International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 11, Issue 12 (December 2015), PP.65-71

Mechanical & Thermal Characterisation of Glass Fiber Reinforced Composites with Polyester Resin Matrices

Ayush Trivedi[1], Shakun Srivastava[2]
[1]*M.Tech. Scholar Mechanical Engineering Department, Kanpur Institute of Technology, Kanpur, U.P.*
[2]*Assistant Professor, Department of Mechanical Engineering, Kanpur Institute of Technology, Kanpur, U.P.*

Abstract:- The composite manufacturing has been a wide area of research and it is the preferred choice due to its superior properties like low density, stiffness, light weight. This has found its wide applications in aerospace, automotive, transportation, FRP doors and panels and sporting industries, etc. There has been continuous lookout for synthesizing composites without compromising on the mechanical and physical properties. In this research, FRP composites were prepared using polyester resin & glass fiber. Glass fiber is added in matrix form of Chopped Strand Mat & Woven Roving fabric for contact moulding process i.e. for hand lay up two layers are chosen of each type of Glass fiber for getting sufficient thickness of laminates. The composites were synthesized using appropriate fiber-resin weight percentage. The prepared composites were tested to study the mechanical properties of the composite such as tensile strength, impact strength and hardness & Thermal Properties using Limiting Oxygen Index Test.

The result of this research indicate better mechanical as well as thermal properties and by the combination of the useful properties of two different materials, quicker processing time, lower manufacturing cost, etc., make it as a versatile material in the field of engineering & Technology.

Keywords: - FRP, Glass fiber, Limiting oxygen index, processing time, Polyester resin, composites.

I. INTRODUCTION

Bakelite was the first fiber-reinforced plastic. Dr. Baekeland had originally set out to find a replacement for shellac (made from the excretion of lac beetles). Chemists had begun to recognize that many natural resins and fibers were polymers, and Baekeland investigated the reactions of phenol and formaldehyde. He first produced soluble phenol-formaldehyde shellac called "Novolak" that never became a market success, and then turned to developing a binder for asbestos which, at that time, was moulded with rubber. [1] By controlling the pressure and temperature applied to phenol and formaldehyde, he found in 1905 he could produce his dreamed-of hard mouldable material (the world's first synthetic plastic) called Bakelite.

Mass production of glass strands was discovered in 1932 when Games Slayter, a researcher at Owens-Illinois accidentally directed a jet of compressed air at a stream of molten glass and produced fibers. A patent for this method of producing glass wool was first applied for in 1933. Owens joined with the Corning Company in 1935 and the method was adapted by Owens Corning to produce its patented "fiberglass" (one "s") in 1936. Originally, fiberglass was a glass wool with fibers entrapping a great deal of gas, making it useful as an insulator, especially at high temperatures. [2]

A suitable resin for combining the "fiberglass" with a plastic to produce a composite material, was developed in 1936 by du Pont. The first ancestor of modern polyester resins is Cyanamid's resin of 1942. Peroxide curing systems were used by then. With the combination of fiberglass and resin the gas content of the material was replaced by plastic. This reduced to insulation properties to values typical of the plastic, but now for the first time the composite showed great strength and promise as a structural and building material. Confusingly, many glass fiber composites continued to be called "fiberglass" (as a generic name) and the name was also used for the low-density glass wool product containing gas instead of plastic. [3]

A fiber has a length that is much greater than its diameter. The length-to-diameter (l/d) ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth, and helical winding, while examples of discontinuous reinforcements are chopped fibers and random mat. Continuous-fiber composites are often made into laminates by stacking single sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 60 to 70 percent. Fibers produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fiber, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibers have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii. Typical fibers include glass, aramid, and carbon, which may be continuous or discontinuous.

