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Analysis of Mechanical Behavior of Treated and Untreated Hemp Yarn Reinforced Epoxy Resin Composites

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Abstract:

Natural fibrereinforcedpolymercompositesareutilizedforvarioustechnicalapplications. Natural fibres such as jute, coir, sisal hemp, banana have been reinforced in theepoxy resin matrix. An attempt has been made in this study by reinforcing the raw and chemicaltreated hemp yarns in the epoxy resin matrix with a foresight that it would find its application infurniture, interior decoration materials, automobile, marine fields and various fields of technicaltextiles. The hemp yarns were treated with Sodium Hydroxide to alter the properties of the yarnandthen reinforcedin composites which wereanalyzedfor the properties byvarious testsnamely Tensile strength, Compression Strength Test, Impact test, Hardness test and ThermoGravimetricAnalysis(TGA).Thecompositestructureswere easilymadeusinghempyarnreinforcement. The treated hemp yarn reinforced composite sample exhibited better properties ofcompressionstrength,elongation,hardness,thermalstabilityandequalimpactstrengthoncomparing with the untreated hemp yarn reinforced sample. Natural fibre composites are lightweight and low in cost and are also environment friendly. This study on treated hemp yarnreinforced epoxy composites was carried out to analyze the changes in the properties of chemicaltreated yarn. The results obtained in the study would help the researchers to do further works inthisarea.

Key Words: Investor Behavior, Mutual Funds, Investments, Demographic.

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Introduction

TheTextileindustryisoneoftheoldestindustriesinIndia.Thesectorhasmadesignificant contributions in terms of foreign earnings and employment. Indian Textile Industryoccupiesaveryimportantplaceintheeconomiclifeof India.Overapastfewdecadescomposites, plastics, ceramics have been the dominant engineering materials.[1] At present, thedevelopment of material are tending towards green composite, due to the challenges of globalenvironmental concerns such as rising sea levels, rising average global temperatures, decreasingpolar ice cap and rapidly depleting petroleum resources.[2] Most of the plant fibres like hemp,flax, sisal are currently receiving more research attention by reinforcing in composite materialsfor the replacement of synthetic fibres composites.[3] Natural fibre composites are claimed toproduce environmentalblessingslikereduceddependenceon nonrenewableenergy/materialsources, lower pollutant emissions, lower greenhouse gas emissions, enhanced energy recoveryand end of life biodegradability of components. Such superior environmental performance hasmultipliedtheuseofNaturalFibres.[4]

Natural fibres are generally lingo cellulosic in nature.[5] Natural fibres are extracted bymethods such as stagnant water retting, chemical retting and decortication.[6] Hemp is an amazingfibre which grows quickly and does not need pesticides because it does not attract pests.[7] Aftersisal, hemp is that the most generally used natural fibre as reinforcement in composites. Thechemical composition of hemp fibres is cellulose- 67.0 per cent, hemi-cellulose-16.1 per cent,pectin - 0.8 per cent, lignin - 3.3 per cent and other constituents - 2.8 per cent.[8] The tensileproperties of Hemp fibres is noted to have the tensile strength of 277 MPa, Modulus of 9.5 Gpaand Strain to failure of 2.3%.The tensile properties of hemp fibres were found to be goodenoughtobeusedas reinforcementincomposite materials.[9]

Fibre reinforced composites owing to their superior properties are usually applied indifferent fields like defense, aerospace, engineering applications and sports goods. Nowadaysnatural fibre composites have gained increasing interest due to their ecofriendly properties.[10]Natural Fibre Composites become green composite when it contains a biobased matrix material.The use of natural fibre reduces weight by 10% and lowers the energy needed for production by80%, while the cost of the component is 5% lower than the comparable fibre glass-reinforcedcomponent. Natural fibres havemany advantages compared to glassfibres,for example theyhavelowdensity,andtheyarerecyclable andbiodegradable.[11]

Composites are advantageous over the materials such as metal and wood are that they arelight in weight, relative stiffness and have excellent strength. Due to their less weight, duringtransportationmorefuelissaved.Thecompositematerialspossessuniquecombinationofproperties such as high strength to weight ratio, better toughness, fatigue and stiffness, functionalsuperiority better corrosion, weathering and fire resistance, electrical insulation and antifrictionproperties.[12] Composite materials have excellent fire resistance property as compared with thelightalloyswithidenticalthickness.[13]AsrecyclabilityandCO[2]emissionsbecomeincreasinglymore important,hempfibrereinforcedcompositescanbeusedasmechanicallyresistantcomponents inavarietyofapplications.[14]

