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Research Article

Investigation on Mechanical Properties of Glass Fiber Reinforced Polypropylene Resin based Composites

S.Vamshi Krishna†*, M.V.Satish Kumar† and K.Shankaraiah†

†Mechanical Department, Kamala Institute of Technology and Science, Karimnagar, Telangana, India

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Abstract

The aim of this work is to develop a composite material with optimum properties so that it can use synthetic fiber reinforced composite material for a suitable application. A completely composite has to be prepared using fibers like Glass as reinforcement and polypropylene as matrix. The composites are to be prepared by using compression molding process and these laminas are evaluated mechanical properties as per ASTM standards. From the results it is observed that the length of fiber increases the strength increases.

Keywords: *Polypropylene, Synthetic Fiber.*

1. Introduction

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

The Mechanical properties of composites depend on many variables such as fiber types, Orientations and architecture. The fiber architecture refers to the performed textile Configurations by braiding, knitting or weaving. Composites are anisotropic materials with their Strength being in any direction. Their stress-strain curves are linearly elastic to the point of failure by rupture. The polymeric resin in a composite material, which consists of viscous Fluid and elastic solids, responds viscoelastically to applied loads. Although the viscoelastic Material will keep and relax under a sustained load, it can be designed to perform satisfactorily. Composites have many excellent structural and some examples are high strength, Material toughness, fatigue endurance and light weight. Other highly desirable qualities are high Resistance to elevated temperature, abrasion, corrosion and chemical attack. Some of the advantages in the use of composite structural members include the ease of Manufacturing, fabrication, handling and erection. Project delivery time can be short. It looks The Russell county engineer one day to install the deck panels in the first vehicular Composites Bridge. Composites can be formulated and designed high performance, durability and Extended service life. They have excellent strength-to-weight ratios. To last 75 years, composites can be economically justified using the life-cycle cost method.

Some of the disadvantages in the use of composites in bridges are high first cost, creep and shrinkage. The design and construction require highly trained specialist from many Engineering and material science disciplines. The composites have a potential for environmental Degradation for example alkalis attack and ultraviolet radiation exposure. They are very little or nonexistent design guidance and /or standards.

2. Problem statement

Plastics are widely used as an alternative to natural materials and have become the most useful part of human life [Birley A.W]. The use of plastics is increasing day by day due to their important properties, such as easy form ability, light weight, resistance to various chemical materials, low electrical

*Corresponding author: **S.Vamshi Krishna**

conductivity and ability to be transparent. Moreover, they can be produced at low cost and colored by mixing with some other materials. The addition of materials like glass fiber to plastics also improves its chemical mechanical properties [Bertin S and Robin J. J, (2002)].

Due to their versatility plastic materials are used widely in both low performance products like wrapping products, bottles, toys, and high performance products like car components, bulletproof suits and a large number of other industrial products. Hence, plastic demand has increased exponentially in the past few decades. It is a common practice that plastic materials are disposed in landfills after their use. The disposal of plastic creates environmental and space problems because they are not very biodegradable and occupy a large volume [Bertin S and Robin J. J, (2002)]. It is, therefore, suggested that recycling is available option to conserve plastic materials.

Even minor changes in the processing parameters can influence the properties of the plastics. These parameters make them very important material for various applications. Therefore, it is shown by the researcher [Birley A.W] that by controlling the process parameters the plastic can be tailored according to the requirements. Fiber and particulate reinforcements can improve the mechanical properties of plastics with less cost as compared to the materials of similar strength [Singha A.S 2009]. Mechanical properties of the composites of plastics and fibers depend on the fiber size, fiber density, fiber fraction, mode of distribution in the structure, working temperature and fiber–plastic adhesion forces [Birley A.W].

Glass fiber reinforced polypropylene (GFRPP) is a widely used cost-effective composite material. The success of these composites relies on the unique performance/cost ratio of polypropylene among various engineering plastics as well as that of glass fibers among different fibrous reinforcements. The properties of the glass fiber reinforced polypropylene can be tailored by adjusting the volume fraction of glass and the length of the fiber. Increase in the fiber contents and fiber length results in improving the impact strength and tensile strength but lowers the process ability of the composite. Another important advantage is the possibility of recycling these composites [Chuan W, Li L. S 2011]. Abdul Kadir G et. al. is of the view that during tensile testing of the reinforced plastics, the load applied to the matrix is transferred to the glass fibers. In order to improve the strength of the composites, a strong interface bonding between the fibers and plastic is required. They also observed that humidity reduces the bonding force between the plastic and reinforcement element. GFRPP shows good resistance against acid and salt solutions but bad resistance against alkali solutions [Abdul Kadir 2006].

