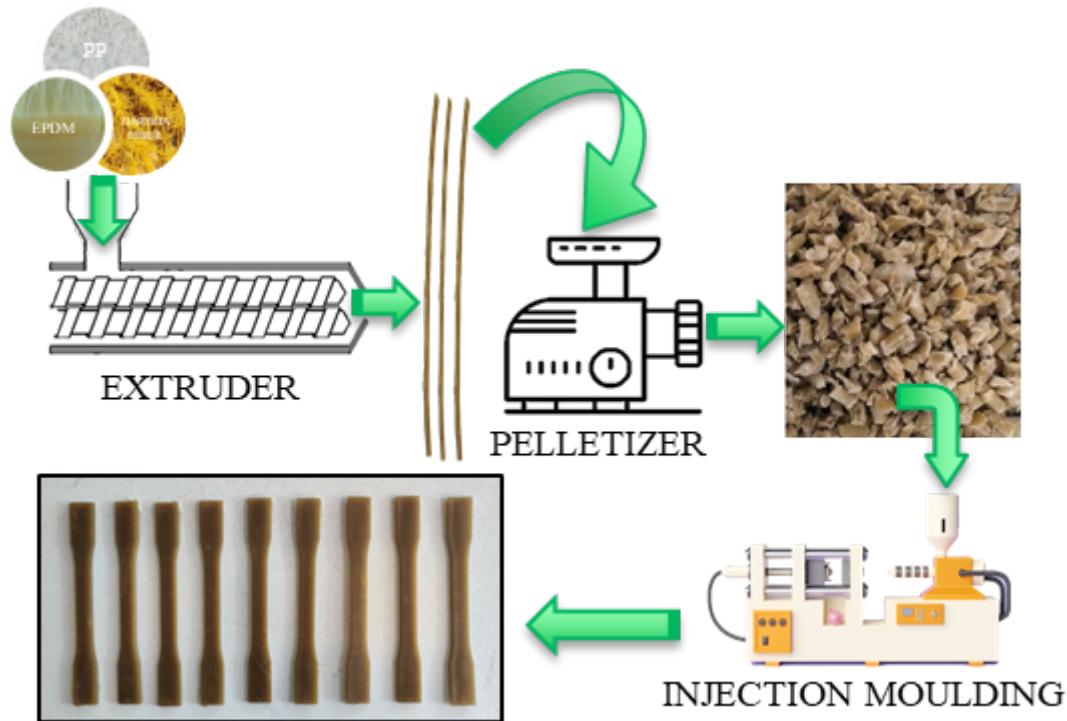


Fig 4.18 Preparation of test specimen

4.4 Mechanical testing

4.4.1 Tensile testing

Tensile testing is a destructive process which destroys the specimen during experiment in order to obtain test results. It provides information about the tensile strength yield strength and ductility of materials. It measures the force required to break the specimen. It provides much information about tensile strain, elongation, tensile modulus and elongation at break. It follows ASTM D 638 standard. Tensile test is conducted on UTM given in the figure 4.13. The test specimen is placed on the testing machine by fixing in two jaws and a strain gauge extensometer is connected to it and load is added to specimen until the test specimen is broken and different properties are identified from the test results.

Here the tensile strength was measured using dumbbell shaped pieces at a crosshead speed of 50mm/min at $25 \pm 2^\circ\text{C}$ using Universal Testing Machine with computer aided testing machine. ASTM D 638 was followed to measure the tensile strength and elongation at break. The average value of the mechanical parameters was calculated by using at least three samples. The testing speed was set as 50mm/min along with load 50 KN and the test was performed at room temperature. The test specimen dimensions are 164mm x 13mm x 3.6mm.



Fig 4.19 Universal testing machine

4.4.2 Impact testing

Impact test is used to determine how the material responds to a sudden stress act on it. It is used to understand properties like toughness, brittleness, and impact resistance of the material. Impact properties of the material have a great advantage in material liability and safety. The test specimen types include notch configuration mainly V-notch, U-notch, and key-hole notch.

Impact tests commonly consist of two types -Charpy and Izod test which is shown in the figure 4.8. The difference between the Charpy and Izod test is the way in which the notch is positioned facing the striker. Hence in the Charpy test the specimen is placed horizontally whereas in the Izod test it is placed vertically, like a fence post. In Charpy it measures the energy absorbed by the specimen while breaking. The test is conducted on a Pendulum Impact tester which is given in figure 4.8. It consists of a specimen with a pendulum arm which strikes the specimen. The energy absorbed by the specimen is determined by measuring the decrease in the motion of the pendulum arm. In the Izod test the impact strength is determined by measuring the loss of height in the pendulum swing. The factors which affect toughness of the material include low temperature, high strain rates, and stress concentrators such as notches, cracks and voids. In the Izod test it is carried out under ASTM D 256 and for the Charpy test, it is carried out by ASTM D 6110.

