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STUDY OF MECHANICAL PROPERTIES OF JUTE FIBRE REINFORCED POLYMER COMPOSITE

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ABSTRACT
Recently natural fibres have been receiving considerable attention as substitutes for synthetic fibre reinforcements due to their low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced thermal and respiratory irritation and renewable resources. The aim of this work is to develop chemically treated and chemically untreated fibre reinforced composite material with optimum properties so that it can replace the existing synthetic fibre reinforced composite material for a suitable application. In this work, polyester resin has been reinforced with jute fabric, so as to develop jute fibre reinforced plastic (JFRP) with a coupling agent. Hand lay-up technique was used to manufacture the composites where Maelic anhydride Methyl Ethyl Ketone Peroxide and cobalt Naphthalene were used as coupling agent, hardner and accelerator respectively. The thickness of the composite specimen was obtained by laying up layer of fibre and matrix. The composites have been prepared and mechanical properties are compared.

Keywords- *Mechanical properties, hand lay-up, Composites, Impact Strength, MEKP.*

I. Introduction

Natural fibre reinforced composites have a good potential as a substitute for wood- Based material in many applications. The development of environment - friendly green materials is because of natural fiber's biodegradability, light weight, low cost, high Specific strength compared to glass and carbon, recycling and renewing natural Sources. Composites , the wonder material with light-weight, high strength- to -weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals , woods etc (Sanjay et al 2015). The material scientists all over the world focused their attention on natural composites reinforced with jute, sisal, coir, pineapple etc. primarily to cut down the cost of raw materials . The jute fibre is an important bast fibre and comprises bundled ultimate cells , each containing spirally oriented micro fibrils bound together from the point of view of wood substitution, jute composites could be an ideal solution. With ever depleting forest reserves, a composite based on renewable resources is poised to penetrate the market. Indigenous wood supply for plywood industry having been stopped virtually and with increasing landed cost of imported plywood veneers, the jute composite boards offer very good value for the customers without any compromise in properties. The jute-coir boards proving superior over application plywood boards find potential in railway coaches for sleeper berth backing, for building interiors, doors & windows besides in transportation sector as backings for seat & backrest in buses (Sanjay et al 2016). Typical jute composites boards do not prove well on the grounds due to its moisture absorption & screw holding strength. Detailed evaluation of the jute-coir board samples has been carried out for their applications as berth backings & partitions in railway coaches; the results conform to the railways ' requirements .

The use of jute fiber mats in combination with polymer films potentially offers a rapid and simple means of manufacturing composites through film stacking, heating and press – consolidation.

In recent years, the interest of scientists and engineers has turned over on utilizing plant fibers as effectively and economically as possible to produce good quality fiber-reinforced polymer composites for structural, building, and other needs. It is because of the high availability and has led to the development of alternative materials instead of conventional or man-made ones. Many types of natural fibers have been investigated for their use in polymer such as wood fiber (Maldas et al 1995), sisal (Joseph et al 1999), kenaf (Rowell et al 1999), pineapple (Mishra et al 2001), jute (Mohanty et al 2006), banana (Pothan et al 2003) and straw (Kamel 2004).

Bax and Mussig 2008 investigated the mechanical properties of PLA reinforced with cordenka rayon fibers and flax fibers, respectively. A poor adhesion was observed using Scanning electron microscopy analysis. The highest impact strength and tensile strength were found for cordenko reinforced PLA at fiber proportion of 30%.

Mwaikambo and Ansell 2003 evaluated the physical and mechanical properties of the natural fiber composites to assess their serviceability. Treated fibers with highest strength were used as reinforcement for cashew nut shell liquid matrix and determined tensile properties, porosity and also 13 examined fracture surface topography of the composites. The objective was to maximize the amount of low cost natural fiber resource in the composite. They concluded that the presence of lignin in the untreated hemp fiber offers additional cross linking sites and the untreated fiber surface is more compatible with CNSL (Cashew Nut Shell Liquid resin) than alkali treated surface. Natural fibers are derived from plants, animals and mineral sources.

