Analysis of Manufacturing Techniques on Strength Properties of Glass Fibre Reinforced Composites to be used in Automobile

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Abstract— In recent era the demands of Fiber Reinforced Composite materials are increasing because overall properties of the composites are superior to those of individual materials. Composites materials are used in almost all aspects of the industrial and commercial fields. Glass Fiber Reinforced Composites are considered to have potential use as a reinforcing material in polymer based composites. Glass Fiber Reinforced Composites have been prepared by various manufacturing technology and are widely used for various applications. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. Glass Fiber Reinforced Composite structures are manufactured by using E-class glass fibre and polyester resin using two different methods - hand lay-up and spray-up manufacturing techniques in the application area of car bumper for passenger cars. The specimens prepared from composite laminates are tested for mechanical properties such as tensile strength, flexural strength and impact strength as per the ASTM standard D638, D790 and D256 respectively. Results show improved strengths for spray-up method.

Key words: Composite, Glass Fiber, Glass Fiber Reinforced Composite, Hand Lay-Up, Spray- Up

I. Introduction

It would be difficult to imagine the modern world without unreinforced and reinforced plastics. Today they are an integral part of everyone's life-style, with products varying from commonplace domestic to sophisticated scientific products. In fact, many of the technical wonders we take for granted would be impossible without these versatile and economical materials.

The term RP refers to composite combinations of resin and reinforcing materials that provide significant property and/or cost improvements than the individual components that can produce products. To be structurally effective, there must be a strong adhesive bond between the resin and reinforcement.

According to American society for materials (ASM) Handbook, composites can be defined as “a macroscopic combination of two or more distinct material having a recognizable interface between them.” A composite material is made by combining two or more materials to give a unique combination of properties.

Composite materials are flexible materials for multifunctional applications due to their significant properties such as high specific strength, modulus, bending stiffness and chemical resistance.

A composite material also called a composition material or shortened to composite which is the common name. A composite is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials. As the composite materials possess great properties they are substituting various other conventional materials therefore, the research on composite materials must be developed further.

Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

Fiber-reinforced composites are essentially axial particulates embedded in fitting matrices. The primary objective of fiber-reinforced composites it to obtain materials with high strength in conjunction with higher elastic modulus. The strength elevation is however affected with applied load transiting from matrix to fibers, interfacial bonding between fiber-matrix, their relative alignment and nature of fiber scheming the overall material behaviors. The alignment of fibers may however be continuous or random depending on the end applications. The choice of the fiber reinforcement and its fitting matrix also depends on application requirements. In recent years, the advent of composite technology has led to the development of different fiber reinforced composite systems via varying manufacturing methodologies to obtain advanced material behaviors.

The rising demand for lightweight and strong materials has prompted leading high performance composites manufacturers to invest heavily in developing low cost and high strength new materials. Over the last 30 years composite materials, plastic and ceramics have been dominating emerging materials. The volume and number of application of composite materials have grown steadily penetrating and conquering new market relentlessly.

A. *Types of Composite Materials*

Composite materials are commonly classified at following two distinct levels:

The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Metal matrix composites (MMC), Ceramic matrix composites (CMC) and Polymer matrix composites (PMC). On the basis of type of polymer resin used, Polymer matrix composites further can be classified into two categories. (1) Thermo-set Composites and (2) Thermoplastic Composites.

The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres. Laminates can be composed of reinforcement material which may be woven, knitted, non woven or braided.

B. Composite Manufacturing Methods

There are numerous methods for fabricating composite components. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application. Composite fabrication processes involve some form of molding, to shape the resin and reinforcement. A mold tool is required to give the unformed resin /fiber combination its shape prior to and during cure.

Classification of composites processing techniques are given below (Refer fig. 1).

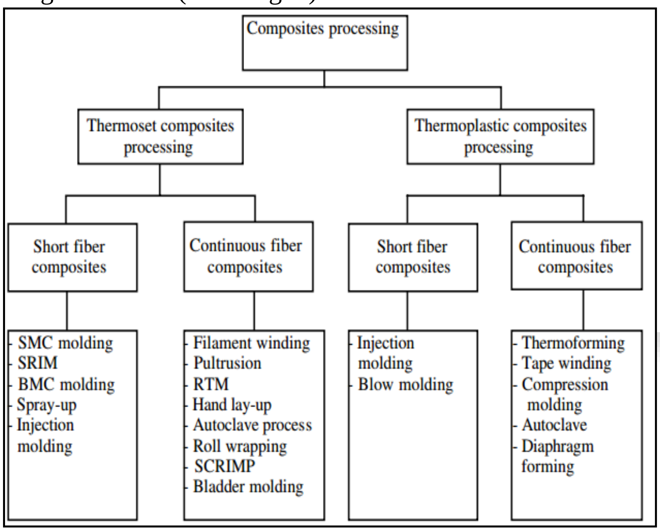

Fig. 1: Classification of Composites Processing Techniques

C. Basic Steps in a Composite Manufacturing Process

There are four basic steps involved in composites part fabrication: wetting/impregnation, lay- up, consolidation, and solidification.

