FABRICATION AND ANALYSIS OF JUTE, HEMP AND BANANA FIBER HYBRID COMPOSITES

[1] P.Nazeer Hussain Khan, [2] O. PAVAN KALYAN, [3] M. KOTESWARARAO, [4] P. HAZARATH

[1]Student, [2]Student, [3]Student, [4]Student
[1]Department of Mechanical Engineering,
[1]Kkr & Ksr Institute of Technology & Sciences, Vinjanampadu, Guntur, 522 017, India

Abstract: An attempt has been made in the present work to explore and the possible use of variety of cultivated/wild grown fiber in the development of jute, hemp and banana fiber reinforced polyester hybrid composites. The fiber is extracted from retting and manual method, and the test specimens are prepared as per “ASTM” standards. Four different contents are incorporated in the specimen, with each fiber content two identical specimens are prepared. Jute, hemp and banana fiber reinforced polyester hybrid composites are prepared by incorporating up to (0.5grms, 1grms, 1.5grms, 2grms) by mass. It is observed clearly (2grms) only mass of fiber compare with (1.5grms) of hybrid composites. Increase in the weight percentage of fibers changes the tensile strength, bending strength, impact strength.

Keywords: *Fiber, jute, hemp, banana, hybrid composites.*

I. INTRODUCTION

The word “composite” means two or more distinct parts physically bounded together”. Thus, a material having two more distinct constituent materials or phases may be considered a composite material. Fiber-reinforced composite materials consist of fiber of high strength and modulus embedded in or bonded to a matrix with distinct interfaces (boundary) between them. In this form, both fiber and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fiber are the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperatures and humidity etc [1]. The properties that can be improved by forming a composite material include strength, stiffness, corrosion resistance, wear resistance, attractiveness, weight, fatigue life, temperature-dependent behavior, thermal insulation, thermal conductivity, acoustical insulation and electrical insulation. Naturally, neither all of the properties are improved at the same time nor is there usually any requirement to do so [2]. Composite materials have a long history of usage. Their beginnings are unknown, but all recorded history contains references to some form of composite material. For example, straw was used by the Israelites to strengthen mud bricks. Plywood was used by the ancient Egyptians when they realized that wood could be rearranged to achieve superior strength and resistance to thermal expansion as well as to swelling owing to the presence of moisture. More recently, fiber reinforced resin composites that have high strength-to-weight and stiffness-to- weight ratios have become important in weight-sensitive applications such as aircraft and space vehicles [3].

II. CLASSIFICATION OF COMPOSITES:

The commonly accepted classification of composites is:

Fibrous composites,
Laminated composites,
Particulate composites.

2.1 The fibrous composite:

The fibrous composites are formed by embedding and binding together of fibbers by a continuous matrix. According to the definition fibre is a material in an elongated form such that it has a minimum length to a maximum average transverse dimension of 10:1, a maximum cross-sectional area of 5.2 x 10 –4 cm 2 and a maximum transverse dimension of 0.0254 cm. A fiber is inherently much stiffer and stronger than the same material in bulk form, because of its perfect structure [4]. Commercially available fibres are of glass, boron, Kevlar and graphite. The matrix is meant for bonding the fibrous so that they act in concert. The purpose of the matrix is manifold, namely to support, to protect and to transfer stress among the fibers. The matrix is usually of much lower strength, stiffness and density and is tougher than the fibres. It would not withstand itself high stresses. Resins are widely used as matrix materials. The composite, resulting from the combination of fibers and matrix, possesses higher specific stiffness and specific strength, and is lighter than conventional engineering materials [5].

2.2 Laminated Composites:

Bonding layers of different materials or same materials makes laminated composites. In this class of composites, discontinuous matrix or mechanical fasteners are used at times to keep the layers together. Depending upon the ways of fabrication, behavior, or constituent materials of laminates, laminated composites are commonly called as bimetal, clad-metals, laminated or safety glass, plastic based laminates, laminated fibrous or hybrid composites and sandwiches [6].

2.3 Particulate composites:

Suspending particles of one or more materials in a matrix of another material produces particulate composites. The particles and matrix can be either metallic or non-metallic. The commonly used particulate composites are concrete, solid rocket propellants, carbides etc [7].