II. MATERIALS AND METHODS

II A. Selection of Jute Fiber

Fig.1: Harvest of jute plants

Jute is multi celled in structure (Fig. 3). The cell wall of a fibre is made up of a number of layers: the primary wall and the secondary wall(S), which again is made up of the three layers (S1, S2 and S3). As in all lingo cellulosic fibres, these layers ma inly contain cellulose, hemicellulos e and lignin in varying amounts. The individual fibres are bonded together by a lignin-rich region known as the middle lamella. Cellulose attains highest concentration in the S2 layer (about 50%) and lignin is most concentrated in the middle lamella (about 90%) which, in principle, is free of cellulose. The S2 layer is us- ually by far the thickest layer and dominates the properties of the fibres. Cellulose, a primary component of the fibre, is a linear condensation polymer consisting of Danhydro- glucopyranose units joined together by ß-1, 4-glucosidic bonds . The long chains of cellulose are linked together in bundles called micro-fibrils (Fig. 3).

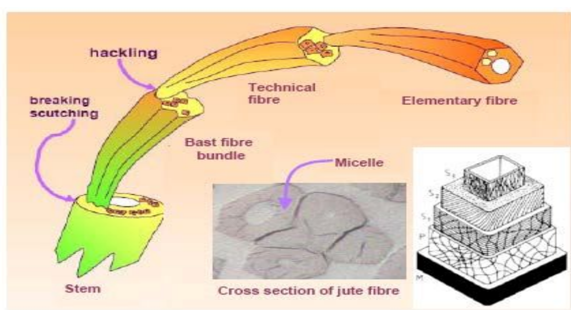

Fig. 2: Jute fibre structure

Hemicelluloses are also found in all plant fibres. Hemicelluloses are polysaccharides bonded together in relatively short, branching chains. They are intimately associated with the cellulose micro fibrils, embedding the cellulose in a matrix. Hemicelluloses are very hydrophilic and have lower molecular masses than both cellulose and lignin. The degree of polymerization (DP) is about 50 – 200. The two main types of hemicelluloses are xylans and

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glucomannans. Lignin is a randomly branched polyphenol, made up of phenyl propane (C9) units. It is the most complex polymer among naturally occurring high-molecular-weight materials with an amorphous structure. Of the three main constituents in fibres, lignin is expected to be the one with least affinity for water. Another important feature of lignin is that it is thermoplastic (i.e., at temperatures around 90℃ it starts to soften and at temperatures around 170℃ it starts to flow).

Constituents	%
Cellulose	60 – 62
Hemi Cellulose	22 - 24
Lignin	12 – 14
Others	1 – 2

Table 1: Chemical composition of jute fibre

Fibre	Density (g/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation At break (%)	Specific Tensile Strength ($MPa/ g.cm^{-3}$)	Specific Young's Modulus ($GPa/g.cm^{-3}$)
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5	286-562	9-19
Flax	1.5	345-1100	27.6	2.7-3.2	230-773	18
Ramie	1.5	400-938	61.4-128	1.2-3.8	267-625	41-85
Sisal	1.45	468-640	9.4-22.0	3-7	323-441	6-15
Coir	1.15	131-175	4-6	15-40	114-152	3-5
E-glass	2.5	2000-3500	70	2.5	800-1400	28
S-glass	2.5	4570	86	2.8	1828	34

Table.2: Properties of Jute Fibre in Comparison with other Fibres.

The jute fibre possesses moderately high specific strength and stiffness. Therefore, it is suitable as reinforcement in a polymeric resin matrix. However, it exhibits considerable variation in diameter a long with the length of individual filaments. The properties of the fibre depend on factors such as size, maturity and processing methods adopted for the extraction of the fibre. Properties such as density, electrical resistivity, ultimate tensile strength and initial modulus are related to the internal structure and chemical composition of fibre.

Fig.3: Jute fiber obtained from stem of Jute plant

II B. Selection of resin:

Unsaturated polyester resins are the most commonly used thermoset resins in the world. Unsaturated polyester resins are produced by chemical reaction of saturated and unsaturated di-carboxylic acids with alcohols. Unsaturated polyester resins form highly durable structures and coatings when they are cross-linked with a vinyl reactive monomer, most commonly styrene. The properties of the cross-linked unsaturated polyester resins depend on the types of acids and glycols used and their relative proportions.

