

Mechanical and Tribological Properties of Natural Fiber Reinforced Epoxy Composites



Thesis submitted in partial fulfillment for the

Award of Degree

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By

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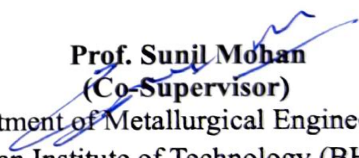
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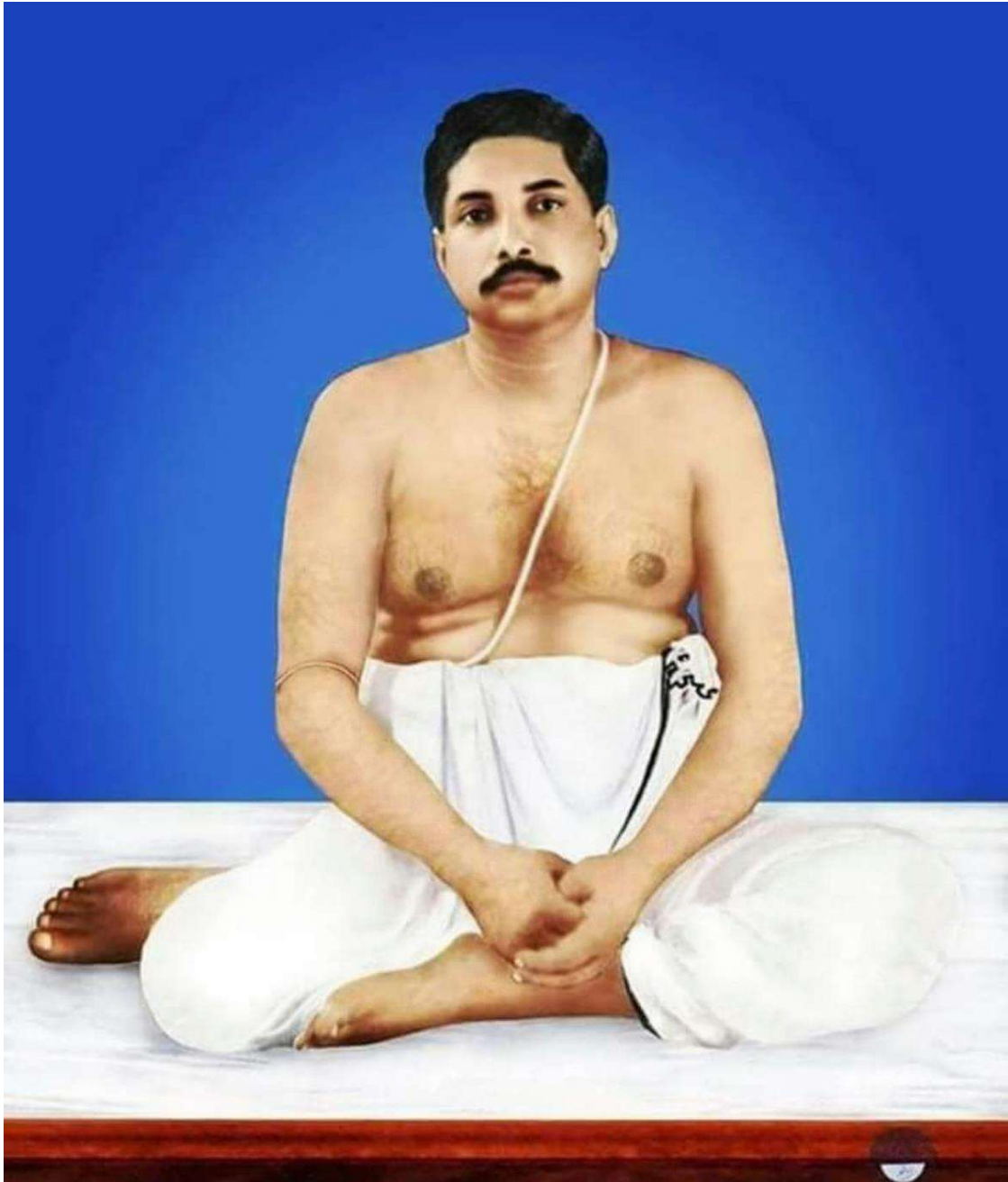
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(Sudhakar Behera)