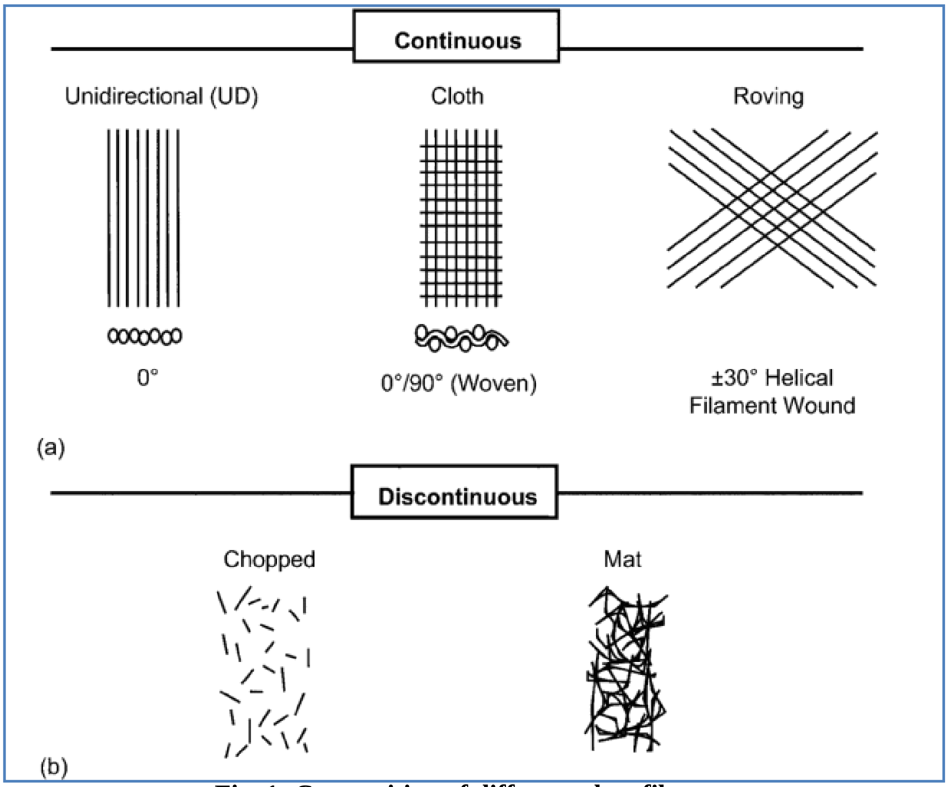

Fig. 1: Composition of different glass fiber

Today over 95% of commercial reinforcement glass fibers are made from E-type compositions. The main compositions of E-glass (electrically conductors) are the oxides of silica, aluminium and calcium. The glass fiber is also regarded as calcium alumino borosilicate glass.The major characteristics of GFRPs are:

a) Light Weight b) Good Toughness c) Good Insulation property d) High Specific Strength e) Process Freedom f) Shape Freedom

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. Reinforcing phase and the one in which the reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and polyester reinforced with glass fibers, etc.

N. V. Rachchh (2014) & Team Investigated that addition of fiber leads to improvement in mechanical properties up to 12.5% fiber level after which there is decrement in properties as resin is not sufficient to transfer load between fibers. [4]

According to S. K. Garkhali et al. (2000) in the last decade, research activities in the area of thermoplastic composites have shifted from high-performance advanced composites towards the development of cost-performance engineering composites, especially, glass-mat-reinforced thermoplastic materials [5]. Composites, the wonder material with light-weight, high strength-toweight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, woods etc. The replacement of steel with composites can save a 60-80 percentage of component weight and 20-50 weight percentages with the aluminium components. The polymer based composite materials use is increasing because of their light weight, good mechanical and tribological responses [6] [7].

After the composite development to meet the challenges of aerospace sector, researchers have focused to cater to needs of domestic and industrial applications [7]. Composite boards have been used in development of panel and flush doors to satisfy the low cost housing needs. Other product development such as panel roofing sheets with glass fiber produces large increase in mechanical properties of composites. Since glass fiber with polyester resin composite being cost effective therefore, it finds its application in building, construction industry (panels, false ceilings, partition boards etc.), packaging, automobile & railway coach interiors and storage devices as it can also be made fire retardant. [8]

In this research the fabrication of composites by using glass fiber i.e. in continuous and discontinuous form with polyester as resin was carried out. The composites were prepared and cured using contact moulding process i.e. Hand Moulding Process and the mechanical properties as well as thermal properties are evaluated and analyzed over its point and area of applications.