III. LITERATURE REVIEW

The moisture absorption effect on the mechanical properties of a hybrid sandwich composite formed by orthophthalic polyester resin, reinforced by bi-directional woven fabrics of glass and jute fibers, with a central layer of polyester fabric (coremat). For the composite characterization, were performed tensile and three-point-bend tests, damage mechanism analysis, and moisture absorption test. A larger absorption was observed for the hybrid composite compared to commonly observed fiberglass composites. This behavior is related to jute fiber as well as the coremat. In the mechanical tests a strong influence of the moisture content on the mechanical properties was verified. The main characteristic of the three-point-bend test was the premature shearing fracture of the coremat under both dry and wet conditions [8] Jute-carbon and glass-carbon hybrid composites of mixed matrix material [epoxy resin of bisphenol-C (EBC) and bisphenol-C-formaldehyde (BCF) of 50 wt% of the fibers] have been prepared by hand lay-up technique at 150°C under 7.6 MPa pressure for 2 h. Alkali-treated jute fibers have been acrylated to improve their physico-chemical properties. Tensile strength, flexural strength, electric strength, and volume resistivity of untreated (JCEBCF-50), treated (TJCEBCF-50) jute-carbon and glass-carbon (GCEBCF-50) composites are 10 MPa, 17 MPa, 1.60 kV/mm, and 5.9 x 10^{12} Ω-cm; 14.65 MPa, 19.33 MPa, 2.09kV/mm, and 6.79 × 10^{12} Ω-cm; and 21.4 MPa, 24.53 MPa, 1.62 kV/mm, and 5.71 × 10^{12} Ω-cm, respectively. Alkali treatment and acrylation of jute fibers resulted in 46.50, 13.71, 24.40, and 15.15% improvement in tensile, flexural, electric strengths and volume resistivity, respectively. Water uptake tendency of jute-carbon composite is considerably reduced upon alkali treatment and acrylation of jute fiber. Observed equilibrium water content in all the three composites is HCl > H_2O > NaCl. Observed reduction in water uptake in TJCEBCF-50 is due to esterification of hydrophilic OH groups. In boiling water saturation time is reduced 20 times for JCEBCF-50 and TJCEBCF-50, and 16 times for GCEBCF-50 without any damage. Hybrid composites may be useful for low load bearing application and also in marine field [9]. The mechanical properties of jute/glass fiber-reinforced unsaturated polyester resin along with additives and initiator, composites are prepared by the hand layup technique at room temperature *25* (degree). Jute fiber composites is optimized with extent of mechanical properties, and composites with 25% jute in studied with higher properties and further improve the properties, the surface of the jute and glass fiber is irradiated under U.V. radiation of different intensities [10]. The experimental and analytical investigations of jute polyester composite for long continuous reinforcement have been studied [10And the effect of a simple fiber treatment with silicon on mechanical and visco elastic response in comparison to traditional treatment have been studied [11]. The relationship of interfacial bond strength between 2-hydroxyethyl methacrylate (HEMA) treated jute fiber and vinyl ester (VE) in the composites have been studied .The fiber orientations on the mechanical properties of polyester *I* jute composites have been studied [12].

3.1 HEMP

Hemp (from Old English *hcenep,* see cannabis (etymology)) is the common name for plants of the entire genus *Cannabis,* although the term is often used to refer only to *Cannabis* strains cultivated for industrial (non-drug) use. Industrial hemp has been tried for many uses, including paper, textiles, biodegradable plastics, construction, health food, and fuel, with modest commercial success. In the past three years, commercial success of hemp food products has grown considerably. Hemp is one of the fastest growing biomasses known, producing up to *25* tons of dry matter per hectare per year, and one of the earliest domesticated plants known. For a crop, hemp is relatively environmentally friendly as it requires few pesticides and no herbicides. *Cannabis sativa* L. subsp. *sativa* var. *sativa* is the variety grown for industrial use in Europe, Canada, and elsewhere, while *C. sativa* subsp. *indica* generally has poor fiber quality and is primarily used for production of recreational and medicinal drugs. The major difference between the two types of plants is the appearance and the amount of t9-tetrahydroeannabinol (THC) secreted in a resinous mixture by epidermal hairs called glandular trichomes, although they can also be distinguished by genetic means. Strains of *Cannabis* approved for industrial hemp production produce only minute amounts of this psychoactive drug, not enough for any physical or psychological effects. Typically, hemp contains below 0.3% THC, while *Cannabis* grown for marijuana can contain anywhere from 6 or 7 % to 20% or even more *[citation needed].* 38 Industrial hemp is produced in many countries around the world. Major producers include Canada, France, and China. While more hemp is exported to the United States than to any other country, the United States Government does not consistently distinguish between marijuana and the non-psychoactive *Cannabis* used for industrial and commercial purposes.

