Studies on the influence of fibre parameters on the compression properties of polymer fibre composites

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Abstract : Fibre-reinforced polymer matrix composite materials for engineering structures are used everywhere. Their low densities, combined with high strength and high stiffness, provide excellent benefits in performance and durability. When combined with the expertise of the current generation of engineers and latest materials prepared to accept the complexity of designing and fabricating structures using anisotropic materials, the range of applications becomes less surprising. Some 25 years ago, the majority of high performance composite materials were manufactured from individual layers of unidirectionally reinforced material. But in the present scenario, a number of reinforcing materials are used to manufacture fibre reinforced plastics. This chapter begins the various types of polymer matrix and reinforcing materials used to manufacture composites. Also deals with the improvement in Compressive properties by the addition of different types of fibres.

IndexTerms – polymer matrix, anisotropic material, composites.

I. Introduction

Fibre-reinforced polymer matrix composite play a major role in our daily life. The y have a number of unique properties like low densities, excellent strength and high stiffness make FRP to be highly useful in performance and durability;. This chapter begins with a brief introduction to continuous fibre-reinforced composite materials before describing the various major types of textile-reinforced polymer matrix composite materials based on the following fabric types: two-dimensional woven, braided, knitted, stitched, three-dimensional woven. In each case, an introduction to the mechanical and damage accumulation behaviour, together with approaches to modelling the composite, is provided. It is the material consisting of a polymer (resin) matrix combined with a fibrous reinforcing dispersed phase. Polymer Matrix Composites are very popular due to their low cost and simple fabrication methods. Use of non-reinforced polymers as structure materials is limited by low level of their mechanical properties: tensile strength of one of the strongest polymers - epoxy resin is 20000 psi (140 MPa).

Composites are multifunctional materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. More than one discontinuous phases are embedded in a continuous phase to form a hybrid composite. The discontinuous phase is usually harder and stronger than the continuous phase and it is called the hybrid reinforcement and the continuous phase is termed the matrix. Composites have been widely used for many applications like automotive parts, aeroplanes interior parts, household appliances and construction materials.

II. MATERIALS AND PROCEDURE

2. 1.TYPES OF COMPOSITES

2.1.1 Metal matrix composites (MMC)

High specific modulus, high specific strength, better properties at elevated temperatures and lower coefficient of thermal expansion are the main advantages of metal Matrix Composites over monolithic metals. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members, aerospace applications etc.

2.1.2 Ceramic matrix Composites (CMC)

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composite.

2.1.3 Polymer Matrix Composite (PMC)

It is the material consisting of a polymer (resin) matrix combined with a fibrous reinforcing dispersed phase. Polymer Matrix Composites are very popular due to their low cost and simple fabrication methods.

Use of non-reinforced polymers as structure materials is limited by low level of their mechanical properties: tensile strength of one of the strongest polymers - epoxy resin is 20000 psi (140 MPa). In addition to relatively low strength, polymer materials possess low impact resistance.

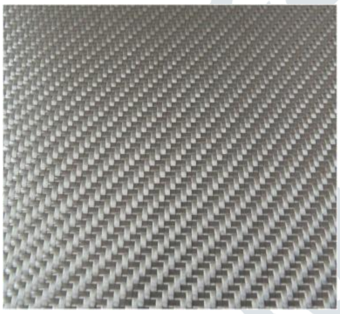
2.2 PROPERTIES OF POLYMER MATRIX COMPOSITES

- High strength
- Excellent stiffness
- Very high Fracture Toughness
- Good abrasion resistance
- Good puncture resistance
- Good corrosion resistance
- Low cost.

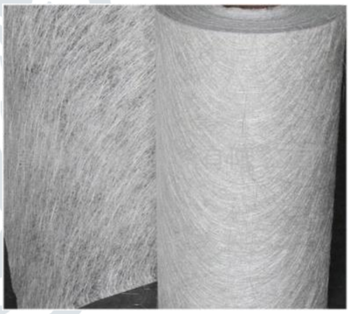
2.3 INTRODUCTION TO GLASS FIBRE

Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". Glass fibers are most commonly used fibers. They come in two forms Continuous fibers, Discontinuous fibers

Glass fiber also called fiberglass. It is material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since the 1930s.


E- Glass Fibre


S- Glass Fibre


C- Glass Fibre

2.3.1 Introduction of E-Glass Fibre

Glass fiber is a material consisting of numerous extremely fine fibers of glass. E-glass have excellent strength & electrical resistivity. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fibre glass.