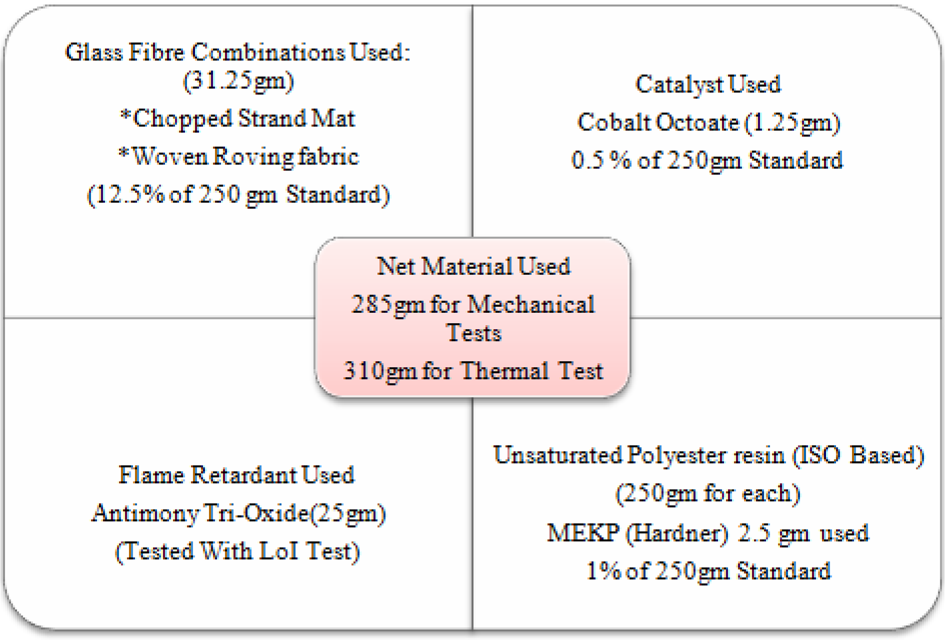

Fig. 2: Net Material Used for Research as per Standards

II. MATERIAL

GFRP specimens are prepared using glass fiber and unsaturated polyester resin using hand layup technique.

2.1. Methodology Used

Laminates of GFRP are made by hand Layup method and glass fiber is added in matrix form of Chopped Strand Mat & Woven Roving fabric as shown in fig. for hand lay up two layers are chosen of each type of Glass fiber for getting sufficient thickness of laminates. Layers are subsequently arranged in mould. Releasing agent is applied for releasing of laminate from mould we used OHP sheets. Next polyester resin is added with 1% of MEKP & 0.5% of Cobalt as accelerator. MEKP promotes cross linking between resin and fiber. The unsaturated polyester amounts to about 75% of all polyester resins used in the world

After adding resin curing process is there. In curing plate is left for about 24 HRS than resin will take its form and become solid after being sufficient hard laminate is removed properly from mould.

Resin needs more time to curing for getting hardness plate is cured for 2 hrs in room temp. For proper use. Now, finally samples are made to cut out for Mechanical testing and Thermal testing acc. To ASTM standards for testing and measurements.

