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Development of Novel Polymer Composites

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Abstract*— Polymers are usually used as in the form of composites which make them applicable to different areas. Most commonly used polymer composite is fiber-reinforced plastic (FRP) which made through polymer matrix reinforced with fibers. Most common type of FRP is glass reinforced plastic (GRP). GRP is a composite of polyester resin and glass fiber which is a lightweight, extremely strong, and robust material. But in glass Reinforced Plastic (GRP), glass fiber is an inorganic compound and polyester resin is an organic compound. That means GRP is a mixture of organic and inorganic compounds. This reduces the adhesion between the compounds. Due to these different characteristics of materials, after damage GRP cannot be degradable and this directly affects natural problems. The introduction of polyester fiber instead of glass fiber with polyester resin makes an organic polymer composition and improves adhesion between compounds. Due to the homogeneous characteristics of the compounds, these materials can be degradable and used as filler material in any other applications. This paper presents the development of composition of polyester fiber with polyester resin and their various properties.

***Index Terms*—Fiber reinforced plastic, Glass reinforced plastic, Polyester fiber, Polyester resin.**

I. INTRODUCTION

Materials science is an interdisciplinary field applying the properties of matter to various areas of science and engineering [1]. Based on atomic structure and chemical composition the traditional groups of material science are classified as ceramics, metals and polymers. A polymer [2] is a chemical compound or mixture of compounds consisting of repeating structural units created through a process of polymerization. Polymers are commonly used in the form of composites. Most commercially produced composites use a polymer matrix material often called a resin solution. The most common types of resin are polyester, epoxy, phenolic, polyimide, polyamide, vinyl ester, polypropylene, polyether ether ketone (PEEK), and others. Polymer composites are very popular due to their low cost and simple fabrication methods. Most commonly used polymer composites are fiber reinforced plastic. Fiber-reinforced plastic (FRP) [3] is a composite material made of a polymer matrix reinforced with fibers. FRP has applications in several areas such as aerospace, automotive, marine, and construction industries. Most commonly used FRP is Glass-reinforced plastic (GRP). GRP is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass [4]. GRP is a lightweight, extremely strong, and robust material. Bulk strength and weight properties of GRP are also very favorable when compared to metals and it can be easily formed using molding processes. Fiberglass is commonly used in aircrafts, automobiles, boats, water tanks, roofing, pipes, cladding, casts, Surfboards, and external door skins. Glass reinforcements used for fiberglass are available in different physical forms such as fine ground, chopped or woven roven mat. Due to high strength and high cost woven roven mat is usually used for insulating purpose which makes the final structure to be strong, and thus the fiber's surfaces must be almost entirely free of defects.

II. OBJECTIVE

Glass reinforced plastic is a composition of glass fiber and resin (polyester resin). As a single material glass fiber is an inorganic material and it has three dimensional networks. These characteristics make them strong and robust. But in composite form like glass reinforced plastic, glass fiber is an inorganic compound and polyester resin is an organic compound. That means GRP is a mixture of organic and inorganic compounds. This reduces the adhesion between the compounds due to weak interface. To develop better adhesion property between composites, usually coupling agent is added. The adhesion properties of glass reinforced plastic are highly proportional to this coupling agent. Besides, due to these heterogeneous characteristics of materials, after damage GRP cannot be degradable by any method and this usually considered as non degradable waste. The introduction of polyester fiber instead of glass fiber with polyester resin makes an organic polymer composition and improves adhesion between compounds. Polyester fiber is a manufactured fiber in which the fiber forming substance is any long chain synthetic polymer composed at least 85% by weight of an ester of a dihydric alcohol (HOROH) and terephthalic acid [5]. The development of new polymer composites of polyester fiber and polyester resin brings homogeneous characteristics in FRP. The adhesion property of polyester fiber composites is very high, so coupling agent is not required. Also due to the homogeneous characteristics of the compounds, these materials can be degradable and used as filler material in any other applications. Polyester fiber composite is light weight, high flexible material compared to glass fiber. Ductile property of polyester fiber composite is also very high. So polyester fiber composites can replace the different areas of GRP where impact load have more important. Also cost of polyester fiber composite is comparatively low when compared to glass reinforced plastic.

III. METHODOLOGY

A. Materials Used For Composites

Different materials used for making required composites are,

- ➢ Polyester Fiber
- ➢ Polyester Resin

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- Catalyst (Methyl ethyl ketone peroxide, MEKP)
- Accelerator (Cobalt (II) naphthenate)
- Acetone
- Silica paste

B. Method Used For Fabrication of Composites

Method used for fabrication of required composites is hand lay-up operation.