1) Impregnation

In this step, fibers and resins are mixed together to form a lamina. The purpose of this step is to make sure that the resin flows entirely around all fibers. Viscosity, surface tension, and capillary action are the main parameters affecting the impregnation process.

2) Lay-up

In this step, composite laminates are formed by placing fiber resin mixtures or prepregs at desired angles and at places where they are needed.

3) Consolidation

This step involves creating intimate contact between each layer of prepreg or lamina. This step ensures that all the entrapped air is removed between layers during processing.

4) Solidification

The final step is solidification. The rate of solidification depends on the cooling rate of the process.

All composites manufacturing processes involve the same four steps, although they are accomplished in different ways. The methods of applying heat and pressure, as well as creating a desired fiber distribution, are different for different manufacturing methods.

D. Glass Fibers Reinforced Polymer Composites

Glass Fiber is one of the most common fibers in the composites industry. The main reason for its use is the relatively low costs involved as glass fiber is significantly cheaper than carbon fiber. This makes glass fiber attractive for the production of many composite structures. Glass fibers are one of the most widely used polymer reinforcements with nearly 90% of all FRPs made of glass fibers.

The material is fairly cheap, which can be very beneficial for large structures. Another benefit is the good chemical resistance to acids and solvents. Furthermore, glass fiber is electrically insulating, has a higher elongation at break compared to carbon fiber and has a high temperature resistance. Combining the properties of glass fiber, i.e. low moisture absorption, high strength, heat resistance and low dielectric constant makes the material ideal for various markets. The material is moisture resistant and has a high strength to weight ratio. Glass fiber can be processed in various ways and in combination with many resin systems: it is easy to trim after curing and processes such as wet layup and resin infusion are as well available and do not require high investments.

Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. It may be in the form of roving’s, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. Suitable compositions and orientation of fibers made desired properties and functional characteristics of GFRP composites was equal to steel, had higher stiffness than aluminum and the specific gravity was one-quarter of the steel.

Classification and physical properties of various glass fibers

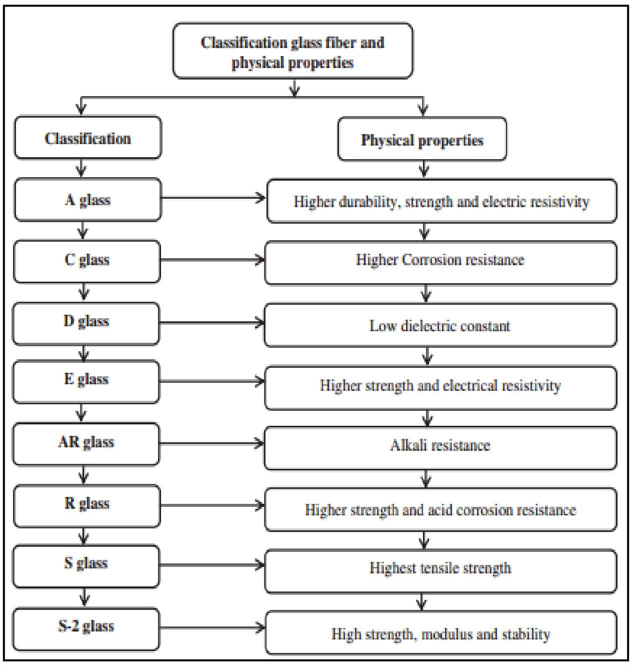

Fig. 2: Classification and Physical Properties of Various Glass Fibers

In routine Car accidents are happening very often with passenger cars. Most drivers are convinced that they can avoid such troublesome situations. Nevertheless, we must take into account the statistics ten thousand dead and hundreds of thousands to million wounded each year. These numbers call for the necessity to improve the safety of automobiles during accidents. However, car accident does not necessarily mean bodily harm. In a low-speed car accident only physical damage occurs, assuming that basic safety regulations.

During accidents, majorly bumper of the car will have the first impact. Car bumper can be made up by variety types of material. If it is made up of steel material it is strong enough, but it will have a heavy mass. If it is made up of plastic material, it will have light weight but not that much sustainable. It may get damage due to minor impact or cut or grooves may generate in it very easily. Many times it is not repairable also. To change this part will also cost more. Here composite material can play a big role, which is not heavy like metal materials and may have more sustainability than plastic materials. Furthermore composites can be repairable also. So here study is carried out for glass fibre reinforced composite, which is prepared by different methods in the application area of car bumper for passenger cars.