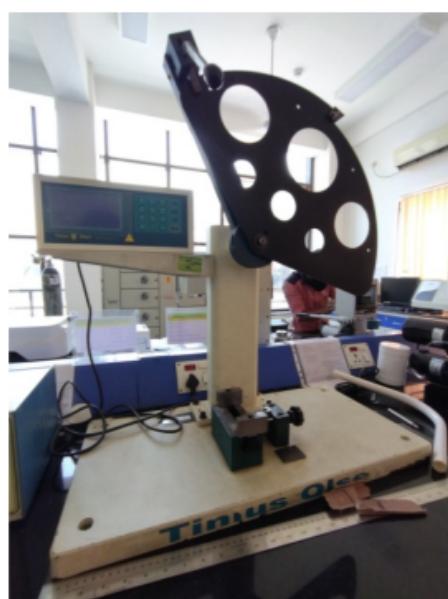


Fig 4.20 Impact testing machine

4.4.3 Flexural testing

The capacity to withstand deformation under load is defined by flexural strength, also known as modulus of rupture. The convex side of the specimen experiences tensile tension, whereas the concave side experiences compression stress. Shear stress develops along the midline as a result of this. Shear stress must be kept to a minimum to guarantee the primary failure is caused by tensile or compression stress. Three-point and four-point bend testing, as defined by ASTM D 790, are the most used flexural tests for plastics. The three-point flexural test is depicted in figure 4.14. Flexural strength, flexural stress, flexural strain at break, and material flexural strain may all be determined during a flexural test. This test can also give you the flexural modulus. The test's many characteristics.

This test can also be used to determine flexural modulus. Different attributes derived from test findings are critical in material selection for various applications.

The following equations are used to compute the rate of speed and deflection.

$$\text{Rate of speed} = (2zL)/(6d)$$

Where, Z=.01 (constant)

L=span length

d=depth / thickness

$$\text{Deflection D} = (2rL)/(6d) \text{ Where, r = .05 (constant)}$$

4.4 Hardness testing

The hardness of the specimen is measured using Durometer which is followed by the ASTM D 2240 standard. The instrument is basically two types. Shore A and Shore D. Shore A is used to find the hardness of soft materials whereas Shore D is used to find the hardness of hard materials. If the shore A value exceeds 90, then the shore D value has to be checked. The average value of the hardness should be calculated by using at least five sample values.



Fig 4.21 Shore D testing machine

4.5 Morphological analysis

4.5.1 Scanning Electron Microscopy

SEM analysis, or scanning electron microscopy, provides high-resolution imaging that may be used to inspect diverse materials for surface cracks, defects, impurities, or corrosion. We get a detailed investigation of material characteristics and provide significant insights to producers using SEM and EDX research. SEM visual study of a surface aids in the detection of impurities or unknown particles, the reason of failure, and material interactions.

SEM analysis is used for particle characterisation, such as wear debris created during mechanical wear testing, in addition to surface assessment. Our SEM analysis' high magnification, high-resolution imaging aids in the measurement of the quantity, size, and shape of tiny particles, helping clients to better understand their material's wear qualities.



Fig 4.22 Scanning electron microscope (SEM)