3.2 BANANA

MUSA L MUSACEAE. *35* numbers of species found. Large herbaceous plants. It seems fairly certain that the edible species, which are triploid, are derived from M. balabisiana. M. paradisiaca, M. sapientum and possibly M. nana are considered to be varieties of M.acuminata. The fibers which are derived from the cultivated Banana and other uncultivated species of Musa or closely related genera, are similar in properties to those derived from Abaca (Musa textiles), which it itself closely related to the banana plant. Banana fiber is obtained from the leaf -sheath of the plant. The fiber is extracted from the plants after the bananas had been harvested, as a useful by-product for the banana producers. After the harvesting of the fruits, the tree is cut as near to the ground as possible. Two or more three of the outermost sheaths are removed and rejected. Interesting a knife at one end, drawing it lengthwise, strips of about 8 to 1 0 cm of breadth are prepared. The tuxiçs are then scraped as clearly as possible to yield strands. The scraping is done by the apparatus gripping ane end of the tuxy facing upwards his foot and drawing a blade of sufficient sharpness away the pith from the fibers. The procee may be repeated after keeping upside down the tuxy till the fibers losses the pith. Then the fiber is cleaned and dried. The dried fibers are bundled. The banana fibers are suitable for manufacturing strings, ropes, cords, cables, packing fabrics as well as mats and rugs.

3.3 JUTE:

Jute is the natural fiber comes from the stem and outer skin of the jute plant. Jute is a rain-fed crop that doesn't need much in the way of fertilizer or pesticides. The finest jute comes from the Bengal Delta Plain, mostly in Bangladesh and India. It takes between four and six months for the plants reach a height of around 12 feet (3.5m). It is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads.. The stalks of the plant are harvested, bundled and soaked in water for about 20 days to soften the tissues and permit the fibers to be separated. The fibers are then stripped from the stalks, washed, dried and baled. Jute has a very soft feel similar to cotton.

IV. EXTRACTION OF FIBERS

4.1 JUTE FIBER:

Jute fiber is a natural bast fiber. It is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. It is harder than other textile fibers. It is environment friendly. Normally jute are used for sacking, burlap, and twine as a backing material for tufted carpets.

Jute fibers are of two types. They are:

1. white jute (corchorous capsularis)
2. Tossa jute (corchorus olitorious)

Jute, as a natural fiber, has inherent advantages like silky luster, high tensile strength, low extensibility, considerable heat and fire resistance and long staple lengths. Jute can be used in many different areas, and has been receiving increasing attention from industry. Their interests focus not only on the traditional uses of jute, but also on the production of other value-added products such as, pulp and paper, geo-textiles, composites and home textiles etc. Retting is the process of extracting fiber from the long lasting life stem or bast of the bast fiber plants. To extract fibers from the jute plant, a small stalk is harvested for pre-retting. Usually, this small stalk is brought before 2 weeks of harvesting time. If the fiber can easily be removed from the jute core, then the crop is ready for harvesting. After harvesting, the jute stalks are tied into bundles and submerged in soft running water. The stalk stays submerged in water for 20 days. However, the retting process may require least time if the quality of jute is better. In most cases, the fiber extraction process of bast fibers in water retting is done by the farmers while standing under water. When the stalk is well retted, the stalk is grabbed in bundles and hit with a long wooden hammer to make the fiber loose from the jute hurd or core. After losing the fiber, the fiber is washed with water and squeezed for dehydration. The extracted fibers is further washed with fresh water and allowed to dry on bamboo poles. Finally they are tied into small bundles to be sold into the primary market.