Unsaturated polyester resins also have excellent service temperatures. They have good freeze-thaw resistance and can be designed for use in many low to moderate temperature applications ranging from refrigerated enclosures to hot water geysers.When it comes to weight for cost comparisons, unsaturated polyester resins are much favoured over their metallic counterparts.

Property	Units	pDCPD	Epoxy	UPR	Vinyl Ester
Tensile Strength	MPa	58	55 - 65	40 - 55	60 - 75
Tensile Strain	%	5 - 6	3 - 4	1 - 2	2 - 3
Tensile Modulus	GPa	2.5	2.9	3.2	3.2
Tg	deg C	110 - 120	70 - 80	60 - 70	75 - 80
Water Absorption (7 days, 23 C)	%	<1	4 - 5	4 - 5	2 - 4
Density	g/cc	1.04	1.15	1.15	1.14
Vol. Shrinkage	%	4 - 5	4 - 5	8 - 10	7 - 8

Table .3: Properties of unsaturated polyester in comparison with resin.

II C. Selection of Hardener

In this work, polyester resin has been methyl ethyl ketone peroxide,and cobalt naphthalene was used to manufacture the composites where Methyl Ethyl ketone peroxide and cobalt Naphthalene were used as hardner and accelerator respectively and composites were prepared under various processing parameters using manual Hand layup technique.

Methyl ethyl ketone peroxide (MEKP)

Methyl ethyl ketone peroxide is an organic peroxide, a high explosive similar to acetone peroxide. MEKP is a colorless, oily liquid whereas acetone peroxide is a white powder at STP; MEKP is slightly less sensitive to shock and temperature, and more stable in storage. Depending on the experimental conditions, several different adducts of methyl ethyl ketone and hydrogen peroxide are known. The first to be reported was a cyclic dimer, $C_8H_{16}O_4$, in 1906.[3] Later studies found that a linear dimer is the most prevalent in the mixture of products typically obtained,[4] and this is the form that is typically quoted in the commercially available material from chemical supply companies.[5] Dilute solutions of 30 to 60% MEKP are used in industry and by hobbyists as the catalyst which initiates the crosslinking of unsaturated polyester resins used in glass-reinforced plastic, and casting. For this application, MEKP is dissolved in dimethyl phthalate, cyclohexane peroxide, or diallyl phthalate to reduce sensitivity to shock.Benzoyl peroxide can be used for the same purpose. MEKP is a severe skin irritant and can cause progressive corrosive damage or blindness.

Fig.4: MEKP

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Cobalt Naphthalene

Cobalt Naphthalene is a mixture of cobalt (II) derivatives of naphthenic acids. Cobalt Naphthalene is a cobalt source that is soluble in organic solvents as an organometallic compound (also known as metalorganic, organo-inorganic and metallo-organic compounds). Cobalt naphthalene is the cobalt salt of naphthenic acids. Naphthenic acids are a complex group of carboxylic acids with the general formula C, HZ~+~O~, where n indicates the carbon number and Z specifies the hydrogen deficiency resulting from ring formation. Cobalt naphthenate is thus a member of the metal carboxylates group. All of the metal carboxylate salts are designed to add metals to chemical reactions. They therefore are expected to dissociate into free metal and free acid. The high purity acetylacetonate anion complexes by bonding each oxygen atom to the metallic cation to form a chelate ring.Because of this property, Cobalt Naphthalene is commonly used in various catalysts and catalytic reagents for organic synthesis. These coordination complexes are widely used as oil drying agents for the autoxidative crosslinking of drying oils. Metal naphthenates are not well defined in conventional chemical sense that they are mixtures. They are widely employed catalysts because they are soluble in the nonpolar substrates, such as the alkydresins or linseed oil. The fact that naphthenates are mixtures helps to confer high solubility. A second virtue of these species is their low cost.