Hand lay-up operation

A release agent, usually in either wax or liquid form, is applied to the chosen mold. Silica paste is commonly used as release agent. This will allow the finished product to be removed cleanly from the mold. Polyester, vinyl or epoxy resin is mixed with its hardener and applied to the surface. Then sheets of polyester fiber matting are laid into the mold and more resin mixture is added using a brush or roller. The material must suitable to the mold and air must not be trapped between the polyester fiber and the mold. Additional resin is applied to the additional sheets of polyester fiber. Hand pressure, vacuum or rollers are used to make sure the resin saturates and fully wets all layers, and removed any air pockets. The work must be done quickly enough to complete the job before the resin starts to cure. In some cases, the work is covered with plastic sheets and vacuum is drawn on the work to remove air bubbles and press the polyester fiber to the shape of the mold.

Procedure for making composites

Procedure for making polymer composite (polyester fiber) is given below.

- Usually rectangle (ceramic) tiles are used as the mold and the mold is placed in position.
- Clean the mould using acetone.
- Take the OHP sheet and place above the mold.
- Apply silica paste on the OHP sheets and give required time to get dried.
- Take the beaker and pour the resin into the beaker.
- After the resin, the accelerator (Cobalt (II) naphthenate) is poured into the beaker.
- The standard ratio of the resin, accelerator and the catalyst is 100:1:1. That means 100 grams of the resin need 1gm of the accelerator and 1gm of the catalyst.
- The resin and the accelerator is stirred using a stirrer.
- The resulting solution is mixed with the catalyst (methyl ethyl ketone peroxide).
- The solution (resin mixture) is pasted on the OHP sheet using hand lay-up method.
- A layer of the polyester fiber is laid above the solution.
- The resin mixture is added to the sheet using a brush or a roller.
- Next layer of the polyester fiber sheet is then laid above the resin solution.
- Again the resin mixture is added to the sheet using a brush or a roller.
- The procedure is repeated until all the layers of the sheets are added with the resin mixture.
- Finally the composite is covered with OHP sheet and the tile.
- Sufficient time should be given to cure the composite.

C. Different Test for Measuring Mechanical Properties of Composites

According to methodology and ASTM standard, samples are developed and following tests are carried out.
Different tests for measuring mechanical properties of composites are:

- Tensile test
- Impact test

Tensile test

Ultimate tensile strength (UTS) is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking [6]. The most common testing machine used in tensile testing is the universal testing machine. Figure 1 shows the image of universal testing machine.

Fig.1: Universal Testing Machine

Impact strength

Impact strength is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy [7]. Izod impact strength testing is an ASTM standard method of determining impact strength. Figure 2 shows the image of Impact testing machine.

Fig.2: Impact Testing Machine

Hardness Test

Hardness [8] is the property of the material which gives it the ability to resist being permanently deformed when a load is applied. There are different measurements of hardness,

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they are scratch hardness, indentation hardness and rebound hardness. Indentation hardness test is commonly used to measure hardness strength of fiber reinforced plastic. Shore durometer [9] is used to measure hardness of FRP.

Fig.3: Shore Durometer

Figure 4 represent the polyester fiber composite samples developed on the basis of methodology and ASTM standard. Rectangle shapes are used to test impact strength and dumbbell shape is used to test tensile strength.

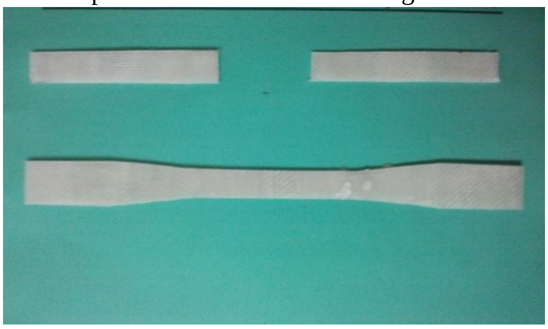

Fig.4: Polyester Fiber Composite Sample

IV. RESULTS AND DISCUSSION

Tensile test and impact test are conducted and results are shown in table. Samples are developed by considering the standard ratio of 100:1:1.That means 100 gms of the resin need 1gm of the accelerator and 1gm of the catalyst. Samples of different curing temperatures are produced.

A. Tensile Test

From table I, it is clear that maximum stress of polyester fiber composite is 147.63 N/mm^2. But maximum stress of glass reinforced plastic is only 137.39N/mm^2. That means tensile strength of polyester fiber is slightly higher than glass reinforced plastic. From table I, it is clear that; strain property of polyester fiber composite is much larger than (about 8-10 times) the strain property of the glass reinforced plastic.