The untreated alkali treated and silane treated sisal and glassfibre reinforced polyesterare used forhybrid composites.Thealkali treated hybrid composites showed better tensilestrength than silane treated and untreated hybrid composites due to the removal of hemicellulosefrom sisal fibres which helpedtoimprovetheadhesivecharacteristics.[15] Sodium hydroxidetreatment on the fibre would remove the impurities like pectin, facts and lignin in the fibre,resulting in the improvement in the adhesion between fibre and matrix also increases mechanicalproperties of fabricated component.[16] Natural fibre composites are very cost effective materialespecially inbuildingandconstruction,packagingpurpose,automobilesandrailway coachinteriors and storage devices. The chemical treatments are considered in modifying the fibrestructureproperties.[17]

2. MaterialsandMethods

Thematerialsandmethodsusedforthestudyareexplainedunderthefollowingheads.

2.1 Procurement of untreated and treated Hemp yarn with known properties

Theuntreatedhempyarnwithpropertiesnamelytensilestrengthof5.7790Kg,elongation of 2.16 percent, breaking tenacity of 9.79 g/tex, twist per inch - 3.26 TPI and thediameter - 0.96 mm was used for the study. Moisture content in the fibres samples are reducedon scouring andbleaching which is very much essential for composite manufacturing.[18] (Plate1a) Use of chemical regents for fibre modification will increase the mechanical properties of thefibre and the strength of the fibre-reinforced cement composite and will improve the adhesionbetweenthefibresurfaceandpolymermatrixbyreducingthewaterabsorptionofthecomposites.[19] So the hempyarns were treated with 5%concentration of Sodium hydroxidesolution.The yarn was submerged in sodium hydroxide solution for one hour at 95^{o}C. Thetreated yarns were then rinsed in soft water to eliminate the sticking of NaoH to the yarn and thiswas dried in oven at 70^{o}C for three hours.[20] The chemical treated hemp yarn had the propertiesnamely tensile strength of 5.1969 Kg, elongation of 2.84 percent, breaking tenacity of 10.30g/tex,twistperinchoftheyarn-3.30TPIand thediameter-1.18 mm.(Plate 1band 1c).

2.2 Preparation of Mold

To make the composite structure, the mold was prepared by the following steps. First the

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thermocol sheet of dimension 300 mm x 300 mm x 15 mm was taken like a frame and a thin layer of OHP sheet was spread at the bottom and stuck to the thermocol frame thereby forming a mold of depth 15 mm. Care was taken that there was no space between the sheet and the thermocol, to prevent the running of resin after pouring.[21]

2.3 Preparation of Composites

Composite preparation involved the following steps.

2.3.1 Mixing ofChemicals

The mold releasing agent PVA was applied on the surface of the base and sides of themold to facilitate easy removal of the composite from the mold after curing. The low temperaturecuring epoxy resin LY556 and corresponding hardener HY951 were mixed in theratio of 10:1by weight.[22] The low temperature curing resin and corresponding hardener were mixed and usedfor the study. The properties of epoxy resin LY556 and hardener HY951 are as given. Propertiesof epoxy resin-LY556 - Viscosity at 250^{o}C-10,000 -12,000 MPa, Visual aspect - clear liquid,Density - 250^{o}C- 1.15 – 1.20 gm/cm^3, Flash point - 1950 ^{o}C Properties of the hardener HY-951-Density - 0.95 g/cm^3, Melting point - 120^{o}C, Boiling point- 266 – 267^o C, Water solubility – solubleandFlashpoint-143^{o}C.Thesewere mixedthoroughlyintheproportion10:1.(Plate1d).

The most adopted epoxy resin (LY556) and industrial application hardener (HY951) areemployed to fabricate the laminated sheets and hybrid combinations. Epoxy resins are widelyusedbecause oftheirhighmechanicalpropertiesandhighcorrosionresistance.[23]

2.3.2HandLayingupofyarns

The hemp yarn was cut into pieces of about 7 cm length. About 40 per cent of hemp yarnfor the weight of resin was taken. Then half the mixture of resin and binder were poured into themold. The yarns were hand laid such that they formed a criss cross effect. Then the rest of themixture was poured and the yarn pieces were laid again in the same manner as before. This wasmade even with a roller placing an OHP sheet which is applied with PVA. Then curing was doneat room temperature for 24 hours. Both the treated and untreated yarns were handlaidin thesame wayforthe compositesamplepreparation[21].(Plate1e).

Plate 1a. Hemp Yarn	Plate 1b. Treatment of Yarn	Plate 1c. Cut Yarn Pieces	Plate 1d. Application of PVA	Plate 1e. Hand laying of Yarn

2.4 Evaluation

The prepared samples were subjected to objective evaluation for essential propertiesnamelyTensile

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strength,Hardness,Impact,CompressionandT GA.