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 FTIR ANALYSIS

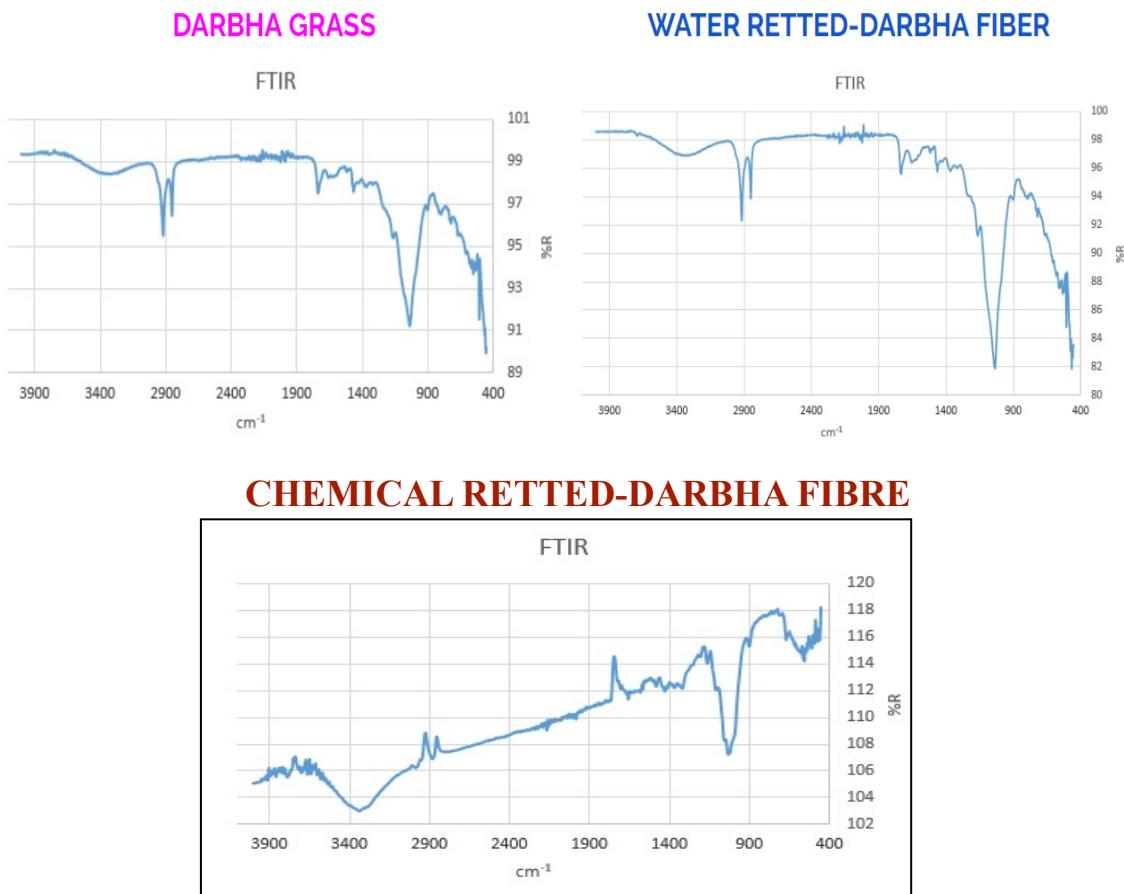


Fig 5.1 FTIR analysis

In this analysis, we were able to obtain the FTIR spectrum of the untreated, water retted(21 days) and chemical retted(24 hours) darbha grass, in the wavelength range of 4000-400cm⁻¹. From comparing the spectrum of untreated and water-retted darbha grass, we have an initial observation of both the spectrums having close resemblance, thus there is no major change in darbha grass after water retting. In the case of chemical retted darbha grass, there is a drastic change in the whole spectrum with greater intensity. As per studies, it stated that when the intensity of a functional group

at a particular peak increases, the bond strength of the chemical bond in that one peak increases, along with the increase in content.

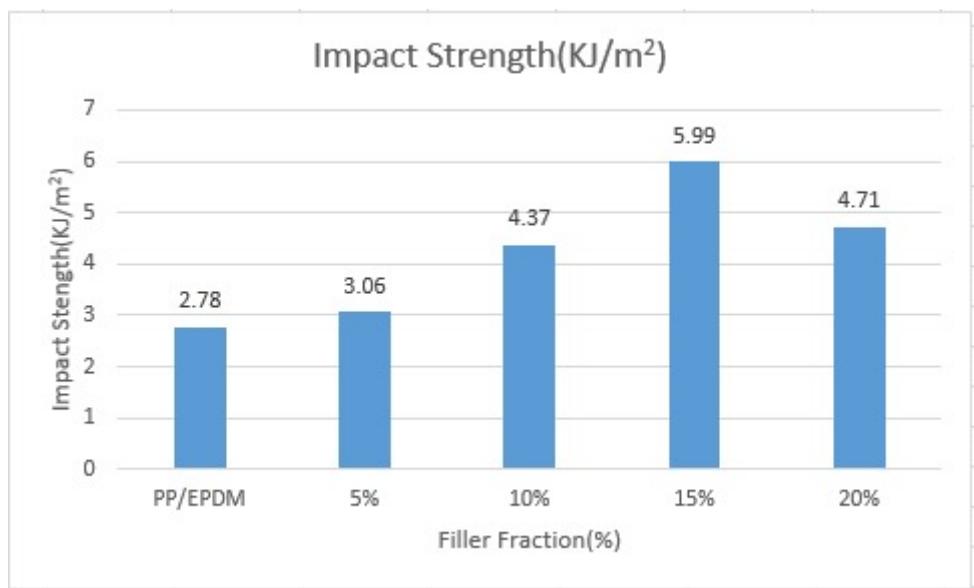
Major functional group Identified	Reflectance frequency range (cm^{-1})
O-H(hydroxyl)	3334.5, 3330.6-2848.79, 3343.3-2849.2
C-H (aromatic compound)	1653.33
C-O (aryl ether)	1028.61, 1035.06, 1034.5
C=O(aldehyde)	1732.09, 1739.5

Table 5.1 Functional groups identified

From the table, the O-H bond represents the hydroxyl group, which indicates the presence of Cellulose. When comparing the intensity of O-H bond present in the three spectrums, we get as: Chemical>Untreated>Water retted. Since the bond strength and content of hydroxyl group is greater in Chemical retted darbha grass, thus the cellulose content obtained in chemical retting is greater. The C=O bond represents the aldehyde groups, which indicates the presence of lignin in both untreated and water-retted darbha grass. The C-O bond represents the aryl ether group which was formed by the hydrocarbon aromatic ring of lignin, and it is present in all the given spectrum of darbha grass.

And the C-H bond represents an aromatic hydrocarbon group which is commonly found during the emergence of a natural fibre. Since this particular bond takes place in chemical retted darbha grass, the chemical retting of the darbha grass is changed into darbha fibre within 24 hours. As there is no indication of the formation of darbha fibre using the water retting process after 21 days, the Darbha fibre obtained from Chemical retting is used for further mechanical testing after blending with PP/EPDM.