In the present work, the effects by using compression molding on the thermal and tensile properties of polypropylene with 30 wt. % glass fiber were investigated. This composition was selected on the basis of the work of H. Liang [Singha A.S 2009], who studied the effects of the glass fiber contents in GFRPP on their mechanical properties. They found that optimum mechanical properties such as impact strength, tensile strength and bending strength were found in GFRPP containing 30 wt. % glass fiber. The possible reason suggested by them is that the increase in glass fiber contents beyond 30 wt. % result in reduction in matrix contents. So it may cause the poor liquidity of glass fibers during injection molding and even result in agglomeration of glass fibers, thus it reduces the mechanical properties of GFRPP.

For the past decades researchers to design the composite materials using synthetic fibers according to the design requirements have carried a lot of experimental and theoretical investigations. Very small contribution of research work was found towards the design and fabrication of composite materials using natural fibers and synthetic fibers. The proposed work is intended to exploit the advantages of composites, fibers as reinforcement (Glass fibers).

3. Objective of the Work

The proposed work is aimed at the development of fabrication technique and providing a basic understanding of the behavior and response of new lightweight materials, and also evaluated the mechanical properties.

4. Experimental Procedure

4.1 Details of Fiber

Fibers are a class of hair–like material that continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be used as a component of composite materials

4.1.2 Glass Fiber Treatment

The glass surface modifications by treatment with a coupling agent are used to improve the fiber/matrix interfacial strength through both physical and chemical bonds, and to protect the fiber surface from environmental conditions, such as moisture and reactive fluids. Organ functional silanes are the most widely used coupling agents for improvement of the interfacial adhesion in glass-reinforced materials. Their effectiveness depends on the nature and pretreatment of the substrate, the silane type, the silane layer thickness and the application process. In a relatively dry state, the proper selection of a silane coupling agent is an effective means of promoting interfacial adhesion and enhancing mechanical properties. Under wet conditions, however, its effectiveness substantially depends on the nature of the chemical bond between the silane coupling agent and the primary constituents, i.e. , the GFs and the polymeric matrix. A variety of mechanisms have been proposed to explain the function of silanes at the inter phase. Plueddemann and colleagues were the first to perform a systematic study of the effectiveness of over a hundred saline coupling agents on the wet strength of epoxy and polyester laminates [Lee S. C 1997]. These data suggest that the primary factors are:

• The chemical reactivity of the saline organ functional group to form covalent bonds with the polymer matrix.

• The primary or secondary chemical bond formation at the glass interface.

• The ability of the polymer matrix to diffuse into the saline “inter phase” to form a rigid, tough, water.

4.2 Fabrication of Composites

The fabrication was done by using compression molding technique

4.2.1 Compression molding Technique

The fiber piles were cut to size from the Glass lampas. The appropriate numbers of fiber plies were taken: two for each. Then the fibers were weighed 70% and accordingly the resin weighed as 30%. Because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of first putting glass fiber on the iron plate. Next PP granules are putting on glass fiber. Then again glass fiber is taken on PP granules. Put another iron plate on that glass fiber and when the compression molding machine is heated up to 180^{0}C. Then the iron plates are kept in the molding machine until the fiber gets heated. When fiber melts in between two iron plates by observing that we can say fabrication is done. When compression is given more the resultant will be perfect no blow holes will be formed. Laminas are prepared in this procedure. This procedure was repeated until three alternating composites are having been made. Finally iron plates are removed from the molding machine and cooled for atmospheric temperature and removing one iron sheet and composite laminar is prepared. For another laminar the iron plates were kept in the molding at the temperature of 180^{0}c for half an hour for curing temperature. Repeat the same procedure for another two laminar. The composites are prepared by using compression molding technique.