II. EXPERIMENTAL METHODOLOGY

A. Material & Methodology

Glass Fiber Reinforced Composite structures manufactured by using E-class glass fibre (450 gsm) and polyester resin in the ratio of 30:70 and suitable hardener and catalyst were added. Glass Fiber Reinforced Composite prepared by using two different manufacturing techniques - hand lay-up and spray-up.

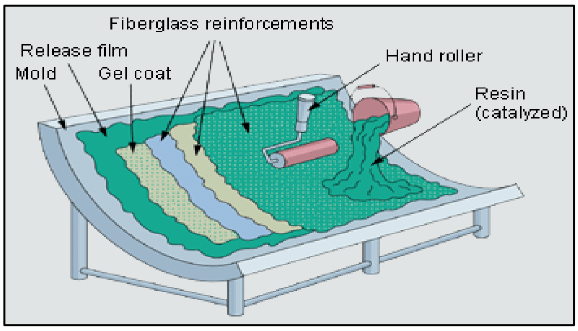

Fig. 3: Hand Lay Up Process

1) Hand Layup

In this process, liquid resin is applied to the mold and then reinforcement is placed on top (Refer fig. 3). A roller is used to impregnate the fiber with the resin. Another resin and reinforcement layer is applied until a suitable thickness builds up. A roller is used to squeeze out excess resin and create uniform distribution of the resin throughout the surface. By the squeezing action of the roller, homogeneous fiber wetting is obtained. The part is then cured mostly at room temperature and, once solidified; it is removed from the mold.

The major processing steps in the wet lay-up process include:

1) A release agent is applied to the mold.
2) The gel coat is applied to create a surface finish on the outer surface. The gel coat is hardened before any reinforcing layer is placed.
3) The reinforcement layer is placed on the mold surface and then it is impregnated with resin. Sometimes, the wetted fabric is placed directly on the mold surface.
4) Using a roller, resin is uniformly distributed around the surface.
5) Subsequent reinforcing layers are placed until a suitable thickness is built up.
6) The part is allowed to cure at room temperature, or at elevated temperature.

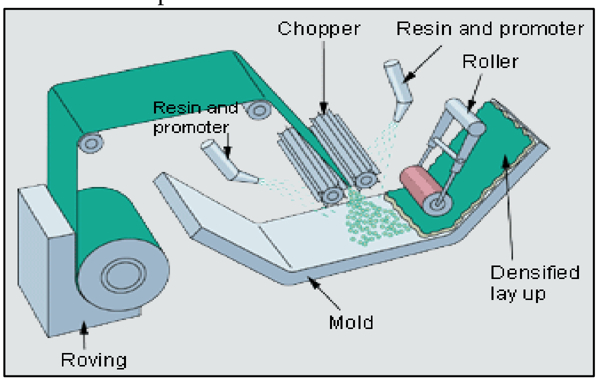

Fig. 4: Spray Up Process

2) Spray Up

The spray-up process is similar to the wet lay-up process, with the difference being in the method of applying fiber and resin materials onto the mold (Refer fig. 4). The wet lay-up process is labor intensive because reinforcements and resin materials are applied manually. In the spray-up process, a spraygun is used to apply resin and reinforcements. The part is then cured mostly at room temperature and, once solidified; it is removed from the mold.

The steps used in the spray-up process are almost the same as for the wet lay-up process, except for the method of creating the laminates.

B. *Testing*

Materials prepared were taken for testing of different properties as per ASTM standards.

1) *Tensile Test*

The test was conducted according ASTM D638 standard with type-I of total length of the specimen 165mm with 50mm gauge length for laminate thickness less than 7 mm. This test was carried out by using a universal testing machine (UTM) at crosshead speed of 100 mm/min and the result was noted for five different specimens.

Fig. 5: Tensile strength test samples

2) *Flexural Test*

The flexural properties were measured with rectangular samples according to ASTM D-790, using the UTM at crosshead speed of 2.8 mm/min. The fracture strength was determined from the peak load (kg) and the result was noted for five different specimens.

Fig. 6: Flexural Strength Test Samples

3) *Impact Test*

The Izod impact test was carried out

Fig. 7: Impact Strength Test Samples

According to ASTM D-256 using an impact tester. The impact test was carried out at room temperature and impact energy was reported in J/m and the result was noted for five different specimens.