(a) **(b)**

Fig. 3: Sample of GFRP Laminates (a) For Mechanical Test (b) For Thermal Test

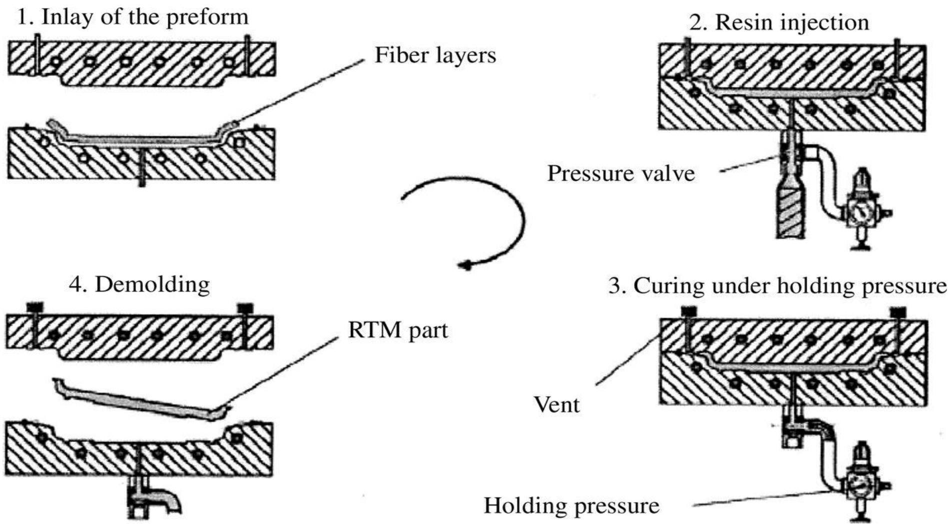

Fig. 3: Hand Layup Technique

III. TESTING

Mechanical and thermal testing plats an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction.

If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads and fire stress that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical thermal testing of engineering materials subjected to tension, compression, bending or torsion loading. Laminates made with glass fiber are tested for tensile strength, Impact strength and hardness for mechanical and limiting oxygen index test for thermal test. Test specimens are prepared with different weight fractions of GFRP using Antimony tri-oxide for making the specimen retardant towards flame and excessive temperature.

3.1 Tensile strength test

The most common type of test used to measure the mechanical properties of a material is the tension test. Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength, yield strength or yield point, elastic modulus, percent elongation and the reduction in area. Toughness, Resilience, Poisson's ratio can also be found by the use of this testing technique. For Testing Specimen are cut as per ASTM D-638 standards and tested for tensile Strength in Universal testing machine.

3.2 Impact test

Impact strength is defined as the ability of material to absorb applied energy its unit is J/m. Test method used is as per ASTM-D 256A (charpy) standards with specimen dimension 63.5 x12.7 x 4.5 mm. In this test the specimen is mounted horizontally and supported at both ends. Only the specimens that break completely are considered acceptable. The Charpy impact strength is calculated by dividing the indicator reading by the thickness of the specimen. The results are reported in ft-lbs/in. of notch for notched specimen and ft-lbs /in. for un notched specimens.

$$\text{Impact strength (J/m) (Charpy)} = \frac{\text{Energy required breaking the sample (J)}}{\text{Thickness (m)}}$$

3.3 Hardness test

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex therefore there are different measurements of hardness, scratch hardness, indentation hardness, and rebound hardness. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness and viscosity.

Rockwell hardness number derived from the net increase in depth impression as the load on an indenter is increased from a fixed minor load a major load and then returned to minor load. Test Method used is as per ASTM D 785 standards with specimen dimensioning of 25*25*4.5 mm.

3.4. Limiting oxygen index test (LOI)

LOI is defined as the minimum oxygen concentration value expressed in volume percent (in a mixture of oxygen and nitrogen) required for the continuous combustion of the material under specified testing condition. The LOI is a measure of the percentage of oxygen that has to be present to support combustion of the composites - the higher the LOI the lower the flammability. It also describes the tendency of a material to sustain a flame and it is a Measure of the minimum concentration of oxygen in flowing mixtures of oxygen and nitrogen that will just support flaming combustion of plastics. Test method used acc. to ASTM D2863, ISO 4589 standards Specimen Dimension physically self-supporting 7(W), 3.5(T), 100 (L) in mm with material GFRP Using Polyester Resin with Antimony Tri-Oxide (Flame Retardant Compound).

IV. RESULT AND DISCUSSION

This study of mechanical and thermal characterization of GFRP composite laminates presents the physical, mechanical and thermal characterization of the class of polymer matrix composite developed for the present investigation. All testing were conducted under ambient conditions in an environmentally controlled room.

4.1. Tensile test result

The standard specimens for tensile stress measurements were cut in dumbbell shape. Test specimens were visually inspected before measurement and were found to be free from pores and nicks. Tensile test is carried out in Universal testing Machine (UTM) as per ASTM D-638 standards. For tensile test three specimens or samples were prepared and tested. The result of tensile test is as shown in bar chart and table no.1.

4.2. Hardness test result

Hardness test is carried out using Rockwell M-Scale at load 100kgf as per ASTM D 785 standards. Test specimens were visually inspected before measurement and were found to be free from pores and nicks. The result of hardness test is shown in below table.