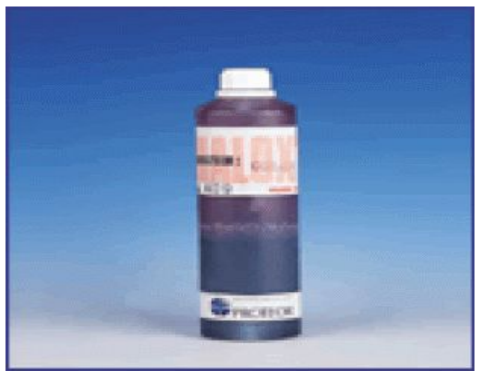


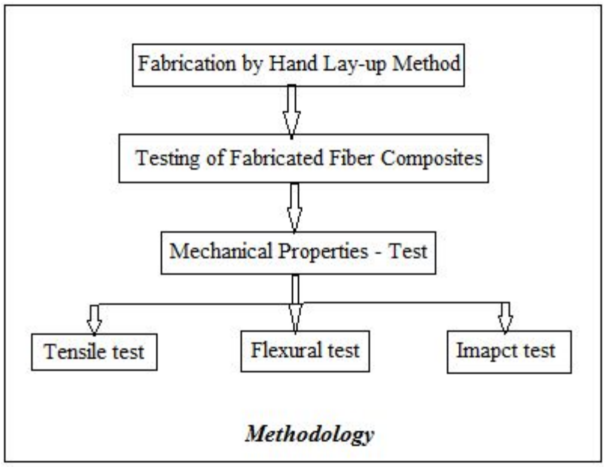
Fig .5: Cobalt Napthalene

II D. Selection of coupling agent:

Maleic anhydride is an organic compound with the formula C_2H_2 $(CO)_2O$. It is the acid anhydride of maleic acid. It is a colorless or white solid with an acrid odor. It is produced industrially on a large scale for applications in coatings and polymers.

- Around 50% of world maleic anhydride output is used in the manufacture of unsaturated polyester resins (UPR). Chopped glass fibers are added to UPR to produce fiberglass reinforced plastics which are used in a wide range of applications such as pleasure boats, bathroom fixtures, automobiles, tanks and pipes. However, the UPR market reflects general economic conditions as it is tied to the construction, automobile and marine industries.
- The production of 1, 4-butanediol (BDO) is also having an impact on the maleic anhydride market. BDO is one of the world’s fastest growing chemicals used in the production of thermoplastic polyurethanes, elastane/Spandex fibers, polybutylene terephthalate (PBT) resins and many other products. However, BDO is made from a crude maleic anhydride which is not traded and only used for this application.
- Another market for maleic anhydride is lubricating oil additives, which are used in gasoline and diesel engine crankcase oils as dispersants and corrosion inhibitors. Changes in lubricant specifications and more efficient engines have had a negative effect on the demand for lubricating oil additives, giving flat growth prospects for maleic anhydride in this application.
- There are a number of smaller applications for maleic anhydride. The food industry uses maleic anhydride in artificial sweeteners and flavor enhancements. Personal care products consuming maleic anhydride include hair sprays, adhesives and floor polishes. Maleic anhydride is also used in water treatment chemicals, detergents, insecticides and fungicides, pharmaceuticals and copolymers.

III. METHODOLOGY



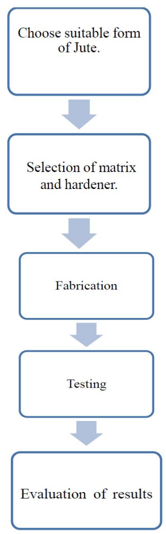


Fig .6: Flow Chart of Methodology

IV. FABRICATION OF COMPOSITE MATERIALS & TESTING

This chapter deals with the fabrication stages carried out to obtain the composite material.

STEPS IN PREPARING SPECIMENS:

STEP1: Specimen preparation by hand lay-up method

- Procuringallthe materials.
- Cut the fiber mat into required shape and size.
- Tabulatethe weight of jute, unsaturatedpolyester, maelic anhydride.
- Mix the hardner with unsaturated polyester for further work.
- A granite slab of dimensions greater than jute is used so that the composite doesnot stick with it
- Sandwitch the jute with unsaturated polyester resin and percentage of maelic anhydride
- For curingthespecimenkeep itin the room for12to 24hr in normal temperature.
- After curing the composite remove it carefully from the granite base.