5.2 IMPACT STRENGTH



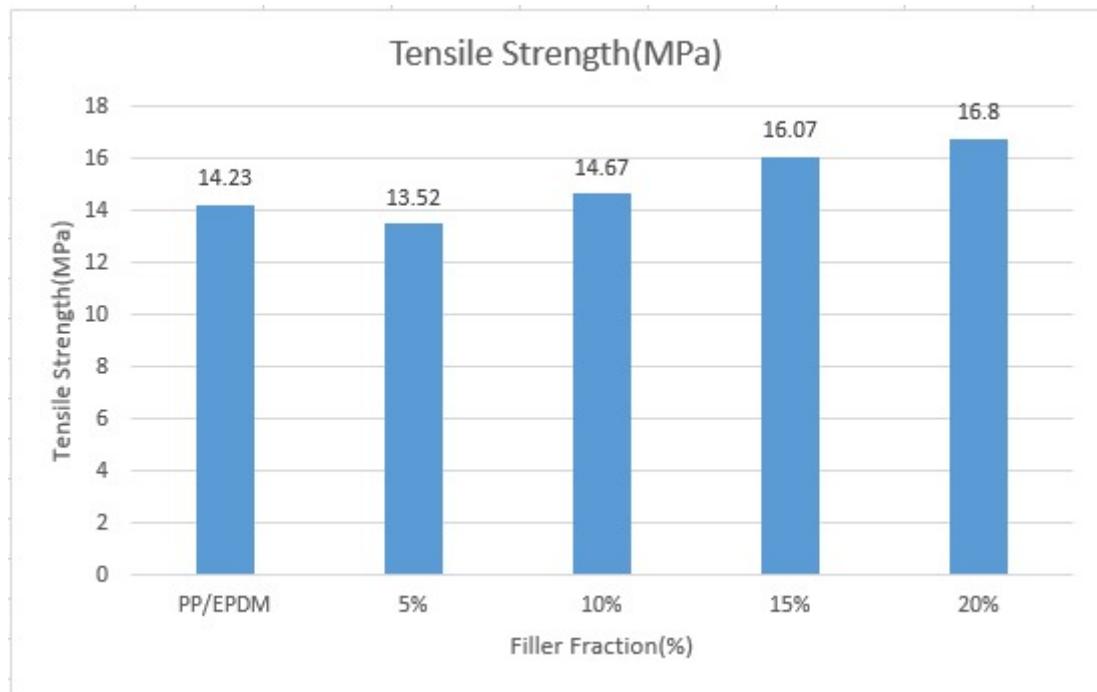
Graph 5.1 Impact strength vs filler fraction

The ability of a material to receive applied energy or withstand breaking under high-speed stress is referred to as impact strength. As seen in graph 5.1, the effect intensity of PP/EPDM/Fibre combinations increased compared to PP/EPDM. As shown in the graph above, the impact strength increases as the fibre content increases. However, this trend is only observable up to a certain fibre level, beyond which the impact strength begins to decline. The 15 percent filler sample's impact intensity rises from 3.06 KJ/m² to 5.99 KJ/m². The value reduces to 4.71 KJ/m² for the 20% sample whereas only 2.78 KJ/m² for PP/EPDM sample. Increased fibre loading may result in more energy, which explains why strength has improved.

The rise in strength may be traced back to the increased fibre loading which may require more energy to break the connection between the interlaced fibre bundles, resulting in increased impact strength. Fibres lower the composite's impact strength in two ways. Fibres reduce the composite's capacity to absorb energy during crack propagation by inhibiting deformation and ductile mobility of polymer molecules; and fibres generate high-stress concentration zones, requiring less energy to develop a fracture. Fibre ends, poor interfacial adhesion areas and spots where fibres come into touch with each other are examples of such areas. For strong impact strength, an ideal bonding level is necessary, which in our investigation is demonstrated by 15% fibre content.

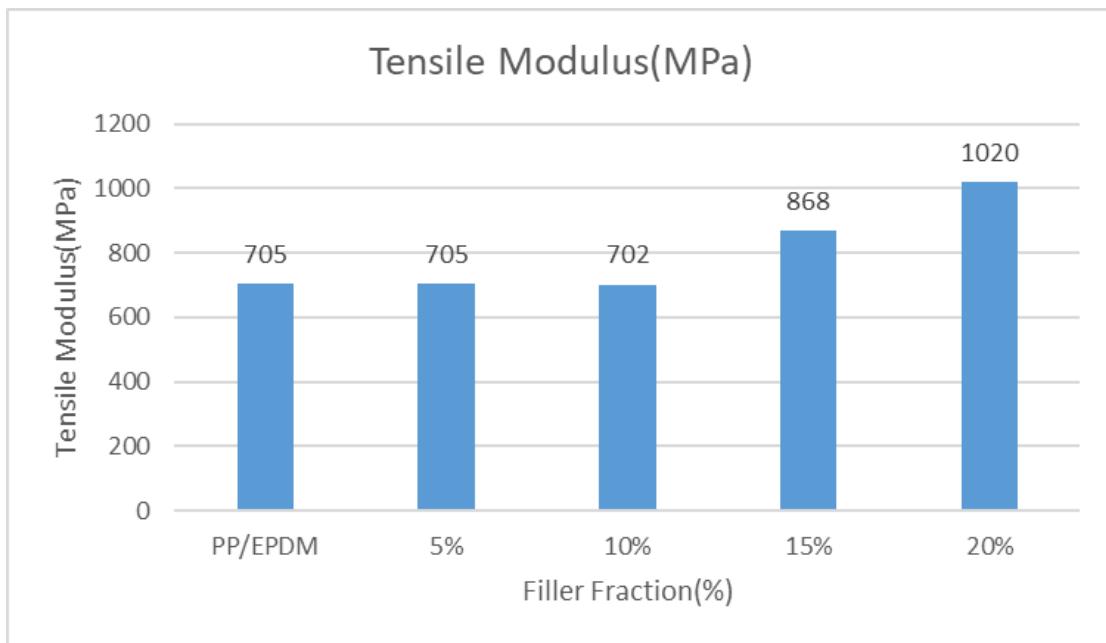
5.3 TENSILE PROPERTIES

The tensile qualities of material tell you how it will behave when stretched or pulled before it breaks. Mechanical parameters of the PP/EPDM/Darbha fibre mix were examined in this work, including tensile strength and Young's Modulus.