4.3 Specimen preparation and testing

Fig.1 Cutting glass fiber

Fig.2 polypropylene resin

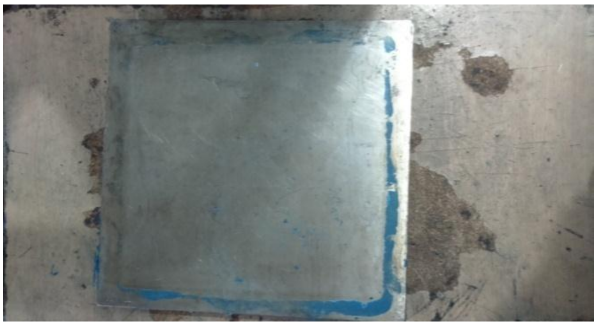

Fig.3 Iron plates

Fig.4 compression molding machine setup

Fig.5 compression moulding machine setup

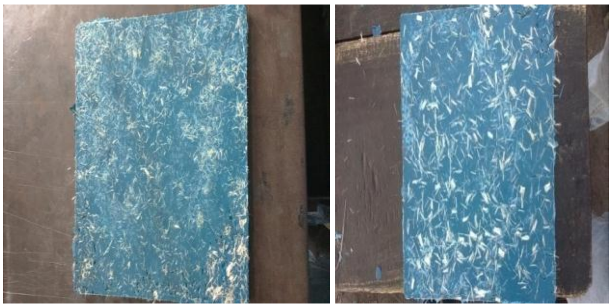

Fig.6 4mm and 6 mm Glass fiber composite

Fig.7 8mm Glass fiber composite

4.4 Testing Methods

All the mechanical testing methods that were carried out were base on American Standard Testing Methods (ASTM). There were three test performed, namely Tensile Test (ASTM D638), Flexural Test (ASTM D790), Water Absorption Test (ASTM D 570), For morphology studies, Scanning Electron Microscope (SEM) was used.

4.5 Preparation of Specimens

Specimens for the Tensile Test, Flexural Test, and Water Absorption Tests are cut on a band saw machine as per ASTM standards.

4.5.1 Tensile Test Specimen

Specimens are cut from laminas on a jig saw machine as per ASTM D 638 Standards [Bertin S 2002]. The standard Type IV dumbbell shaped specimens are used in the testing.

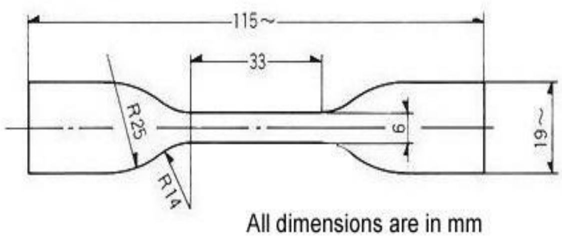

Fig.8 ASTM – D638 Type IV Tensile Test Specimen Details [30]

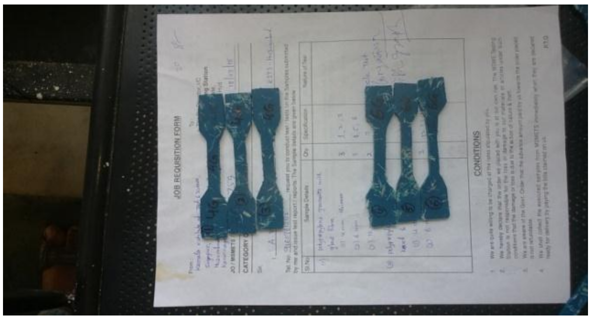

Fig.9 Tensile test specimens

4.5.2 Flexural Test Specimen

Specimens for flexural test are cut from laminas as per ASTM D790 standards [Bertin S 2002].

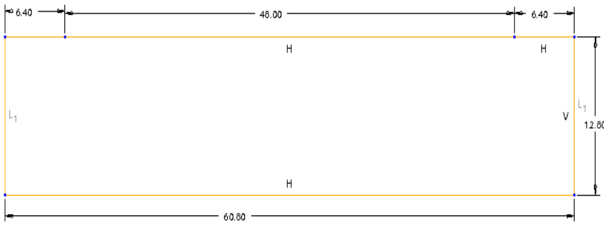

Fig.10 ASTM – D790 Flexural Test Specimen Details

Fig.11 Flexural test specimens

5. Results

5.1 Tensile Testing

Table 1 tensile property of different lengths of Glass fiber composites

Fiber	Length	Ultimate tensile strength (MPa)	Specific tensile strength (MP/g/cm^3)	Tensile Modulus (MPa)	Specific Tensile Modulus (MPa/g/cm^3)
glass	4mm	6.3375	5.27	416.94	347.45
	6mm	10.5377	8.78	439.03	365.89
	8mm	11.2	9.33	464.9	387.43