4.2 BANANA FIBRE:

Banana fiber is ecofriendly like jute fiber. The technology of banana fiber extraction has been developed in South India where in a good number of banana fiber extraction units have been running very successfully. Some firms are exporting the banana fiber products. The extraction of the natural fiber from the plant required certain care to avoid damage. In the present experiments, initially the banana plant sections were cut from the main stem of the plant and then rolled lightly to remove the excess moisture. Impurities in the rolled fibers such as pigments, broken fibers, coating of cellulose etc. were removed manually by means of comb, and then the fibers were cleaned and dried. This mechanical and manual extraction of banana fibers was tedious, time consuming, and caused damage to the fiber. Consequently, this type of technique cannot be recommended for industrial application. A special machine was designed and developed for the extraction of banana fibers in a mechanically automated manner. It consisted mainly of two horizontal beams whereby a carriage with an attached and specially designed comb, could move back and forth. The fiber extraction using this technique could be performed simply by placing a cleaned part of the banana stem on the fixed platform of the machine, and clamped at the ends by jaws. This eliminated relative movement of the stem and avoided premature breakage of the fibers. This was followed by cleaning and drying of the fibers in a chamber at 20^0C for three hours. This fibers were then labeled and ready for lamination process. After extraction of fiber, weaving is done in the looms as per normal process like any other material.

4.3 HEMP FIBRE:

Hemp belongs to the Mulberry family (Moracea) and cultivated hemp varieties belong to the Cannabis sativa species. These hemp varieties can be very different in height and leafage. Hemp is one of the fibres which are usually named after their country of origin – thus Italian, Turkish, Chinese, Indian hemp varieties are available. It is an annual plant, grows in season from the middle of April to the middle of September. The bast layer (phloem) of the stalk contains more important component of textile fibres. Once the stalks are retted, dried, and baled, they are brought to a central location for processing. With mechanical separation, in a process called breaking, stalks are passed between fluted rollers to crush and break the woody core into short pieces (called hurds), separating some of it from the bast fiber. The remaining hurds and fiber are separated in a process called scutching. Fiber bundles are gripped between rubber belts or chains and carried past revolving drums with projecting bars that beat the fiber bundles, separating the hurds and broken or short fibers (called tow) from the remaining long fiber (called line fiber). Fiber and hurds also can be separated with one machine called a decorticator.

V. FABRICATION OF COMPOSITE SPECIMEN

The standard test method for bending properties of fiber-resin composites, ASTM-D790M-86 is used to prepare specimens as per the dimensions. The test specimen has a constant cross section with tabs bonded at the ends. The mould is prepared on smooth ceramic tile with rubber shoe sole to the required dimension. Initially the ceramic tile is cleaned with shellac (NC thinner) a spirituous product to ensure clean surface on the tile. Then mould is prepared keeping the rubber sole on the tile. The gap between the rubber and the tile is filled with mansion hygienic wax. A thin coating of PVA (polyvinyl alcohol) is applied on the contact surface of specimen, using a brush. The resulting mould is cured for 24 hours. Hand layup method is adopted to fill the prepared mould with general-purpose polyester resin. ECMALON 4411 is an unsaturated polyester resin of ortho-phthalic acid grade with clear colourless or pale yellow colour. Its viscosity is 500-600 CPS (Brookfield Viscometer) and specific gravity is 1.13 grams/c.c. at 25^0 C. Acid Number (mg KOH/g) is 22 and monomer content is 35%. Cobalt accelerator and MEKP catalyst are added for curing the resin at room conditions. The quantity of each of these materials, added is 1.5% of the volume of resin. The gel time is found to be about 20 min. The accelerator is mixed thoroughly with the resin and the catalyst is added later to avoid explosion. A thin coating of the resin is applied to the mould surface and known weight of the fiber is placed along the longitudinal direction of the specimen so that the fibres are oriented 0^0 along the axial direction of the specimen. Then the rest of the mould is filled with the resin making sure that there are no air gaps in the mould. Then, a thin Polyethylene paper of 0.2mm thick is placed on the rubber mould. A flat mild steel plate is placed on the mould and a pressure of $0.05MN/m^{-2}$ is applied and left for 24 hours to cure. Later the specimen is removed and filed to obtain the final dimensions. The specimen is cleaned with NC thinner and wiped off to remove dirt particles. The ends of both flat sides of the specimen are roughened enough using a sandpaper, so as to bond the end tabs. Two such identical specimens are prepared for each fibre content in the specimen. Four different fibre contents (0.5, 1.0, 1.5, 2.0 grams) are incorporated in the specimen. Two plain polyester are also prepared in order to compare the results of natural fibre reinforced composites. The percentage volume of fibre present in the specimen is determined for each set.