4.3. Impact test result

The charpy test specimens were made acc. To the dimensions of ASTM D 256A in which the dimension is 63.5 x12.7 x 4.5 mm. One of the main reasons of concern for composites generally is the low values of impact energy but we see as per our test that the impact strength is quite improved using the fiber of two different allocations with polyester resin where as the reason being less impact strength in natural fibers i.e. jute, rattan, coir etc., is their higher cellulose content and lower micro fibril angle results in higher work of fracture. The results for the following tests are as presented in subsequent table:

Table 1: Test Results

S .No.	Sample	Tensile Strength at Max. Load (N/mm^2)	Tensile stress at Break (N/mm^2)	Hardness Test (Rockwell M-Scale) At Load 100kgf	Impact Test (Joule)
1	A	171.54	171.54	48.4	+6.2875
2	B	153.55	151.74	49	+5.0529
3	C	166.52	154.53	48.6	+5.6066

4.4. Limiting oxygen index Test

Antimony try-oxide is a white, free-flowing powder used at fairly low loading levels (2-10 phr), that must be used with a halogen synergist (bromine or chlorine). It is known to be a fire retardant compound as it resists fire. It has melting point of 656 °C, Formula Sb_2O_3 with molar mass 291.52 g/mol having density 5.20

g/cm³ and boiling point of 1,425 °C. For this test three samples were prepared using ASTM D 2863 standards and tested for the subsequent results.