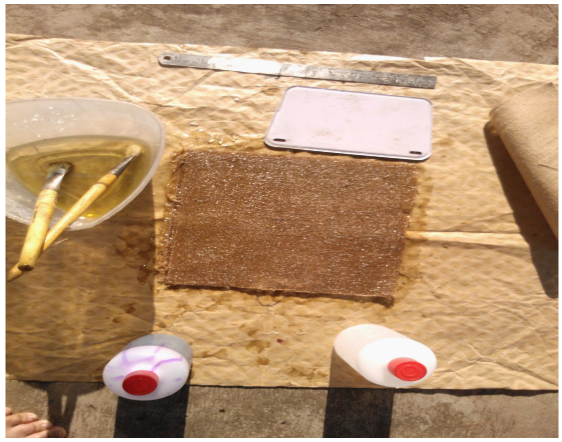


Fig .7: Preparation of composite

STEP2: Cutting the specimen according to ASTM standards

- MarkingandCuttingthespecimenaccordingtoASTMstandardandconducting tests (Bending, Tensile, Hardness, impact)
- Standard used for cutting the specimen is ASTM D638 standard; the dimensions of the standards are as follows.

Tensile specimen dimensions:

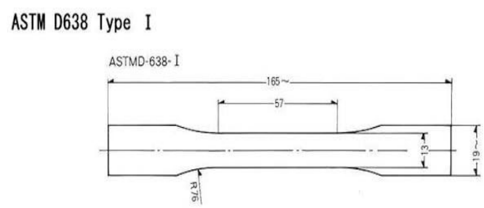


Fig.8: Tensile specimen dimension

Bending specimen dimensions:

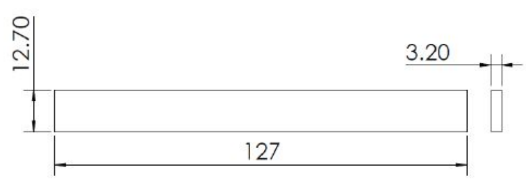


Fig. 9: ASTM D790 test specimen for flexural test

Impact specimen dimensions:

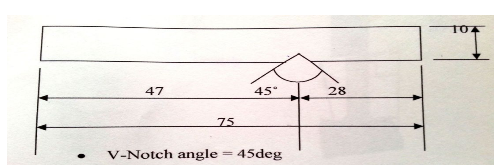


Fig. 10: ASTM D256 test specimen for Izod test

Hardness specimen dimensions:

20

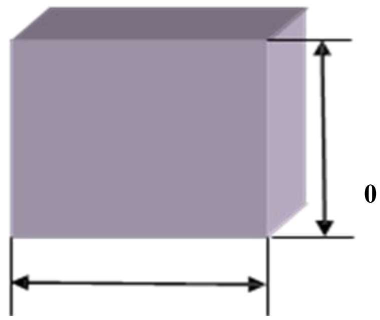


Fig. 11: Hardness specimen dimensions ASTM E10

V. CALCULATIONS

The calculations made to find the right amount of each of the constituent is given below. The below calculation is based on the Weight Fraction formula of the "Rule of Mixture" for the composite is used.

$$(W_c/\rho_c) = (W_m/\rho_m) + (W_s/\rho_j) + (W_s/\rho_c)$$

Total volume of the composite to be fabricated = (250*250*6) mm^3

Density of the fibre= **1.46gm/cm^3**

Density of the unsaturated polyester resin =**1.52gm/cm^3.**

Density of the maelic anhydride = **1.11gm/cm^3**

FORM OF JUTE	WEIGHT OF FIBRE (gm.)	WEIGHT OF UNSATURATED POLYESTER (gm.)	WEIGHT OF MAELIC ANHYDRIDE (gm.)
0% COUPLING AGENT	**297.9**	**198.6**	**0**
5% COUPLING AGENT	**302.48**	**176.44**	**25.2**
10% COUPLING AGENT	**307.125**	**153.56**	**51.87**

Table 4: Tabulation of weight of jute, polyester and maelic anhydride

VI. RESULTS AND DISCUSSIONS

TENSILE TEST:

The tensile test results for different forms of Jute reinforced composites obtained are tabulated in table.