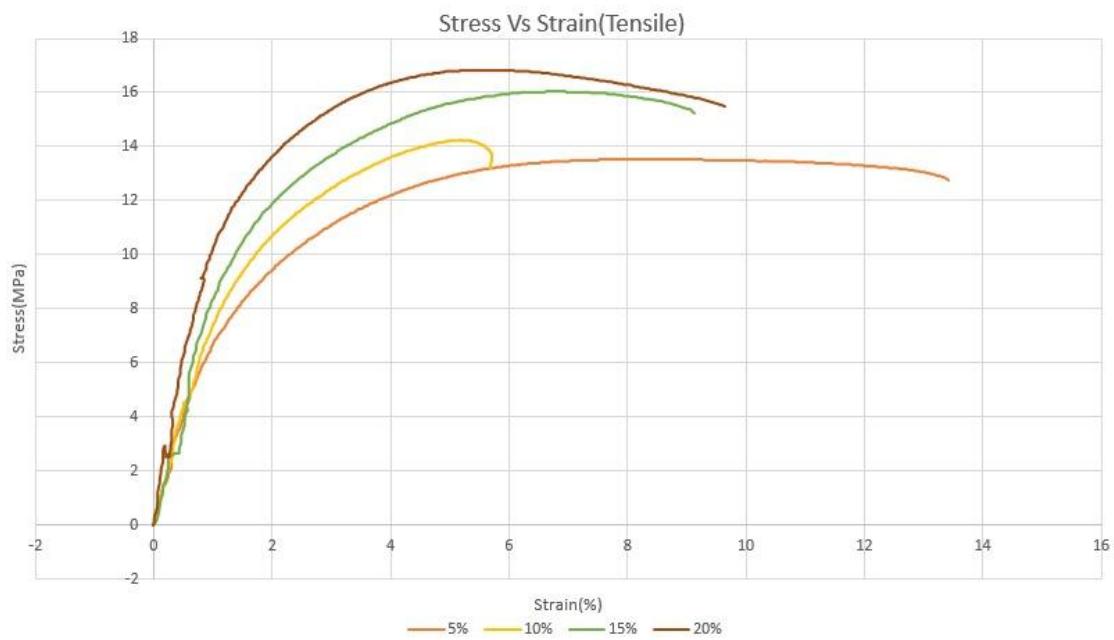
Graph 5.2 Tensile strength vs filler fraction

The graph above shows the tensile strength of the various fibre mixes. It shows that when the fibre content rises, the tensile strength increases as well. The tensile strength of PP/EPDM is 14.23 MPa. The tensile strength increases from 13.52 MPa at 5% fibre content to 16.8 MPa at 20% fibre content. This tendency can be attributed to the fact that fibres offered significantly higher strength and stiffness values than the matrix alone, exhibiting remarkable fibre-matrix compatibility. When a ternary fibre phase is introduced into a PP/EPDM matrix, voids emerge, which fill up as the fibre content increases, resulting in increased tensile strength.



Graph 5.3 Tensile modulus vs filler fraction

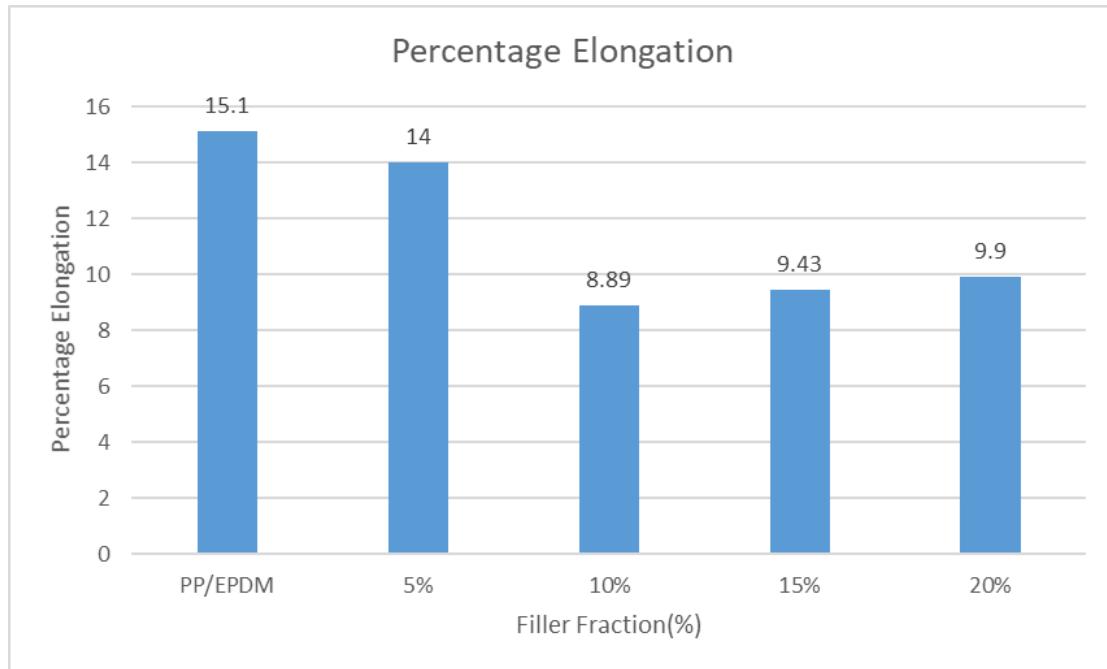
Increase in fibre results in a rise in tensile modulus, which is attributable to the reinforcing fibre content. As the fibre content increases, the void in the matrix reduces, resulting in more energy dispersion, which enhances the Tensile modulus.