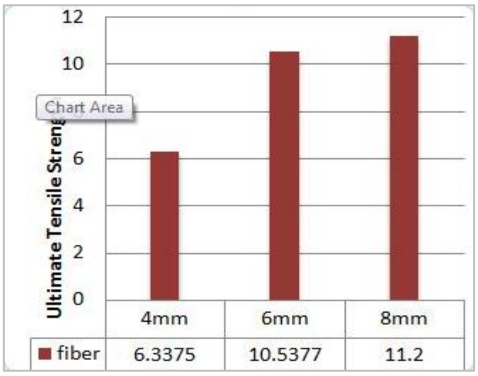

Fig.12 ultimate tensile strength

Experimental results of polypropylene Glass fiber composites are prepared with different fiber length. It is obvious strength increases when 4mm fiber length is impregnated with polypropylene matrix. Mechanical properties (i.e. tensile) increased when polypropylene matrix impregnated with 6mm fiber length of each as mentioned above. Mechanical properties are increased when fiber length is further increased.

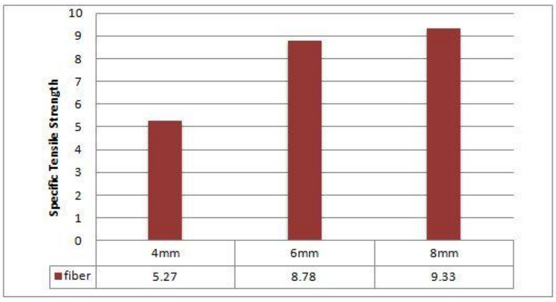

Fig.13 Specific Tensile Strength

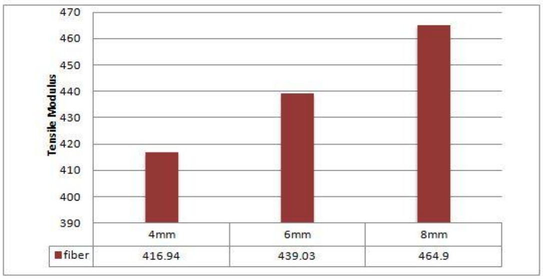

Fig.14 Tensile Modulus

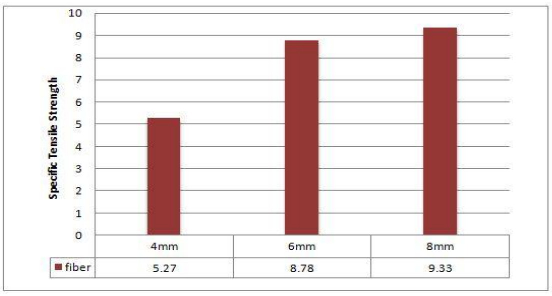

Fig.15 Specific Tensile Modulus

5.2 Flexural Testing

Table 2 Flexure Test observations for *fiber 4mm* Glass composite

Deflection (mm)	Load(N)		
	Specimen 1	Specimen 2	Specimen 3
0.5	6	6	6
1.0	10	10	9
1.5	14	14	12
2.0	17	16	14
2.5	18	18	15
3.0	19	19	_
4.0	_	20	_

Table 3 Mean values of flexure test observations for Glass fiber 4mm composite

Deflection (mm)	Mean Load (1 Div=3.75N)	Flexural stress (N/mm^2)
0.5	6	13.5826
1	9.6666	21.88305
1.5	13.333	30.1836
2	15.66	35.4657
2.5	17	38.4842
3	19	43.0118
3.5	20	45.2755

Table 4 Flexure Test observations for Glass fiber 6mm composite

Deflection (mm)	Load(N)		
	Specimen 1	Specimen 2	Specimen 3
0.5	6	6	6
1.0	11	12	12
1.5	15	15	17
2.0	18	18	20
2.5	-	19.5	22
3.0	-	19.8	23
4.0	-	-	24

Table 5 Mean values of flexure test observations for Glass fiber 6mm composite

Deflection (mm)	Mean Load (1 Div=3.75N)	Flexural stress (N/mm^2)
0.5	6	13.5826
1	11.3333	25.6560
1.5	15.666	35.4507
2	18.6666	42.2570
2.5	20.75	46.9734
3	23	52.0669
3.5	24	54.3307