FORM OF JUTE COMPOSITE	PEAK LOAD (N)	% REDUCTION AREA	UTS (N/mm^2)	YOUNG'S MODULUS (N/mm^2)
0%MAELIC ANHYDRIDE	**2206.5**	**0.124**	**43158**	**24553**
5%MAELIC ANHYDRIDE	**2834.1**	**0.102**	**64237**	**34646**
10%MAELIC ANHYDRIDE	**2863.5**	**0.124**	**56921**	**28282**

Table 5: Average values for tensile test specimens

The load v/s deflection and stress v/s strain graph of one specimen of each form obtained by tensile test conducted on computerized universal testing machine is given below.

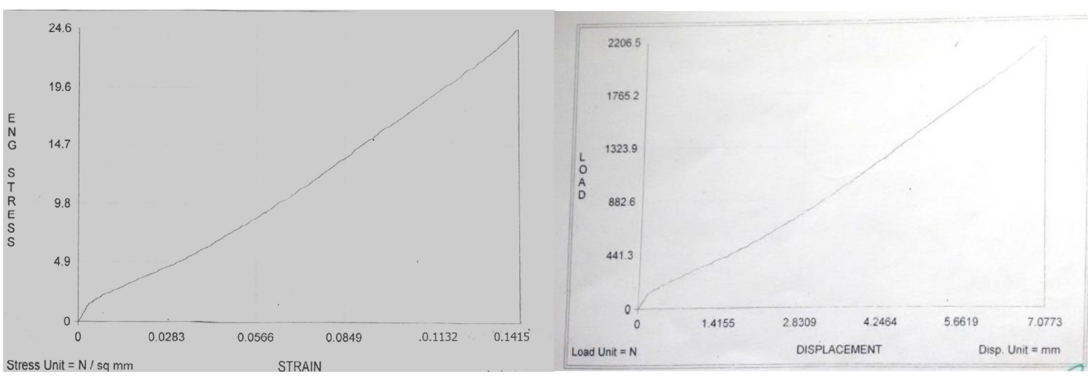


Fig.12: Graph for tensile test specimen with 0% coupling agent

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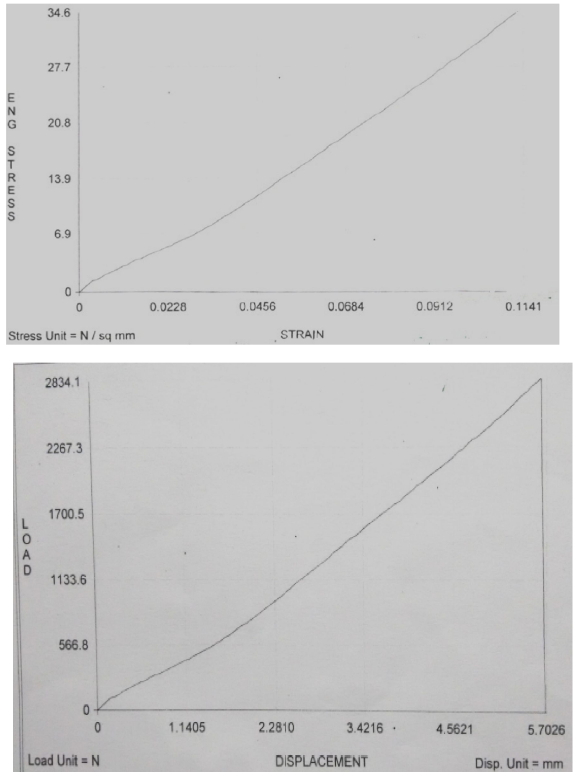