Graph 5.4 Stress vs Strain (tensile)

As the amount of fibre grows, stress increases, as shown in the graph above. This is due to the fact that as the amount of fibre in the diet increases, so does the amount of

stress in the body. The region under the stress-strain curve determines toughness. Toughness refers to a material's ability to absorb energy and bend plastically without cracking. Increased fibre content limits polymer molecule deformation and ductility, lowering the composite's capacity to absorb energy during fracture propagation and, as a result, lowering the composite's ability to absorb energy during crack propagation.

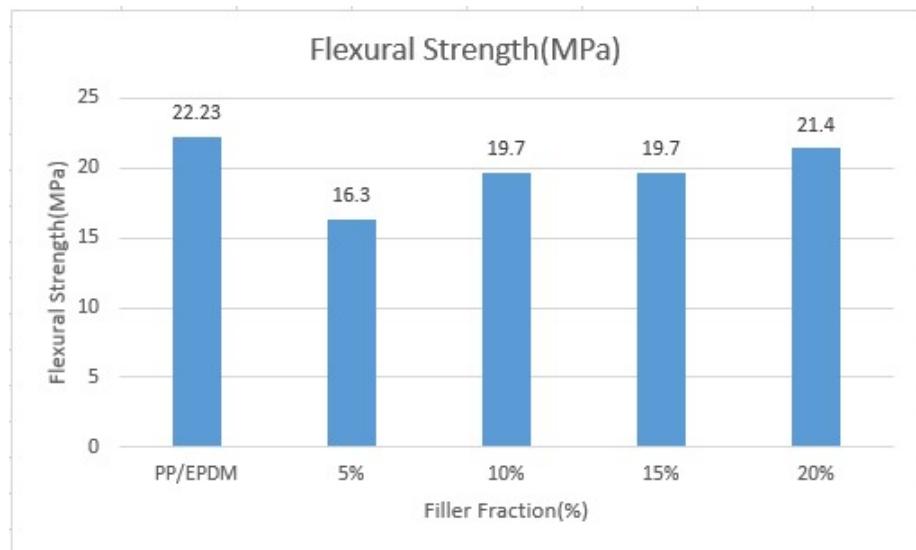


Graph 5.5 % elongation vs Filler fraction

PP/EPDM sample has the highest elongation compared to other fibre added samples. Out of the four fibre fractions tested, the 5% fraction showed the highest elongation. This is attributed to the higher ductile mobility of molecules because of the high PP/EPDM matrix content. As the fibre content increases ductile mobility decreases and elongation decreases. However slight variations in trend is shown by 10%, 15% & 20% sample. This may be due to fibre agglomeration leading to a slight increment in ductile nature.

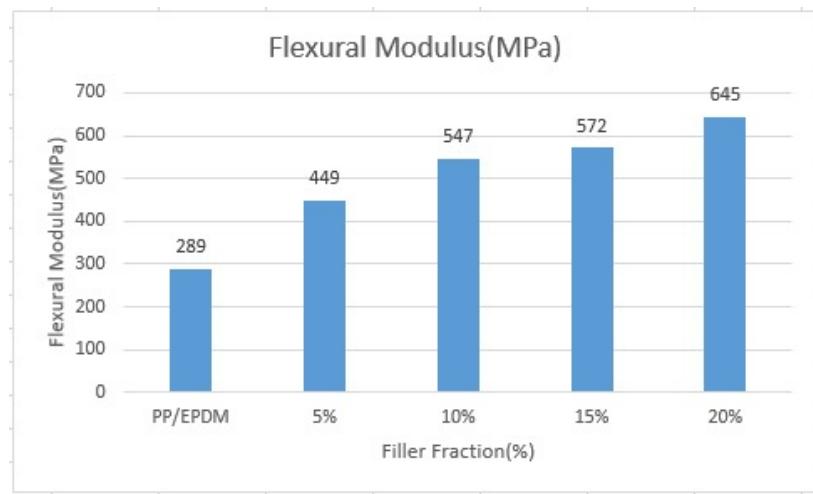
5.4 FLEXURAL STRENGTH

Graph 5.6 presents the flexural strength value of PP/EPDM and PP/EPDM/Darbha fibre blends. Flexural strength is the ability of a material to withstand bending forces applied perpendicular to its longitudinal axis and it is equal to the maximum stress in the outer fibres at the moment of break. It has been observed from graph 5.6 that the PP/EPDM has the highest flexural strength. But when 5% fibre is added it slightly decreases due to less amount of fibre. But when the fibre fraction is increased, flexural strength increases due to increased bonding between fibers. So there is an increase in the value of flexural properties with increasing percentage ratios of Darbha in PP/EPDM blends. During the flexural test information about flexural strength, flexural stress, flexural strain at break, and flexural strain of the material can be obtained. Flexural modulus can be also obtained from this test.