2.3.2 Properties of E-Glass fibre

- Low cost
- High strength
- High stiffness
- Non-flammable
- Resistant to heat
- Good chemical resistance
- Relatively insensitive to moisture
- Good electrical insulation
- Higher density compared to carbon fibres and organic fibres.
- Good electrical insulation
- Able to maintain strength properties over a wide range of conditions

2.4 INTRODUCTION OF GRAPHENE

Graphene is a one-atom-thick layer of carbon atoms arranged in a hexagonal lattice. It is the building-block of Graphite (which is used, among other things, in pencil tips), but graphene is a remarkable substance on its own - with a multitude of astonishing properties which repeatedly earn it the title "wonder material".

Graphene is the thinnest material known to man at one atom thick, and also incredibly strong - about 200 times stronger than steel. On top of that, graphene is an excellent conductor of heat and electricity and has interesting light absorption abilities. It is truly a material that could change the world, with unlimited potential for integration in almost any industry.

Graphene is an extremely diverse material, and can be combined with other elements (including gases and metals) to produce different materials with various superior properties. Researchers all over the world continue to constantly investigate and patent graphene to learn its various properties and possible applications.

2.4.1 Properties of Graphene

Due to the strength of its 0.142 Nm-long carbon bonds, graphene is the strongest material ever discovered, with an ultimate tensile strength of 130,000,000,000 Pascals (or 130 gigapascals), compared to 400,000,000 for A36 structural steel, or 375,700,000 for Aramid (Kevlar). Not only is graphene extraordinarily strong, it is also very light at 0.77milligrams per square metre (for comparison purposes, 1 square metre of paper is roughly 1000 times heavier). It is often said that a single sheet of graphene (being only 1 atom thick), sufficient in size enough to cover a whole football field, would weigh under 1 single gram.

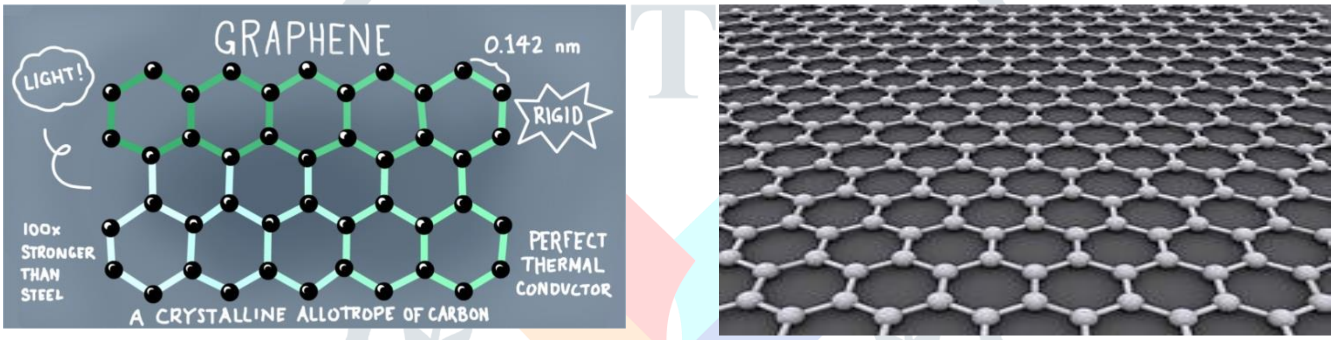


Figure 1 Graphene is an atomic-scale hexagonal lattice made of carbon atoms

2.4.2 Advantage of Graphene

- It is two hundred times stronger compare to steel and incredibly flexible.
- It is thinnest material possible and it is completely transparent which can transmit more than 90 % of the light.
- It can transfer electrons at much faster rate compare to silicon. It can pass at the speed of 1000 Kms/sec which is about 30 times fast compare to silicon.
- It can be used in flexible electronic newspaper, foldable televisions etc.
- It can be used in clothing which uses graphene based photo-voltaic cells as well as super conductors. Due to this tablets and mobile phones can be charged in minutes while in the pockets itself.
- It can be used for wide variety of applications such as flexible displays (OLEDs, LCDs), RAM, energy efficient transistors, energy storage devices, textile electrodes, copper nano wires, thermal management, spintronics etc.