Fig. 13: Graph for tensile test specimen with 5% coupling agent

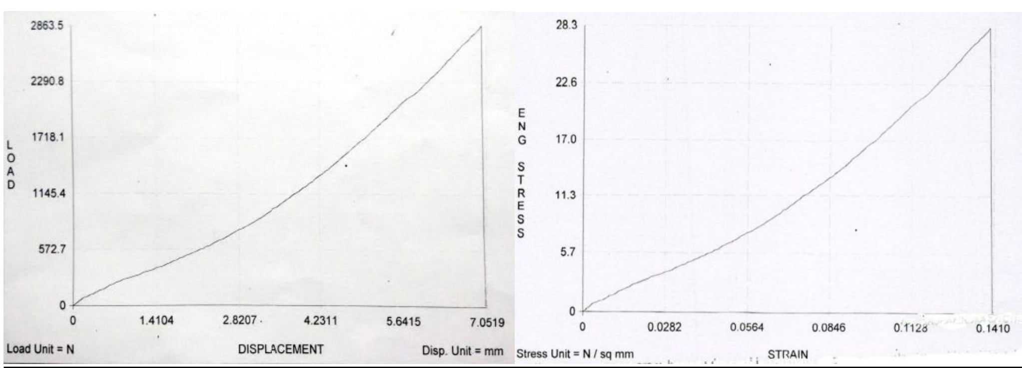

Fig. 14: Graph for tensile test specimen with 10% coupling agent

BENDING TEST:

The bending test results for different forms of jute reinforced composites obtained are tabulated in table

FORM OF JUTE COMPOSITE	PEAK LOAD (N)	% REDUCTION AREA	3Pt BEND FLEXURAL STRENGTH (MPA)	3Pt BEND FLEXURAL MODULII (MPA)
0%MAELIC ANHYDRIDE	**382.5**	**0.046**	**50.49**	**42.7**
5%MAELIC ANHYDRIDE	**441.3**	**0.047**	**54.68**	**48.3**
10%MAELIC ANHYDRIDE	**480.5**	**0.039**	**65.2**	**52.9**

Table 6: Average value for bending test specimens

The load v/s deflection and stress v/s strain graph of one specimen of each form obtained by bending test conducted on computerized universal testing machine is given below.