III. RESULTS & DISCUSSIONS

A. *Tensile Strength Test*

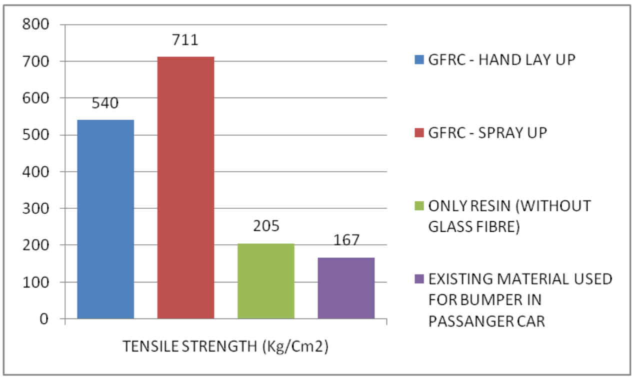

Fig. 8: Tensile Strength Test Chart

Test results for the tensile strength test shows that GFRC prepared by spray-up method shows highest strength, which is 132% higher than GFRC prepared by hand lay-up method, 347% higher than material prepared with only resin (without glass fibre) and 426% higher than existing material used for bumper in passenger car.

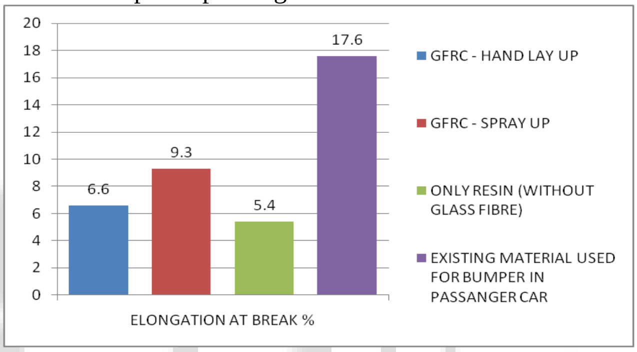

Fig. 9: Elongation at break % chart

Test results for Elongation at break % shows that GFRC prepared by spray-up method shows elongation at break 141% higher than GFRC prepared by hand lay-up method. Here existing material used for bumper in passenger car shows highest elongation at break.

B. *Flexural Strength Test*

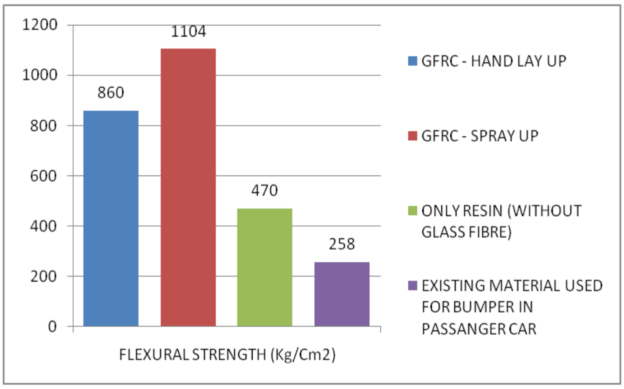

Fig. 10: Flexural Strength Test Chart

Test results for the flexural strength test shows that GFRC prepared by spray-up method shows highest strength, which is 128% higher than GFRC prepared by hand lay-up method, 235% higher than material prepared with only resin (with out glass fibre) and 428% higher than existing material used for bumper in passenger car.

1) Impact Strength Test

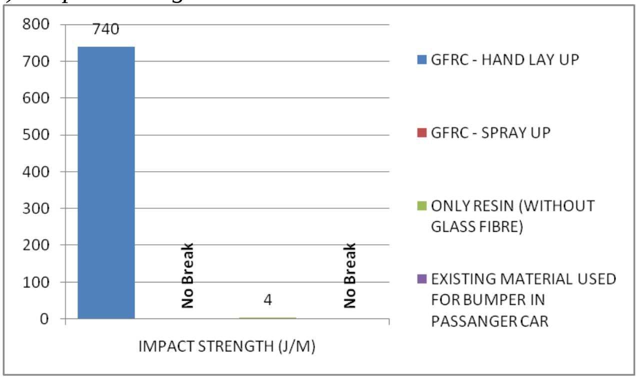

Fig. 11: Impact Strength Test Chart

Test results for the impact strength test shows that GFRC prepared by spray-up method shows very high strength than GFRC prepared by hand lay-up method because here digital impectometer which is operated with hammer of 4 Joule did not observe any break for all specimens. GFRC prepared by hand lay-up method shows 185 times higher strength than material prepared with only resin (with out glass fibre). Even no break observed for all specimens for existing material used for bumper in passenger car.

IV. CONCLUSIONS

In order to understand the effect of different manufacturing techniques on properties of Glass Fiber Reinforced Composite experimental studies were carried out. Test results shows that Glass Fiber Reinforced Composite prepared by spray-up method shows higher tensile strength, flexural strength and impact strength than GFRC prepared by hand lay-up method. GFRC prepared by spray-up or hand lay-up method shows higher mechanical properties than the material prepared with only resin (with out glass fibre) and the existing material used for bumper in passenger car.

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