2.5 INTRODUCTION TO EPOXY RESIN

Epoxy resins are much more expensive than polyester resins because of the high cost of the precursor chemicals most notably epi chloro hydrin. However, the increased complexity of the 'epoxy' polymer chain and the potential for a greater degree of control of the cross linking process gives a much improved matrix in terms of strength and ductility. Most epoxies require the resin and hardener to be mixed in equal proportions and for full strength require heating to complete the curing process. This can be advantageous as the resin can be applied directly to the fibres and curing need only take place at the time of manufacture. And known as pre-preg or pre impregnated fibre.

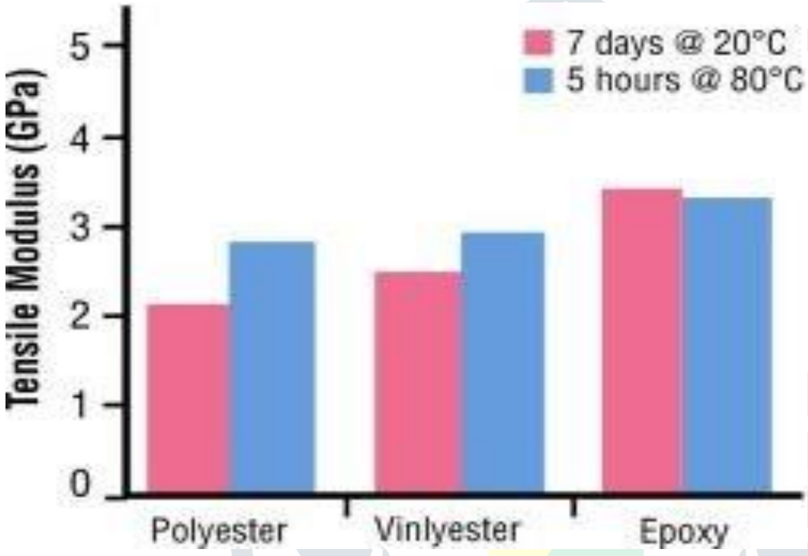
2.5.1 Properties of Epoxy

- High shear and peel strength
- Tough and resilient
- Good resistance to dynamic loading
- Bonds a wide variety of materials in common use
- Epoxy also has excellent resistance to chemical.

2.5.2 Advantages of Epoxy Resin

- Low shrink during cure
- Excellent moisture resistance
- Excellent chemical resistance
- Good electrical properties
- Increased mechanical and fatigue strength
- Impact resistant.

Figure 2. Comparison of polyester, vinylated, epoxy Tensile Modulus



2.6 COMPRESSION MOLDING

Compression molding is a popular manufacturing technique for composite parts. In particular, the development of high-strength sheet molding compounds drove wide adoption of compression molding process in automotive and appliance applications. In this chapter, we present some advantages and disadvantages of compression molding. We also introduce molding materials for compression molding such as sheet molding compound and bulk molding compound. To obtain high quality products, it is important to optimize mold design and processing conditions. Process modeling, such as flow and cure analysis, is especially useful to predict the knit line formation, part curing, fiber orientation and separation in the final product.

Figure 3. Compression Molding machine

2.6.1 Advantages of the Compression Molding Process

- Good surface finish with different texture and styling can be achieved.
- High part uniformity is achieved with compression molding process.
- Good flexibility in part design is possible.
- Maintenance cost is low.

2.7 FABRICATION OF COMPOSITE MATERIAL

2.7.1Compositions of composite material

Compositions of composite material for preparation of sample for Testing are shown in table 2.2

Specimen No.:	Epoxy Resin :Hardner Ratio	Graphene Weight (%)	E-Glass Fibre (No. of layers)
1	10:6	9 %	3 layers
2	10:6	12 %	3 layers

Table 1 Compositions of composite material

The fabrication of the polymer matrix composite was done at room temperature. The required ingredients of resin and hardener were mixed thoroughly in beaker.

2.7.2 Dough Preparation

The required mixture of resin & hardener were made by mixing them in (10:6) and (10:5) parts in a beaker by stirring the mixture in a beaker by a rod taking into care that no air should be entrapped inside the solution. graphene were mixing with dough ratio is 9 % and 12% of the epoxy composition.

Figure 4. Dough and Mould preparation

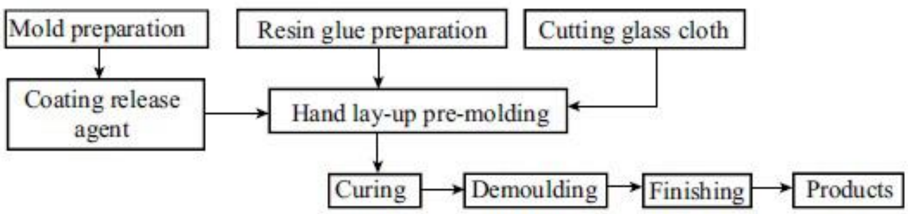
2.7.3 Mould preparation

Two mild steel moulds of size 300 X 300 X 10 (mm) were used for casting of polymer matrix composite slabs. The moulds made of mild steel. The mould comprises of two plates one top & other bottom &third square mould cavity inside.