VI. TESTING OF COMPOSITES

6.1 TENSILE TESTING:

A 2 ton capacity - Electronic tensometer, METM 2000 ER-I model , supplied by M/S Mikrotech, Pune, is used to find the tensile strength of composites. Its capacity can be changed by load cells of 20Kg, 200Kg & 2000 Kg. A load cell of 2000 Kg. is used for testing composites. Self-aligned quick grip chuck is used to hold composite specimens. A digital micrometer is used to measure the thickness and width of composites.

Fig 6.1 Specimens Subjected to Tensile Testing (Before and after testing)

6.2 FLEXURAL TESTING:

A 2 ton capacity - Electronic tensometer, METM 2000 ER-I model (Plate II-18), supplied by M/S Microtech, Pune, is used to find the flexural strength of composites. Its capacity can be changed by load cells of 20Kg, 200Kg & 2000 Kg. A load cell of 2000 Kg. is used for testing composites. Self-aligned quick grip chuck is used to hold composite specimens. A digital micrometer is used to measure the thickness and width of composites.

Fig 6.2: Specimens Subjected to Flexural Testing (Before and after testing)

6.3. IMPACT TESTING

An analog Izod/ charpy impact tester supplied by M/S International Equipments, Mumbai (photo), was used to test the impact properties of fiber Reinforced composite specimen. The Equipment has four working ranges of impact strength and are 0-2.71 J.0-5.42 J,0-10.84 J and 0-21.68 J, with a minimum resolution on each scale of 0.02 J, 0.05 J, 0.1 J and 0.2 J respectively .Four scales and corresponding hammers (R1,R2,R3,R4) are provided for all the above working ranges.

Fig 6.3: Specimen Subjected to Impact Testing (Before and after testing)

VII. EXPERIMENTAL RESULTS

S.NO	W %	t (mm)	B (mm)	Load (N)	Elongation (mm)	Tensile strength (N/mm2)
1	0	3	12.5	1363	2.4	36.36
2	5	3	12.5	2147	2.5	57.25
3	10	3	12.5	2236	1.9	59.63
4	15	3	12.5	3393	2.7	90.48
5	20	3	12.5	2991	2.3	79.76

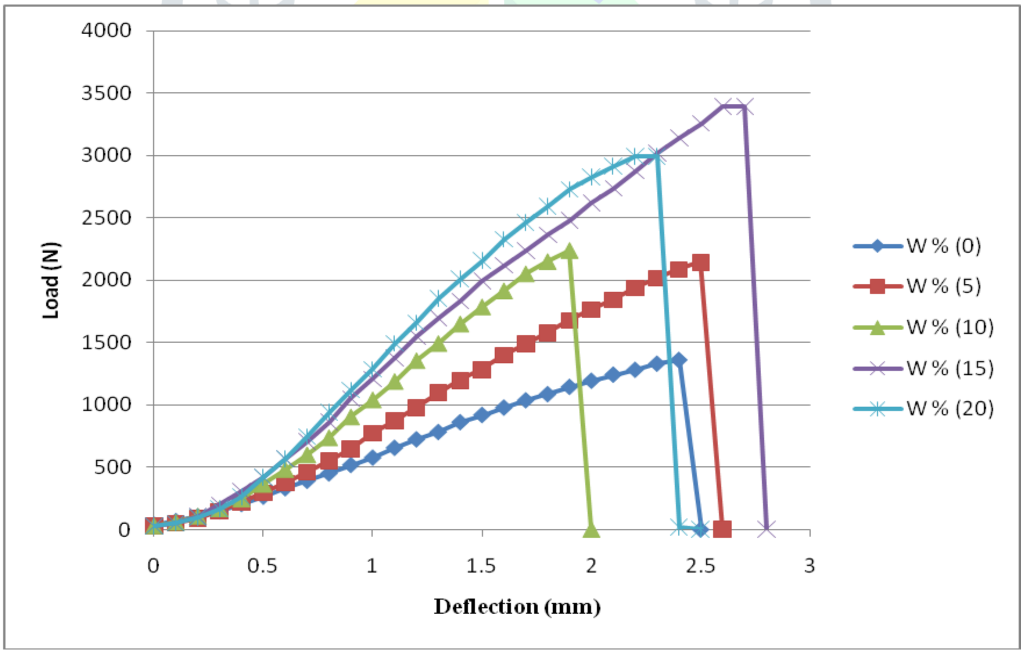
Table 7.1 Tensile strength for Jute, hemp and banana fibre hybrid composites at various Wt %