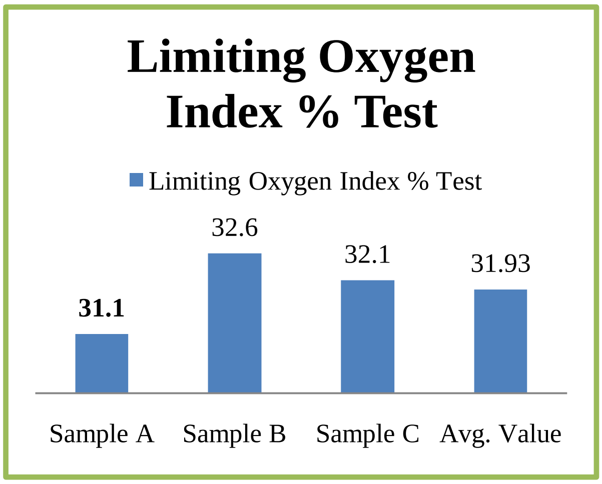

Fig. 4: LOI Test Graph

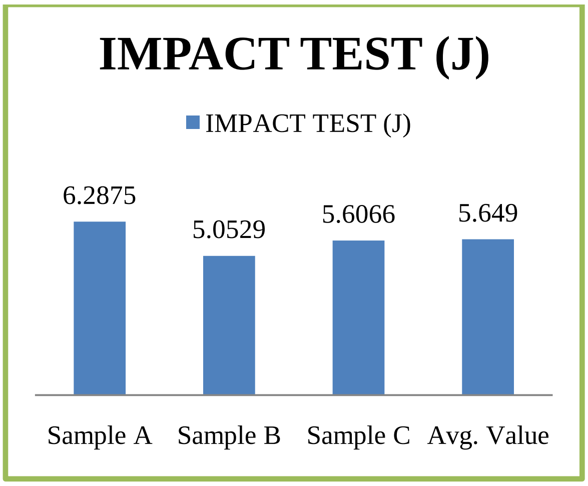

Fig. 5: Impact Strength Test Graph

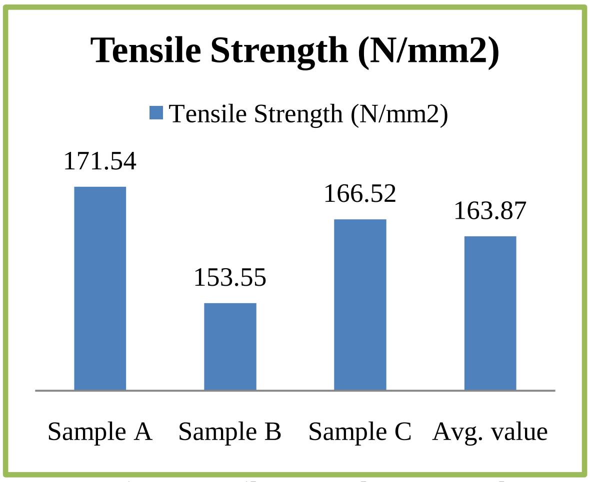

Fig. 6: Tensile Strength Test Graph

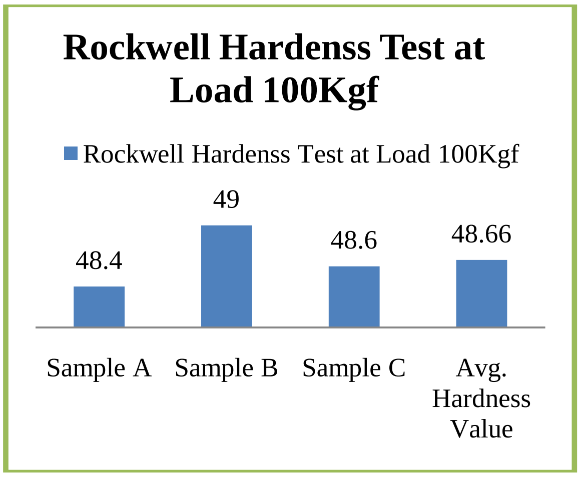

Fig. 7: Hardness Test Graph

V. CONCLUSION

The Economical material developed can bring vital subsequent changes in engineering applications due to inherent properties and advantages:

The Glass fiber – polyester composite specimens prepared as per ASTM standards subjected to mechanical and thermal characterization results were analysed of which a combination of two differently oriented glass fibers i.e. woven form and strand matt form were used as reinforcement and tested to yield vital important results which makes composite to be used on an broad scale of application as they are combination of the useful properties of two different materials, quicker processing time, lower manufacturing cost, etc., make them as a versatile material in the field of engineering and technology.

Fiber-reinforced polyester composites provide improvements in strength, stiffness and toughness. They also could have corrosion resistance in different hostile environments.

Applications vary significantly in size, complexity, loading temperature, surface quality, suitable production volume and added values. Common driving forces for the use of GFRP materials include the ability to save weight, increase mechanical properties, reduce the number of elements in a component, obtain a unique combination of properties, and to increase shaping freedom. GFRP composites are used in following with importance off- Light Weight, High Strength, and Strength Related to Weight, Corrosion, High-Impact Strength, Design Flexibility, Dimensional Stability, Nonconductive, Nonmagnetic, Radar Transparent, Low Thermal Conductivity and Durable.

Hence with this conclusion, it is sure that the technology shows composite is the most wanted material in the recent trend.

ACKNOWLEDGMENT

The authors express their thanks to CIPET, Lucknow and DMSRDE, Kanpur for providing facilities to carry out this research.

REFERENCES

[1]. Smallman, R. E., and R.J. Bishop. Modern Physical Metallurgy and Materials Engineering. 6th ed. Oxford: Butterworth-Heinemann, 1999.
[2]. Erhard, Gunter. Designing with Plastics. Trans. Martin Thompson. Munich: Hanser Publishers, 2006.
[3]. "New Chemical Substance" (PDF). The New York Times. February 6, 1909.pg 2-4
[4]. N. V. Rachchh, “Mechanical characterization of rattan fiber polyester composite”, procedia material science 6(2014) 1396 – 1404.
[5]. S. K. Garkhali et al., "Mechanical Properties of Natural-Fibre-Mat-Reinforced Thermoplastics based on Flax Fibres and Polypropylene," Applied Composite Materials, vol. 7, pp. 351–372, 2000.
[6]. Ramesh Chandra Yadaw, and Sachin Chaturvedi. An Investigation of Mechanical and Sliding Wear Behavior of Glass Fiber Reinforced Polymer Composite With or Without Addition of Silica (SiO2). International Conference on PFAM XXI, IIT Guwahati, (2012).
[7.]Ajith Gopinath et al., “Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices”, Procedia Engineering 97 (2014) 2052 – 2063
[8]. Mukul Kant Paliwal and Sachin Kumar Chaturvedi. An Experimental Investigation of Tensile Strength of Glass Composite Materials with Calcium Carbonate (CaCO3) Filler. Int. J. Emerg. trends in Eng. and Dev. 2012; 6 (2) : 303-309..