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A review on Bio-composites based on polypropylene reinforced with natural fibers: Mechanical properties

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ABSTRACT: Now these days green technology is worldwide popular in field of material science because of environmental issues. There are some challenges in working with bio-composite such as environmental conditions (temperature, moisture, etc.) and also related to strength. A comprehensive review of literature on polymer matrix (polypropylene) with different natural fibers (nut shells, almond shells, pine core, doum and hemp fibers) is presented in this paper. The structure, type, composition, and also thermal & mechanical properties will be reviewed. Moreover, various chemical treatment methods (alkali, esterification, etherification) and coupling agents (styrene and butadiene, styrene-ethylene-butene-styrene) will be reviewed. Manufacturing process such as hot pressing, extruding, compressing molding, etc. will be discussed. Also the concept of hybrid bio composite which contains jute and core as natural fiber will be discussed. Finally the review will conclude with a comparison in a gain of young's modulus of different natural fibers at various compositions and with or without coupling agent.

KEYWORDS: Green technology, bio composite, natural fibers, polypropylene, alkali treatment, esterification, coupling agent

1. INTRODUCTION

This paper provides an overview on the bio-composites and their thermal & mechanical properties. Bio composites are composite material which contains one or more phases of biological origin. One phase of bio composites is plant fibers which include cotton, hemp, flax fibers or by product of crops and other phase is a matrix which may be polymers. Today thermoplastics like polypropylene, polyethylene, and polystyrene are widely used as polymer matrix. Bio composites have large benefits such as light in weight, ecofriendly and non hazardous for living beings.

2. LITERATURE REVIEW

2.1 Pine core fibers reinforced compatibilized polypropylene composites [1]:-

In hilly areas, pine core are widely available from these high cellulosic fibers which can be used as reinforcement in a polypropylene. From its structure and morphology, we can estimate its usefulness compared with the other natural fibers. The pine core fibers are treated with alkali for the purpose of cleaning. To improve the adhesion between the fibers and matrix the coupling agent (styrene-ethylene-butene-styrene) with Maleic anhydride is used. Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy, Tensile test, Thermo-gravimetric Analysis and torsional Tests on composite were employed at different contents of fibers and Polypropylene. The result shows the improvement in mechanical properties of binary and ternary composite, again in young's modulus was 43% and 49% respectively.

2.2 Different chemical treated Alfa fibers reinforced polypropylene composites [2]:

Green technology and material science were attracted towards the use of thermoplastic polymer reinforced with natural fibers. Plant fibers had an issue of compatibility with the polymer matrix. So in this paper the alfa fibers were treated with different chemical modification (etherification treatment, alkali treatment and esterification treatment) and their impact on mechanical and thermal properties was studied. To evaluate the chemical modification, percentage of alfa fibers (20%wt) were fixed in composite. The result showed that there was improvement in the mechanical and thermal properties of treated fibers as compared with non-treated fibers. The best improvement showed in young's modulus of esterified fibers with 35% increment. Using etherification treated fibers thermal stability was best improved.

2.3 Moroccan hemp fibers reinforced polypropylene composites: A study of thermo-mechanical properties [3]:-

In north morocco, high cellulosic fibers are obtained of the morocco hemp. These fibers were used for the reinforcement of plain polypropylene matrix. The hemp fibers were cleaned by alkali treatment. For improving the adhesion between the fibers and matrix the three block copolymer styrene-ethylene-butene-styrene grafted with Maleic anhydride was used. Tensile test, Scanning Electron Microscopy, Torsional test and Thermo gravimetric Analysis were done with different content of fibers. The binary composite of polypropylene/hemp fibers and ternary composite which also include coupling agent Maleic anhydride shows good adhesive between interfaces. When the fibers were 25%wt composite without coupling agent, a gain of 50% of the young's modulus and with coupling agent when fibers 20%wt composite a gain of 74% in young's modulus. The coupling agent shows good stabilization in a tensile strength curve.

2.4 Nut shells of argan particles for reinforcement of polypropylene composites: A study of thermal and mechanical properties [4]:-

This paper gives the thermal and mechanical properties of polypropylene composite reinforced with nut shell of argan particles, with the combined effect of both particle size and loading. For improving the adhesion between the particles and matrix the linear block copolymer based on styrene and butadiene coupling agent of 8%wt grafted polypropylene matrix used of three range sizes particles. Melt-blending was used for preparing the specimen and hot press molding machine was used for the tensile specimen. Different contents of particles such as 10, 15, 20 and 25%wt were used to characterize the composites for Scanning Electron Microscopy, Fourier Transform Infrared Spectroscopy, Thermo Gravimetric Analysis, Differential Thermal Analysis and tensile tests. The result shows a gain of 42.65%, 26.7%and 29% at 20%wt particles loading range 1, 2, 3 respectively. The improvement shown in young's modulus compared with plain polypropylene. Decrement in particle size observed increment in young's modulus and decrease in thermal stability with particle loading from 10 to 25% with respect to plain polypropylene.

2.5 Polypropylene reinforced composites with particles of almond shells [5]:

In this polypropylene thermoplastic matrix was reinforced with particles of almond shells. The binary composite contains only almonds shell particles/polypropylene and ternary composite also contains compatilizer with them, which investigated at different contents of particles. Twin screw extruder was used to prepare the composites. Dynamic Mechanical Analysis, Fourier Transform Infrared Spectroscopy, Tensile testing and Thermo-gravimetric Analysis were employed to investigate the mechanical and thermal properties. The result shows that the binary composite had a gain in young's modulus of 56.2% and ternary composite had 35% at 30%wt of particles. The result shows an increment into the initial thermal decomposition temperature investigated by thermal analysis.