2.7.4 Castings of samples

The dough prepared was transferred to mould cavity by care that the mould cavity should be thoroughly filled. Leveling was done to uniformly fill the cavity. it is done by hand layup technique.

Figure 5 Flow of hand layup Technique



2.7.5 Curing

Curing was done at room temperature for approx. 24 hrs in Compression mouding machine. After curing the mould was opened slab taken out of the mould and cleaned.

Figure 6. Curing in Compression MoldingMachine

2.8 COMPRESSION TESTING

Compressive strength or compression strength the maximum strength a sample can withstand when it is subjected to compressive force. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

Compressive strength is often measured on a universal testing machine. Measurements of compressive strength are affected by the specific test methods and the conditions of measurement.

Most of the structural members include the compression members. Such members can be loaded directly in compression or under a combination of flexural and compression loading. The axial stiffness of such members depends upon the cross sectional area. Thus, it is proportional to the weight of the structure. One can alter the stiffness by changing the geometry of the cross section With in limits. However, some of the composites have low compressive strength and this fact limits the full potential application of these composites.

Figure 7. Compression Testing Machine

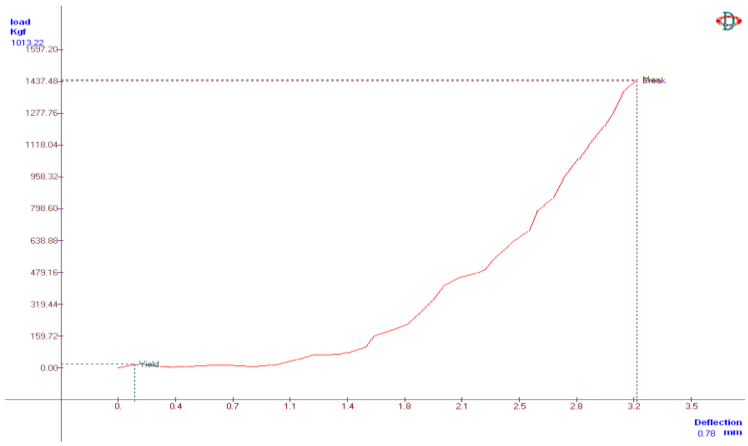
III. RESULTS AND DISCUSSION

3.1 COMPRESSION TEST

3.1.1 COMPRESSIVE STRENGTH TEST REPORT FOR SPECIMEN

Specimen code	1		
Ref. Standard	ASTM D 695		
Grip Length	50 mm	Guage Length	0 mm
Sample Width	50 mm	Sample Thickness	3 mm