Table 6 Flexure Test observations for Glass fiber 8mm composite

Deflection (mm)	Load(N)		
	Specimen 1	Specimen 2	Specimen 3
0.5	6	6	4
1.0	11	12	07
1.5	15	16	9
2.0	16	19	11
2.5	18	22	-
3.0	-	26	-

Table 7 Mean values of flexure test observations for Glass fiber 8mm composite

Deflection (mm)	Mean Load (1 Div=3.75N)	Flexural stress (N/mm²)
0.5	5.5	12.4507
1	10	22.6377
1.5	13.333	30.1836
2	15.33	34.7112
3	26	58.85

Table 8 Properties for different composites

Fiber	Length	Flexural Strength (MPa)	Specific Flexural strength (MPa/ g/cm^3)	Flexural Modulus (MPa)	Specific Flexural Modulus (MPa/ g/cm^3)
Glass	4mm	45.27	37.25	1270.3	1058.5
	6mm	54.33	45.27	1784	1486.7
	8mm	58.85	49.04	2390	1991.8

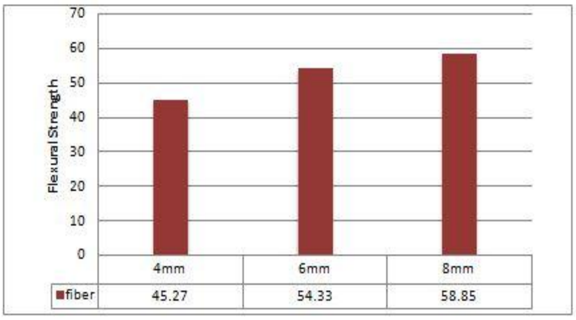

Fig.16 Flexural Strength for Different composites

It is observed that 8mm fiber length composites were optimal flexural strength than 4mm and 6mm fiber length composite. This surface offers the excellent fiber-matrix interface adhesion as a results improved mechanical properties.

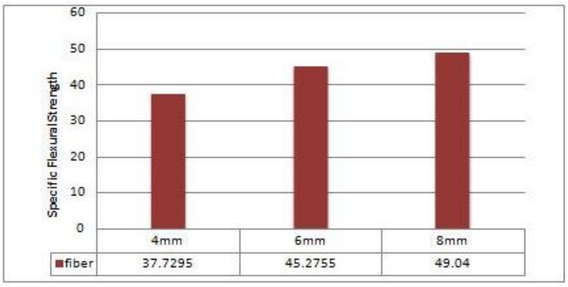

Fig.17specific flexural strength for various composites

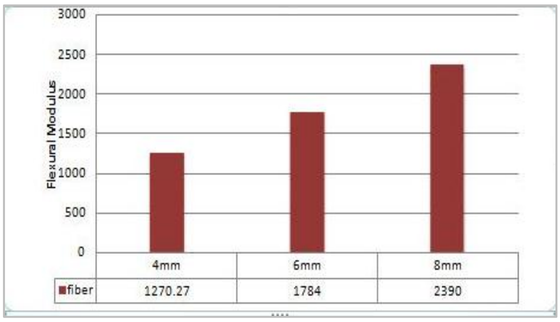

Fig.18 Flexural modulus for different composites

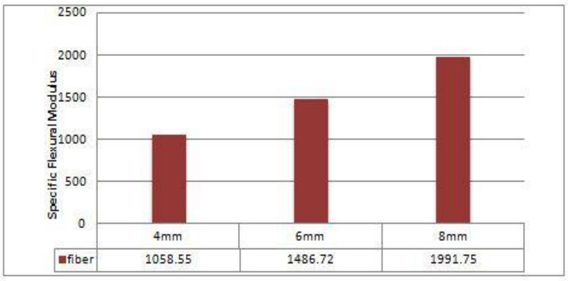

Fig.19 specific flexural modulus for different laminas

Conclusions

The Glass fibers was successfully used to fabricate synthetic composites with 30% fiber and 70 % resin, these fibers are bio degradable and highly crystalline with well aligned structure. So it has been known that they also have higher tensile strength than other composites and in turn it would not induce any serious environmental problem.

The variation of mechanical properties like tensile strength, flexural strength, of polypropylene based Glass lampas composites has been studied as function of fiber length. It is observed that composites fibers are observed optimal tensile and flexural strength.

These composites may find applications as structural materials where higher strength and cost considerations are important.

Glass fiber polypropylene composites (30% fiber/weight) were successfully fabricated using compression molding and the mechanical properties were evaluated.

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