2.6 Mechanical behavior analysis of bio-composites based polymer matrix reinforced with doum fibers [6]:

The environment friendly fibers reinforced polymer composites were quite popular these days, the doum palm fibers are one of them. The innovative thinking allows the use of doum fiber reinforcement in polymer matrix. Firstly the fibers were treated with alkali for cleaning and then interaction made of polymer & fibers. Tensile properties of that composite were measured for found the effect of fiber in composite properties. For improving the adhesion between the fibers and polymer the coupling agent (ethylene-butene) were used. Results shown that when fibers are added to composite their tensile properties were improved and also improve when a coupling agent were used compared with plain polymer. In binary composite a gain of 70% and in ternary composite a gain of 77% in young's modulus at 30%wt fibers was obtained. Also the tensile strength was improved 18% when fibers were 10%wt of composites for ternary composite.

2.7 Jute and coir fiber reinforced polypropylene composites [7]:

Jute and coir fiber are presently used widely in preparation of bio composites. In this paper both jute and coir fibers were used together in varying ratio with thermoplastic polypropylene matrix. Hot pressing machine was used to prepare the composite in which fiber were in different proportion (5, 10, 15, 20wt %) and also different ratio of jute: coir (1:1,3:1,1:3) were prepared. The fiber first treated using 5% and 10% NaOH solution. Impact, tensile, hardness and flexural test were examined for characterization of composites. Results show when fiber loading increases the impact strength, flexural modulus and hardness values increased. Young's modulus increase with the fiber loading, but tensile strength show decreased. Results indicate that 5% NaOH treated shows best result as compared to 10% NaOH treated fiber.

2.8 Effect on mechanical and thermal behavior of natural fiber in fiber/polypropylene composites of coupling agent [8]:

To increase the adhesion between the fiber and the matrix coupling agent or compatilizer of Maleic anhydride grafted polypropylene was used. There were different proportions required for different composites. So the need of systematic work should be investigated optimum MAPP percent of different natural fiber. Investigation of coupling agent source, fiber content (30 %, 50%) coupling agent ratio (0%, 6.67%, 13%, 16.67%) was carried out. Result show that the optimum MAPP to fiber ratio was lying between 10% and 13.3% investigated mechanically, thermally and microscopically. Also the melting temperature decreases with increase of MAPP.

2.9 Short flax fiber reinforced polypropylene composites: Impact on mechanical behavior of variability of flax fiber [9]:

Short flax fiber composite materials are widely applicable because of biodegradable and renewability properties. Geometrical and mechanical properties had a real impact on the strength of composite and also the fiber content. The lack of knowledge about the quantity of fiber is the main obstacle. This paper gives the information about quantitative and qualitative impact of variability of fiber properties. Different orientation and fiber content, including distributed and in plane orientation was considered. The result shows the range of variation of composite depends upon the weight of fiber in composite. Therefore, indirectly related to the manufacturing process, but directly related to fiber content.

2.10 Modeling of properties and mechanical properties of reinforced polypropylene composites with sisal fiber [10]:

To investigate the modeling of properties and mechanical properties of polypropylene reinforced with sisal fiber mercerization treatment with sisal fiber. Fiber were examined into three parts first were treated with sodium hydroxide (NaOH) and second treated with potassium hydroxide (KOH). Both of them were treated at 50˚C temperature water for 4 hours. The third part of the fibers were untreated. The soil retting process was used for fiber extraction and cut down into 10 mm in length. The predetermine proportion mixture of fiber and polypropylene matrix were subjected to heat (170˚C) and pressure in compression molding machine for 10 min. From Response Surface Methodology Model (RSM) and Universal Testing Machine flexural and tensile properties were observed. The result shows that the fiber, which was treated with KOH was best in tensile and flexural testing with compared to NaOH treated and untreated fiber.

3. CONCLUSION

- Polypropylene reinforced with pine core fibers shows the improvement in mechanical properties of composite without and with a coupling agent, a gain in young's modulus were 43% and 49% respectively.
- Alfa fibers reinforced polypropylene composite gave best improvement when the fibers were treated by an esterification method with a gain of 35% in young's modulus at 20%wt of fiber content.
- In hemp fibers/polypropylene composite when the fibers are 25%wt composite without coupling agent a gain of 50% of the young's modulus and with coupling agent when fibers 20%wt composite a gain of 74% in young's modulus.
- Nut shells of argan particles for reinforcement of polypropylene composites shows the improvement in young's modulus of 42.65% at 20%wt fiber content.
- Polypropylene reinforced with almond shells shows the increment in young's modulus of 56.2% and 35% at 30%wt fiber content without and with coupling agent respectively.
- In doum fiber/polypropylene composite there was improvement in young's modulus of 70% and 77% at 30%wt fiber content without and with coupling agent respectively. For more details see table 1.

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S no.	Natural fiber	Polymer matrix	Fiber treatment	Coupling agent	Increase in young's modulus (%)
1.	Nut shells	Polypropylene	-----	styrene and butadiene	42.65% at 20%wt fiber content
2.	Doum fibers	Polypropylene	Alkali	Styrene–(ethylene–butene)–styrene	70% and 77% at 30%wt fiber content without and with coupling agent respectively
3.	Hemp fibers	Polypropylene	Alkali	Styrene–(ethylene–butene)–styrene	50% at 25%wt and 74% at 20%wt fiber content without and with coupling agent respectively
4.	Pine cores	Polypropylene	Alkali	Styrene–(ethylene–butene)–styrene	43% and 49% without and with coupling agent respectively
5.	Almond shells	Polypropylene	-----	Maleic anhydride	56.2% and 35% at 30%wt fiber content without and with coupling agent respectively
6.	Alfa fibers	Polypropylene	Esterification	-----	35% at 20%wt fiber Content

TABLE.1 Comparison of results of polypropylene composites reinforced with different natural fibers.