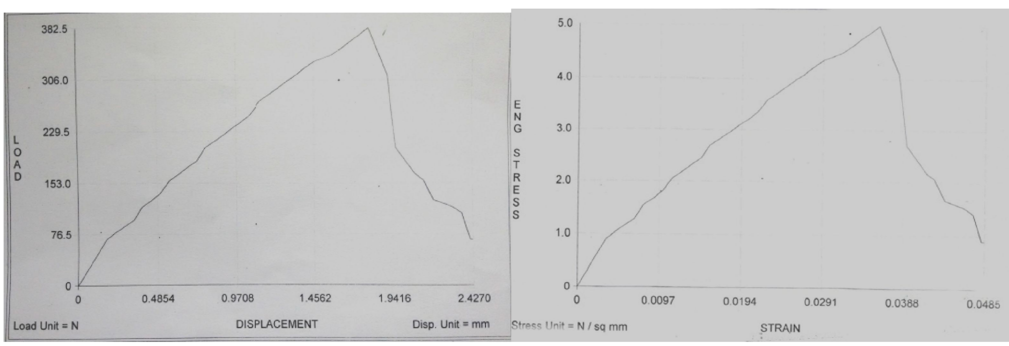

Fig.15: Graph for bending test specimen with 0% coupling agent

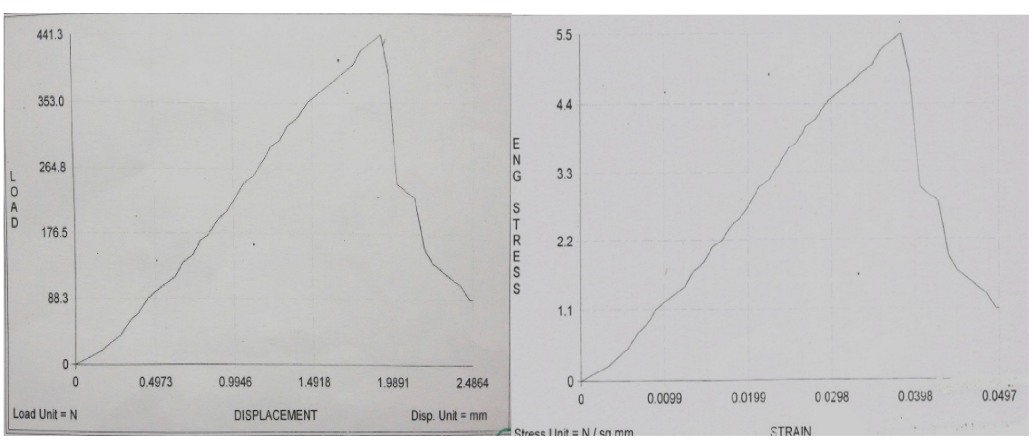

Fig.16 : Graph for bending test specimen with 5% coupling agent

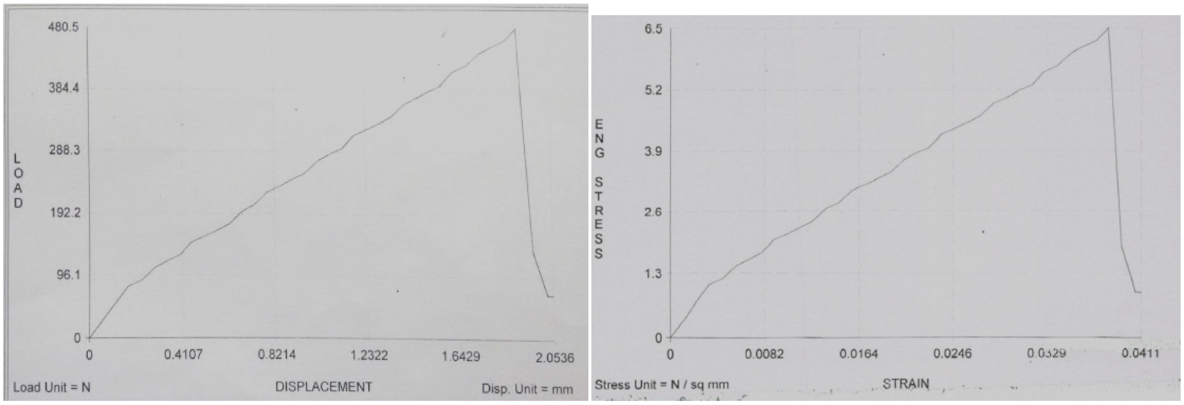

Fig. 17: Graph for bending test specimen with 10% coupling agent

IMPACT TEST:

The Izod impact test results for different forms of jute reinforced composites obtained are tabulated in table.

FORM OF JUTE COMPOSITE	IMPACT ENERGY ABSORBED (JOULES)
0% MAELIC ANHYDRIDE	**2.25**
5%MAELIC ANHYDRIDE	**3**
10%MAELIC ANHYDRIDE	**3**

Table 7: Energy absorption by different forms of jute composites

HARDNESS TEST:

FORM OF JUTE COMPOSITE	Rockwell Hardness Number (C Scale)
0% MAELIC ANHYDRIDE	**41**
5%MAELIC ANHYDRIDE	**44**
10%MAELIC ANHYDRIDE	**46**

Table 8: Hardness test result

VII.CONCLUSION

The experimental investigation on tensile, bending, impact, and hardness of jute fibre reinforced polymer composite with different percentage of as maelic anhydride material has been successfully carried out. The conclusions drawn from the present work are as follows:

- Composites were fabricated successfully using hand lay-up technique.
- The ultimate tensile strength of jute fibre composite with coupling agent (maelic anhydride) is higher compared to composite made without addition of coupling agent.
- The flexural 3 point bending strength of jute fibre composite shows a systematic increase with respect to addition of coupling agent.
- The Impact energy absorbed is greatest at addition of 5% of coupling agent after which there is no noticable changes.

Overall it is observed that the various mechanical properties of jute reinforced polymer composites with addtion of coupling agent (maelic anhydride) is superior to the composite made without the coupling agent.

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