S.NO	W %	t (mm)	B (mm)	Load (N)	Elongation (mm)	Flexural strength (N/mm2)
1	0	4	25	177	11.1	92.9
2	5	4	25	196	6.3	102.9
3	10	4	25	225	7.5	118.1
4	15	4	25	265	4.4	139.1
5	20	4	25	264	4.9	138.6

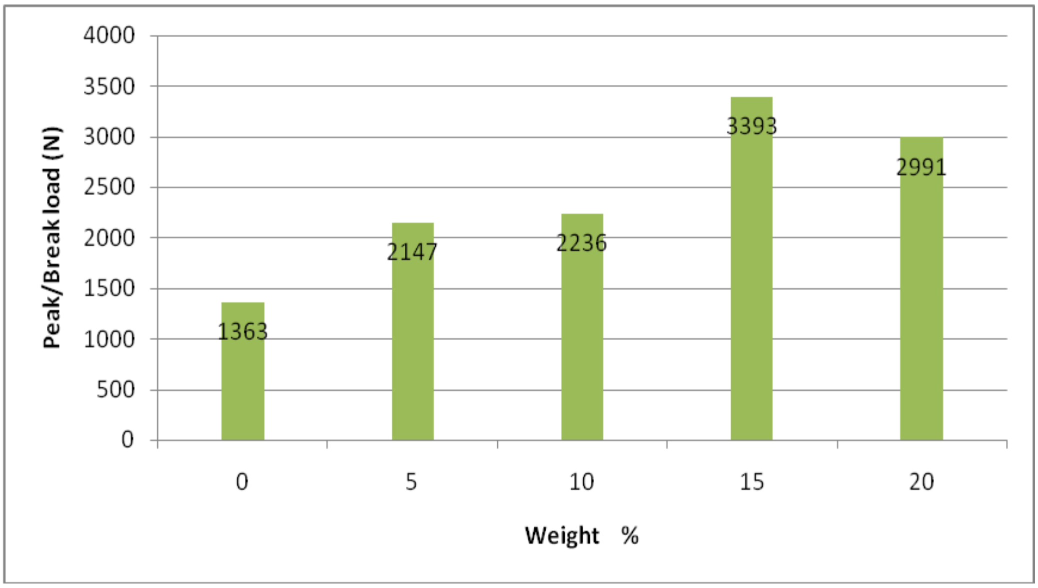
Table 7.2 Flexural strength for Jute, hemp and banana fibre hybrid composites at various Wt %

S.NO	Weight %	Width (mm)	Thickness (mm)	Impact Energy (J/m)
1	0	12.7	10	18
2	5	12.7	10	40
3	10	12.7	10	140
4	15	12.7	10	90
5	20	12.7	10	200

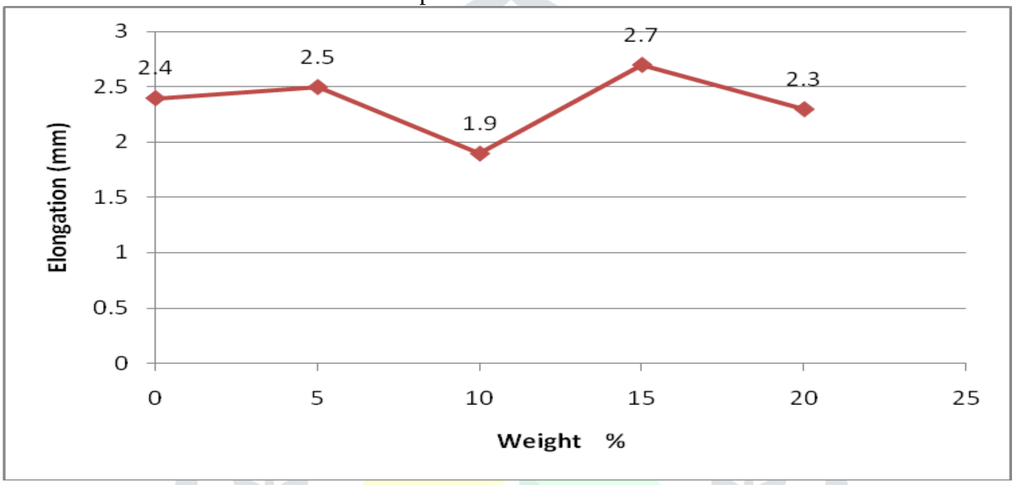
Table 7.3 Impact energy of Jute, hemp and banana fibre hybrid composites at various Wt %