2.4.1 Tensilestrength

The tensile strength was carried out for all the samples as per standards ASTM A370:20.The load at yield point, yield stress, load at peak, tensile strength and elongation were noted andtabulated.(Plate2a).

2.4.2 Hardness test

The concept of hardness can be counted as a measure of the plastic deformation that thematerial can suffer under the influence of external stress.[24]Rockwell hardness tester was used forfinding the hardness of the untreated and treated yarn reinforced composite structures as perASTM D 2240. Three trials were taken and the readings were noted in unit SHORE-D for whichthe averagewasfoundandrecorded.(Plate 2b).

2.4.3 Impact test

Charpy impact testing machine was used for finding the impact of the composite. The testmethod used was ISO 148-1 2016, (AIT /300 ASTM D). The capacity of the machine used was300 Joules. It was carried out at room temperature of 2.5-2^{o}C. Three trails were taken for whichthe average was calculated and recorded in Joules. It was carried out for both the samples. (Plate2c).

2.4.4 Compression Strength

The composite samples were analyzed for compressive strength modulus of elasticity andPoisson's ratio. UTM – based compression tests were carried out as per the ASTM standard at across-head speed of 1 mm/min. It was held in a UTM between grips with a small gauge length of12 mm to avoid bucking of the specimen during the application of compressive load in a test.[25]The specimens areloaded,leavingan unsupportedlength as testsection. This testwas carriedoutforbothsamples,namelyUHCandTHC.

2.4.5 Thermo Gravimetric Analysis (TGA)

Thermal degradation by TGA Thermo-Gravimetric Analysis is a technique in which themassofasubstanceismonitoredasafunctionofte mperatureortimeinacontrolledatmosphere. The instrument used was thermal analyzer of the model S11 TG/DTA 6300 for thestudy. The experiment was carried out in the Nitrogen gas environment. The TGA instrumentconsists of a sample pan that is supported by a precision balance.The pan resides in a furnaceand is heated or cooled during the experiment. The mass of the samplewas monitored duringtheexperiment. Thesampleenvironmentiscontrolledinnitrogenga satmosphere.(Plate2d).

			
Plate 2a Tensile Strength Tester	Plate 2b Hardness Test	Plate 2c Impact Test	Plate 2d TGA

2.5 Nomenclature

ThenomenclatureusedforthesamplesareUHCfor UntreatedHempyarnreinforcedCompositeandTHCfor TreatedHempyarnreinforcedCompositestructure

3. Results and Discussion

Theresultsobtainedfromthestudyandthediscussionareexpressedunderthefollowingheads.

3.1 Tensile Strength Test

TheresultoftheTensilestrengthispresentedinTableIandFigure1.

Table I
TensileStrengthTest

S.No	Samples	Load at yield(KN)	Yield stress (N/mm²)	Load at peak	Tensile strength (N/mm²)	Elongation %
1	UHC	1.56	9.226	3.100	18.334	0.53
2	THC	0.02	0.08	1.180	5.161	**3.42**

From the Table I it is clear that the sample UHC exhibited tensile strength of 18.334 N/mm^{2}and sample THC showed tensile strength of 5.161 N/mm^2. It showed a drastic reduction instrength in the treated sample THC over the sample UHC. As far the elongation is concerned, itwashigherinthesampleTHCof3.42percentfollowedbythesampleUHCof0.53percent.InthefindingsmadebySatishandSingh,2019[26]thehempcompositeshowstensilestrengthof10.65 MPa and in the present study the tensile strength of the untreated hemp exhibited a bettertensile strength than the earlierstudy.Henceitcould be concluded that though the tensilestrength was lesser the elongation was more in the treated yarn reinforced sample (THC) than theuntreatedyarnreinforcedsample(UHC).Theoutputof t-testalsoprovedthatthereisnostatistical significant difference between the given variables in load at yield, yield stress, load atpeak,tensilestrengthandelongationforTHAand UHC.

3.2 HardnessTest

TheresultofthehardnesstestispresentedinTableIIand Figure2

TableII
HardnessTest

S.No	Samples	SHORE-D T1	T2	T3	Average (SHORE-D)
1	UHC	75	76	78	76
2	THC	80	82	82	81

From the Table II it is obvious that the hardness was higher in sample THC with 81 SHORE-D followed by the sample UHC with 76 SHORE-D. The hardness test of the hemp fibre (40%) epoxy (60%) combination was observed to be 57.95 SHORE D and the combination of hemp fibre (50%) epoxy (50%) was 60.22 SHORE D. 27 But the results obtained in the present study exhibited more hardness which may be due to the reinforcement of twisted fibres (hemp yarn pieces). The output of t-test, shows that there is statistical significant difference at 1 % level between the given variables of UHC and THC. Hence it could be concluded that the hardness was higher in the treated yarn reinforced composites than the untreated sample and also that hardness was more in the hemp yarn reinforced structures than the hemp fibre reinforced structures.