3.1.1.1 Graph View



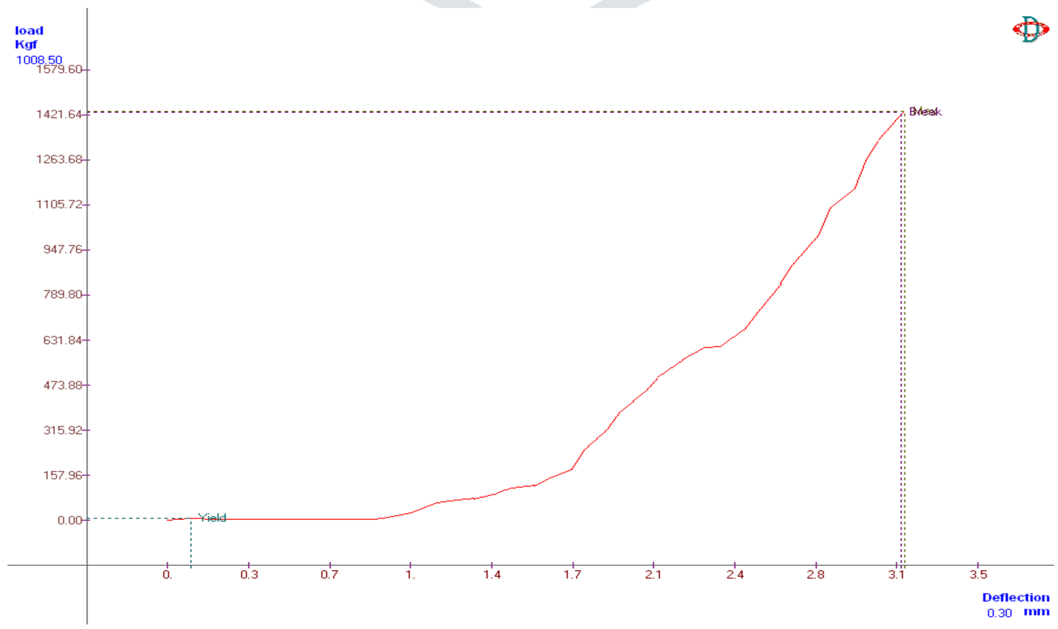
3.1.1.2 Obtained Result

Sr. No.	Results	Value	
1	Area	1.50	cm^2
2	Yield Force	19.00	kg
3	Maximum Force	1439.7	kg
5	Total Deflection	3.21	mm
6	Compre. Yeild strength	12.67	kg/cm^2
7	Compressive strength	959.77	kg/cm^2
8	% Deflection	6.41	

3.1.2 COMPRESSIVE STRENGTH TEST REPORT FOR SPECIMEN 2

Specimen code	2 (12% Graphene)		
Ref. Standard	ASTM D 695		
Grip Length	50 mm	Guage Length	0 mm
Sample Width	50 mm	Sample Thickness	3 mm

3.1.2.1 Graph View



3.2.1.2 Results Obtained

Sr. No.	Results	Value
1	Area	1.50 cm^2
2	Yield Force	7.00 kg
3	Maximum Force	1430.2 kg
5	Total Deflection	3.16 mm
6	Compre. Yeild strength	4.67 kg/cm^2
7	Compressive strength	953.48 kg/cm^2
8	% Deflection	6.31

Specimen	Yield Force (kg)	Compressive Yield Strength (kg/cm^2)	Compressive Strength ($Kg/cm^{2)}$	% deflection
1	7	4.67	953.48	6.31
2	19	12.67	959.71	6.41

3.1.3 COMPRESSION RESULTS

<u>Specimen 1</u>
3 layer Glass fabric +Weight % Epoxy Resin + 9% Graphene .
<u>Specimen 2</u>
3 layer Glass fabric +Weight % Epoxy Resin + 12% Graphene .

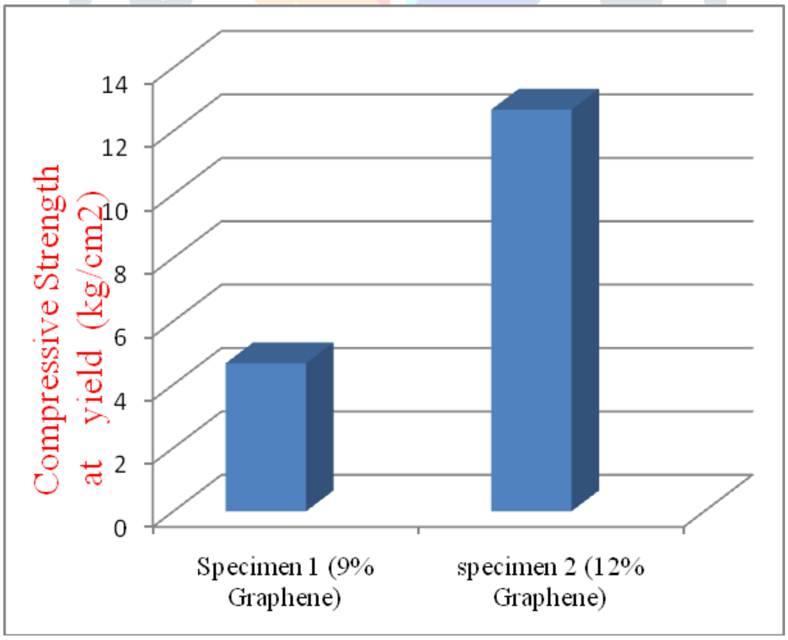


Figure 8. Comparison Chart for Compression Tests

Figure 8. Test Specimen

IV CONCLUSION

- The Mechanical properties of the composites are Improving, when graphene is added with matrix as Epoxy Resin during the prepare the composite.
- Compression strength of 9 % Graphene Specimen is 953.48 kg/cm^2 and 12 % Graphene Specimen is 959.71 kg/cm^2 ,Here no improvement in Compression Strength of Both 9% and 12% Graphene Specimen but Compression Strength at yield are improved.

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