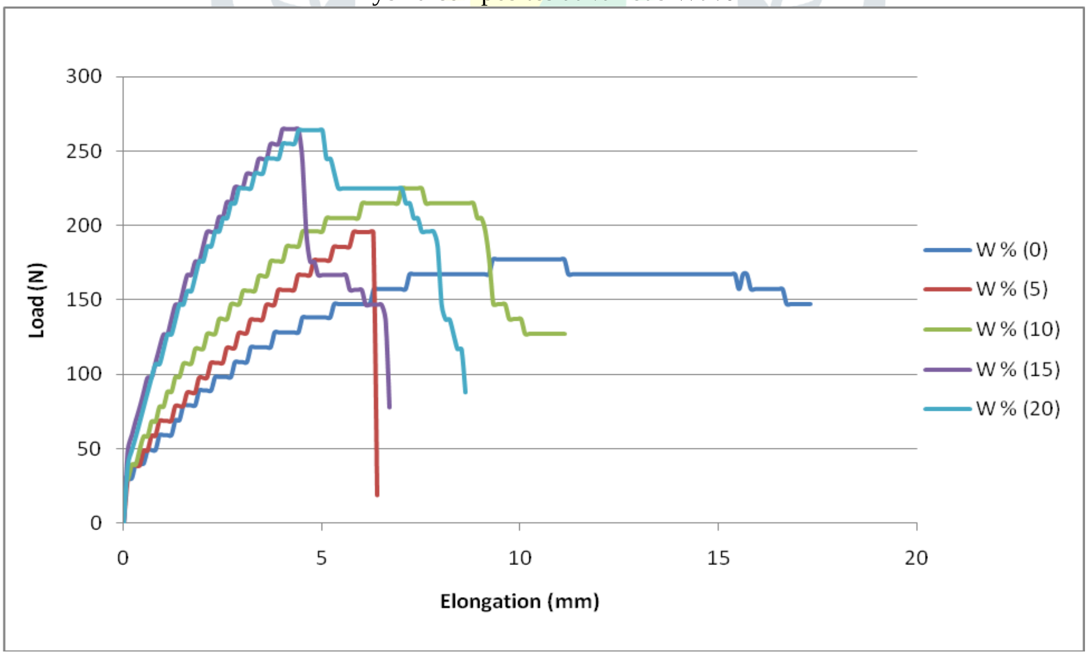
Graph 7.1 Tensile Load vs Deflection curves of Jute, hemp and banana fibre hybrid composites at various Wt %



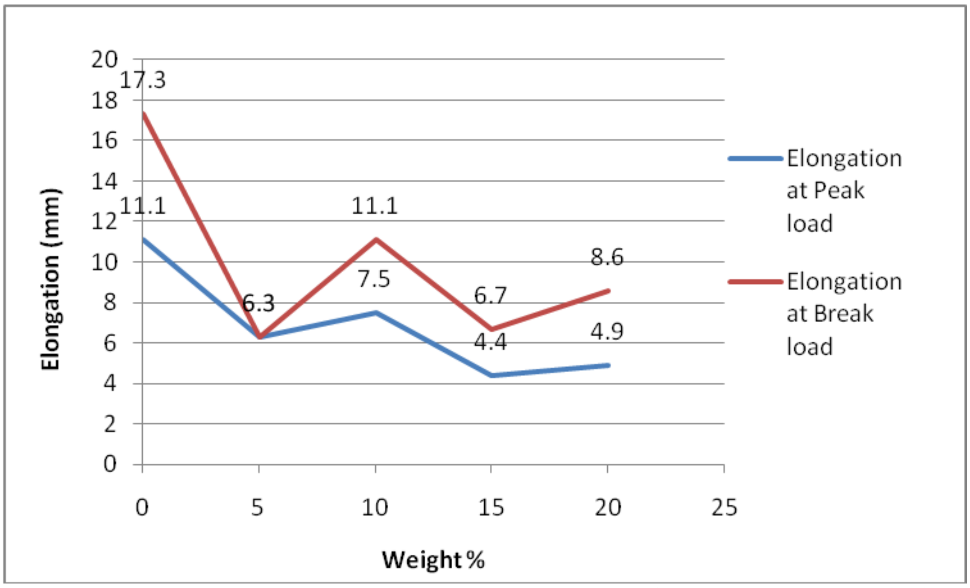
Graph 7.2 Tensile Load (Peak/Break) vs Weight % of Jute, hemp and banana fibre hybrid composites at various Wt %