Graph 5.6 Flexural strength vs filler fraction

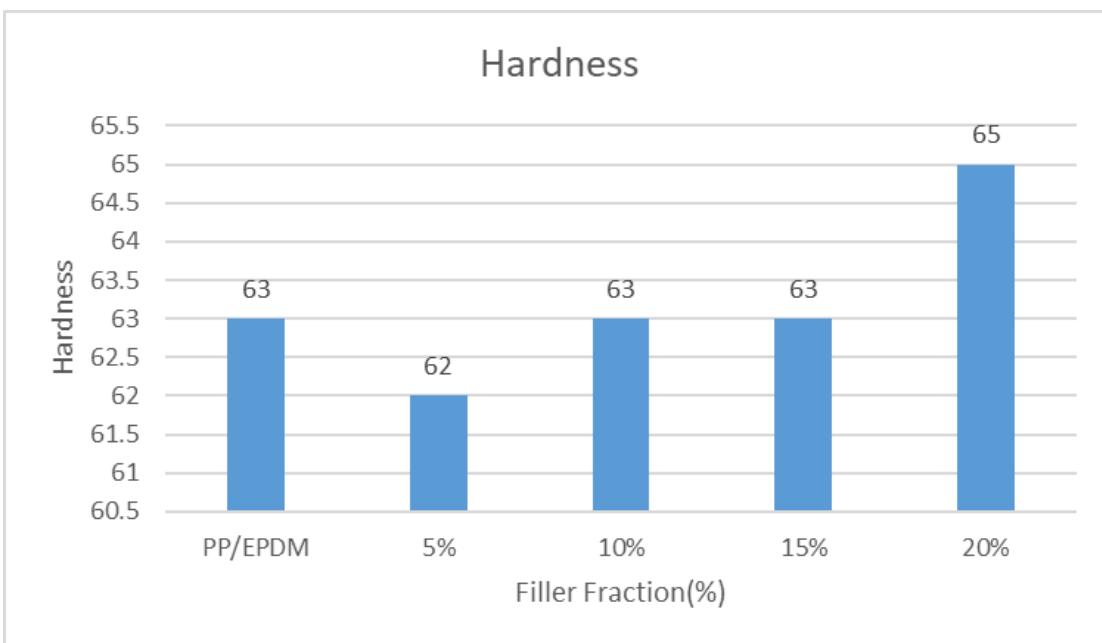
An increase in flexural strength and flexural modulus were observed as the filler fraction increased. The flexural strength and flexural modulus values of PP/EPDM are 22 MPa and 289 MPa. The flexural strength value increases from 16.3 MPa for 5% filler to 21.4 MPa for 20% filler samples. Similarly, the flexural modulus also increases from 449 MPa for 5% filler to 645 MPa for 20% filler. This increment is due to Darbha fibres increasing the energy absorption under flexural loading conditions.



Graph 5.7 Flexural modulus vs filler fraction

5.5 HARDNESS TEST

This method measures the resistance of plastics towards indentation and provides an empirical hardness value that doesn't necessarily correlate well to other properties or fundamental characteristics. Shore Hardness, using either the Shore A or Shore D scale, is the proffered method for rubbers/elastomers etc. The Shore A scale is used for “softer” rubbers while the Shore D scale is used for “harder” ones.



Graph 5.8 Hardness vs filler fraction

The hardness value of PP/EPDM is 63. The general trend followed in the case of the hardness test is an increase in hardness with an increase in fibre content. This stays

true for 5% with 62 N/mm², 10% with 63.6 N/mm² and 20% with 65 N/mm². For 15% filler fraction, the hardness value is found to be decreasing; this may be due to fibre agglomeration or improper mixing.