Table I .Tensile Strength Comparison Table

	POLYESTER FIBER COMPOSITES			GLASS REINFORCED PLASTIC		
	Temperature of 30°	Temperature of 55°	Temperature of 80°	Temperature of 30°	Temperature of 55°	Temperature of 80°
MAXIMUM STRESS (N/mm²)	138.15	144.37	147.63	137.39	112.48	95.92
MAXIMUM STRAIN (%)	41.61	41.86	42.176	4.725	4.93	5.45

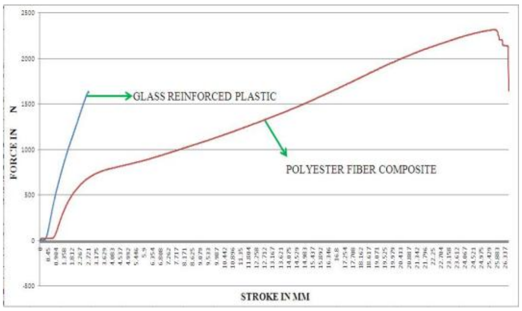

Fig.5: Stress Vs Strain Graph of Polyester Fiber Composite and Glass Reinforced Plastic

Figure 5 represent the stress vs strain graph of both composites and from graph we observed that elastic and plastic region of polyester fiber composite is much larger than the glass reinforced plastic.

B. Impact Test

Table II . Impact Strength Comparison Table

	POLYESTER FIBER COMPOSITES			GLASS REINFORCED PLASTIC		
	Temperature of 30°	Temperature of 55°	Temperature of 80°	Temperature of 30°	Temperature of 55°	Temperature of 80°
Impact strength (KJ/m²)	No break	No break	No break	94.75	84.97	125.48

From table II, under impact load there is no break on polyester fiber composites. This is because polyester fiber composite has large ductile property and high elastic and plastic region. This is clearer from figure 6. In figure 6, the area under the energy curve of polyester fiber composite is 29173.71mm^2. But the same of glass reinforced plastic is only 2234.044 (Figure 7). That means area under the curve of polyester fiber composite is 13 times higher than the glass reinforced plastic. This is the reason for no breakage. So the polyester fiber composite have very high impact strength.

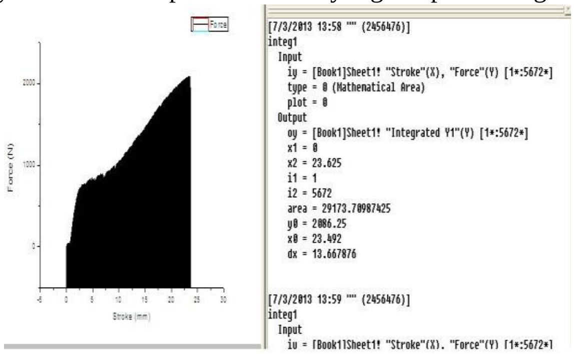

Fig.6: Area under the energy curve of polyester fiber composites

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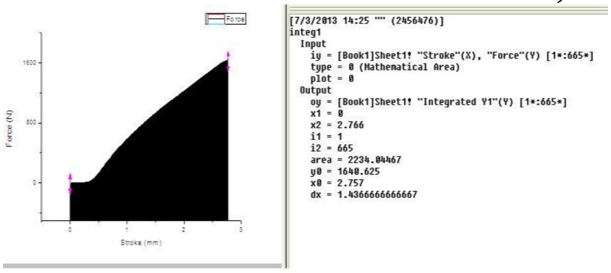

Fig.7: Area under the energy curve of glass fiber composites

C. Hardness Test

Table III. Hardness Strength Comparison Table

	POLYESTER FIBER COMPOSITES			GLASS REINFORCED PLASTIC		
	Temperature of 30°	Temperature of 55°	Temperature of 80°	Temperature of 30°	Temperature of 55°	Temperature of 80°
Hardness Strength (SHORE D)	84	83	85	83	87	85

From table III, it is clear that hardness strength of new FRP is almost same as glass reinforced plastic. This will bring more advantages to new polyester fiber composites.

V. CONCLUSION

Nowadays the usage of glass reinforced plastic is increased in various fields due its competitive property and its low cost compare with metals. So it has various applications in automobiles, military, aerospace, water tanks and so on. But its non degradable property due to its heterogeneous characteristic limits their applications in various fields. The introduction of new polyester fiber composites can replace the application of GRP where ductility and flexibility have major important or high impact strength is required. This means that more research on polyester fiber composite makes them more applicable in future.

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