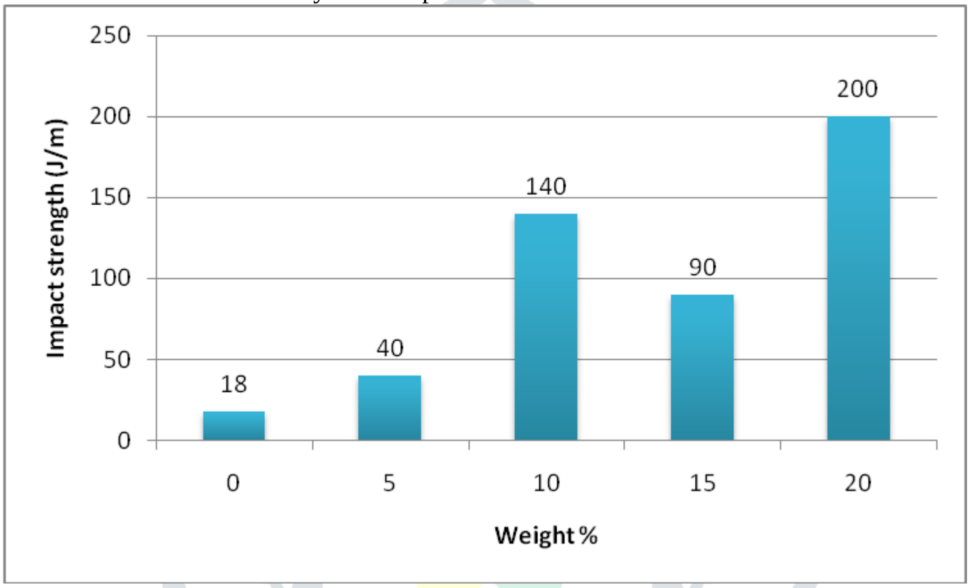
Graph 7.3 .Elongation at peak/break load vs Weight % of Jute, hemp and banana fibre Hybrid composites at various Wt %



Graph 7.4 .Flexural Load vs Deflection curves of Jute, hemp and banana fibre hybrid composites at various Wt %



Graph 7.5 .Elongation at peak and break load vs Weight % of Jute, hemp and banana fibre Hybrid composites at various Wt %



Graph 7.6. Impact strength vs weight percentage for Jute, hemp and banana fibre hybrid composites at various Wt %

VIII. CONCLUSIONS

In tensile testing of fiber composites, the tensile strength and weight percentage calumns observed that there is increases the weight percentages of jute, hemp and banana fiber percentage contain (0% to 15%) there is increase the tensile strength. Compare to 20% of jute, hemp and banana fiber the strength of 15% is 1.13 times more. The curve drawn between Tensile load Vs deflections, the peak/break load of 15% jute, hemp and banana fibre composites is more than the other w% (5%, 10%, 20%) about 1.58, 1.51, 1.13 times respectively. The elongation at tensile load is of weight percentage 15% is more compare to other wt percentages(5%, 10%, 20%) about 1.08, 1.42, 1.17 times respectively. It is 1.12 times more than the pure polyester composite specimen. In flexural testing, the bending strength of the composites of wt % 15% and 20% are nearly same (15% is 1.003 times more than 20%) and it is 1.35, 1.17 times more for 5%, 10%. The bending strength of 15% composite is almost 1.50 times more compared to pure polyester matrix composite. In Flexural Load vs Deflection curves of Jute, hemp and banana fibre hybrid composites at various Wt % it is clearly observed that peak load of any specimen is more than the break load and it almost double. The peak load of 15% specimen is more than the other w%. Elongation is more in flexural break load than the peak load. It is more for pure polyester material than the other w% of composite

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