3.3 Impact Test

TheresultoftheImpactTestispresentedinTableIIIandFigure3

Table III
ImpactTest

S.no	Samples	Trials			Impact (Joules)
		T1	T2	T3	
1	UHC	2	2	2	2
2	THC	2	2	2	2

From the Table III itis clear that the impact of the samples UHC and THC wereobserved to be 2 Joules.The impact strength of the hemp fibre reinforced composites arenotedto be 0.189 J/mm^2 in the findings of Kannan.[27] But in this study both the samples UHC and THCshowed a better impact strength of 2 Joules. This may be due to the reinforcement made usinghemp yarn. Hence it could be concluded that both the samples UHC and THC exhibited equalimpactcapacity.

3.4. Compression Strength Test

TheresultofthecompressionstrengthtestispresentedinTableIVandFigure4

TableIV
CompressionStrength

S.No	Sample	Compression strength Average (N)	
		Mean	SD
1	UHC	23,782	23.75
2	THC	46,081.65	46

From the Table IVit is clear that the compression strength was the higher in the sampleTHCinveryhighdifference with 46,081.65Nfollowedbythe sampleUHC23,782N.

3.5ThermoGravimetricAnalysis(TGA)

TheresultsoftheTGAtest arepresentedintheTableVandFigures5&6.

TableV
TGA

S.No	Samples	Temperature (Celsius)	Decomposition (%)
1	UHC	334.1	94.7
2	THC	332.6	92.7

From the Table V itis clear that the temperature requiredfor decomposition was higherin the sample UHC 334.1^o C than sample THC 332.6^o C. Hence it could be concluded that thetemperature required for decomposition was lesser in treated sample THC than the untreatedsample.

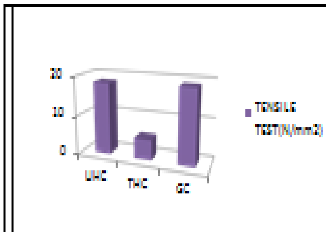

Figure - 1 Tensile Test

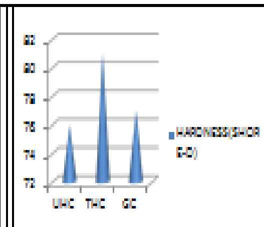

Figure -2 Hardness

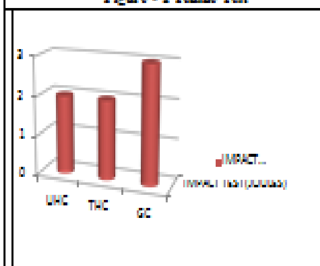

Figure – 3 Impact

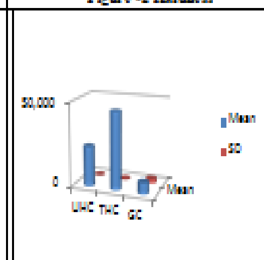

Figure – 4 Compression

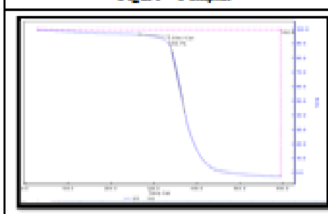

Figure – 5 Graph of Sample UHC

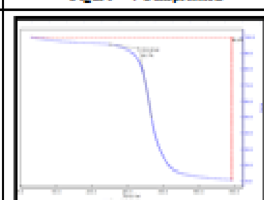

Figure – 6 Graph of Sample THC

4. Findings of the Study

The tensile strength was lesser and the elongation was more in the treated hemp yarnreinforced sample (THC) than the untreated hemp yarn reinforced sample (UHC). The hardnesswashigherinthetreatedhempyarnreinforcedcompositesthantheuntreatedhempyarncompositesample.Both thesamplesUHCandTHCexhibitedequalimpactcapacity.Thecompression strength was the higher in the sample THC with 46,081.65N followed by thesampleUHC23,782N.FromtheThermoGravimetricAnalysisitisclearthatthetemperaturerequiredfordecomposition waslesserin samplethe treatedhempcomposite sample than theuntreatedhempreinforcedcompositesample.

Conclusion

The composite structures were easily possible with hemp yarn reinforcement. The treatedhemp yarn reinforced composite sample exhibited better properties of compression strength,elongation,hardness,thermalstabilityand equalimpactstrengthoncomparingwiththeuntreated hemp yarn reinforced sample. So depending on the end usesto be manufactured thenatural fibres or yarns may be given chemical treatment for modifying the characteristics of thesetoobtaintherequiredproperties.

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