5.6 SCANNING ELECTRON MICROSCOPY

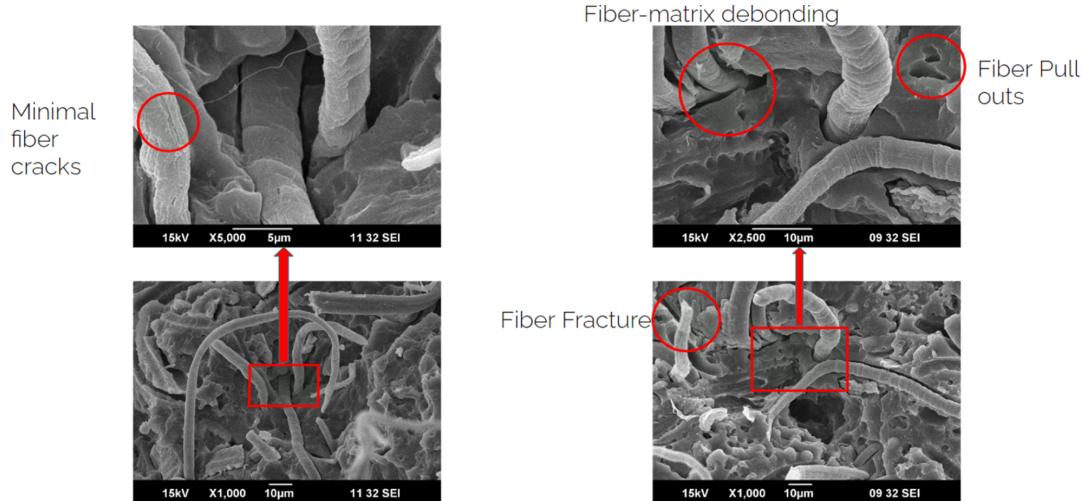


Fig 5.2 SEM images of fractured specimen of PP/EPDM/15% Darbha fiber

From the SEM images from both sides of the fractured surface, it is very evident that there are fibre matrix debonding and fibre pullouts. Delamination, intralaminar matrix cracking, longitudinal matrix splitting, fibre-matrix debonding, fibre pullout, and fibre fracture are the principal failure mechanisms in fibre reinforced composites caused by impact force.

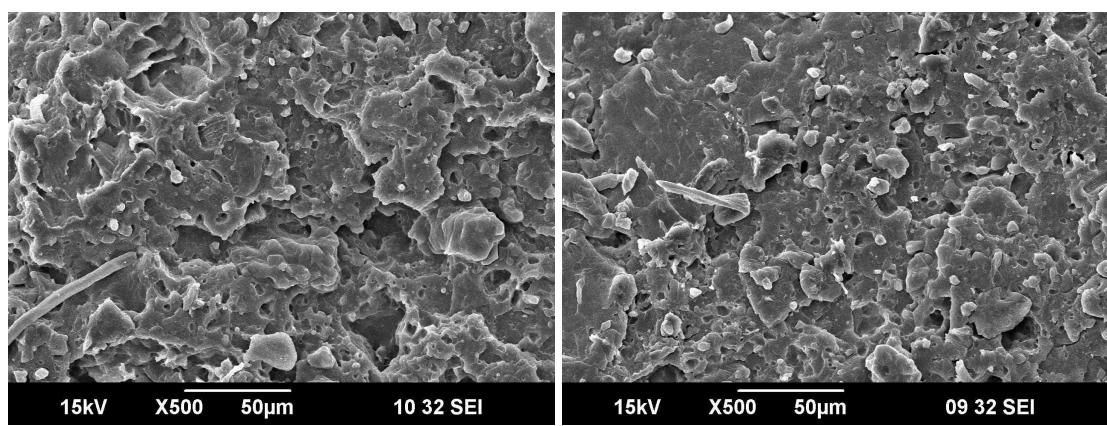


Fig 5.3 SEM images of a fractured specimen of PP/EPDM/5% Darbha fiber

The SEM images of the 5% fiber blend observed that there is an increased matrix fracture. There is a greater matrix failure occurrence observed in 5% than other specimens which thus points to the less energy absorption capabilities

of PP/EPDM/5% Darbha fiber. The fiber pullouts in 5% fiber composite are less than 15% fiber composite, because in 15% fiber blend load-bearing fibers have increased. Thus PP/EPDM/15% Darbha fiber contains the best impact strength out of the provided test specimens.

We can detect a decreasing trend in Impact property after 15 percent fibre content from the mechanical data above. This might be because the fibre content has increased, causing more pullouts and debonding.

CHAPTER 6

CONCLUSION

When compared to synthetic composite products, natural fibre reinforced polymer composites have benefits such as low density, lower cost, and lower solidity, allowing them to be used in commercial applications (automotive industry, buildings, and constructions). The use of natural fibres as reinforcement for polymeric composites improves the mechanical properties of the polymers. Mechanical, FTIR, and SEM studies are used to analyse the features and attributes of PP/EPDM reinforced with Darbha fibre composites. The use of NFPCs in autos and industries is also discussed. Chemical retting's impacts on Darbha fibre characteristics were also investigated.

Successful fabrication of the Darbha fibre reinforced thermoplastic elastomeric composite has been done by injection moulding. The tensile, impact, Hardness and flexural properties are found to increase with the increase in fibre content. It was found from the study that the sample with 15% fibre content showed the highest impact resistance. Properties like tensile, impact and flexural strength are found to be greatly affected by void content. SEM results show minor fibre cracks, fibre pullouts and debonding in some regions. Possible future work can be carried out by selecting a suitable bonding material.

CHAPTER 7

FUTURE WORK

1. **Sound absorption-** From a study, compared with some of the major natural grass, they found that Darbha grass possesses superior sound absorption properties with an NRC(Noise Reduction Coefficient) of 8.5, either individually or in a composite.
2. **Radiation shielding-** Various web reports state that Darbha grass shows the ability of shielding from X-Ray radiation.
3. **Compatibilizers-** Use of compatibilizers in the surface treatment of darbha fibre for better compatibility and stability between immiscible materials.
4. **Supercapacitor-** Darbha grass has good electrochemical properties and can help create a supercapacitor with improved energy density without any loss in power density. The supercapacitor produced in such a manner is able to retain 88% of its initial specific capacitance and it also possesses the feature of fast charging without any degradation while discharging.
5. **FDM filament-** Blending PLA, which is a green material is being widely used as an FDM filament due to its ability of fast processability and biodegradability, along with Darbha fibre has a large possibility of being a competitive bio-filament in the current market.
6. **Textile industry-** The strength that is shown by Darbha fibre has the possibility of it being used in the textile industry.

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