Dedicated to my love lord
Sree Sree Thakur
Anukulchandra



Abbreviations/symbols

Abbreviations/symbols	Description
MMCs	Metal matrix composites
CMCs	Ceramic matrix composites
PMCs	Polymer matrix composites
PVC	Polyvinyl chloride
PPS	Polyphenylene sulfide
PEEK	Poly-ether-ether ketone
PLA	Polylactic acid
PHB	Polyhydroxybutyrate
SEM	Scanning electron microscopy
XRD	X-Ray diffraction
FTIR	Fourier transform infrared spectroscopy
TGA	Thermogravimetric analysis
DSC	Differential scanning calorimetry
MPa	Mega-Pascal
GPa	Giga-Pascal
S1	Outer layer
S2	Middle layer
S3	Inner layer
OH	Hydroxyl
UV	Ultra violet
PP	Polypropylene
NaHCO ₃	Sodium hydrogen carbonate/Sodium bicarbonate
TGIC	Triglycidyl isocyanurate

RF	Ramie fiber
NaOH	Sodium hydroxide
KMnO ₄	Pottasium permanganate
COF	Coefficient of friction
CGFs	Calotropis gigantea fibers
AS	Areca sheath
PVA	Polyvinyl alcohol
SF	Sisal fibre
PF	Pineapple fiber
PA	Pineapple fly-ash
PI	Polyimide
CSF	Corn Stalk Fiber
Na ₂ CO ₃	Sodium carbonate
H ₂ O ₂	Hydrogen peroxide
C ₁₈ H ₂₁ ClO ₃	Bisphenol-A
BADGE	Bisphenol-A-Diglycidyl-Ether
TETA	Tri-ethylene-tetramine
ST	Sodium carbonate treated
PT	Peroxide treated
h	Hour
°C	Degree celcius
vol%	Volume percentage
wt%	Weight percentage
w/v	Weight in volume
mins	Minutes
UT	Untreated

AT	Alkali treated
GT	Glutamic acid treated
AGT	Alkali + Glutamic acid treated
SAT	Stearic acid treated
SCT	Sodium citrate treated
SHT	Sodium hydrogen carbonate treated
ATR	Attenuated total reflectance
Å	Angstrom
kV	Kilovolt
mA	Milliampere
I _c	Crystallinity index
<i>I</i> ₀₀₂	Highest diffraction intensity of the crystalline material
<i>I</i> _{am}	Lowest diffraction intensity of the amorphous material
gm	Gram
°C/min	Degree celcius per minute
mm	Millimeter
HFREC	Hemp fiber reinforced epoxy composites
SFREC	Sisal fiber reinforced epoxy composites
JFREC	Jute fiber reinforced epoxy composites
ASTM	American Society for Testing and Materials
<i>W_F</i>	Weight of the composite specimen after immersion
<i>W_I</i>	Weight of the composite specimen before immersion
P	Maximum load
L	Sample's span length
b	Specimen's width
t	Specimen's thickness

m	Slope of the tangent to the initial straight-line portion of the load deflection curve
ILSS	Interlaminar shear strength
F	Load
X and Y	Diagonals
H	Arithmetic mean of diagonals
H _v	Vickers microhardness
VLS	Wear volume loss
ΔM	Mass loss
ρ	Density of the composite sample
C	Carbon
O	Oxygen
H	Hydrogen
=	Double bond
-	Single bond
2θ	2-theta
DMA	Dynamic mechanical analysis
NFRPC	Natural fiber reinforced polymer composites

Abstract

Polymers' mechanical characteristics are insufficient for many structural applications because of their inferior strength and stiffness properties when compared to those of ceramics and metals. As a result, to increase mechanical characteristics and expand structural applications, polymers are frequently reinforced with strong but costly and environmentally unsustainable synthetic fibers. In the past three decades, scientists and researchers have shown a great deal of interest in using natural fibers as reinforcing materials in polymer composites due to its advantages such as low cost, ease of availability, light weight, and high specific properties. In addition to the above benefits, natural fibers are also biodegradable and causes less wear and tear to the machining tools.

Despite the natural fibers' appealing characteristics, their usage in a variety of structural applications is limited. Natural fibers are hydrophilic in nature, which is responsible for improper interfacial interaction of fiber and the polymer matrix, as well as swelling of the fiber, resulting in the poor mechanical performance of the natural fiber reinforced polymer composites. Physical (plasma treatment, ozone treatment, laser treatment, etc.) and chemical (alkali, coupling agent treatment, etc.) treatments of the fibers, as well as matrix modification like the addition of nanoparticles into the polymer matrix, can be used to overcome these obstacles. Chemical treatment methods are typically based on the use of reagent functional groups capable of reacting more effectively with the chemical constituents of the natural fiber and removing impurities and non-cellulosic materials from the fibers. As a result, this surface modification technique aids fiber bonding with polymeric matrices. However, most of these surface modification techniques are harmful to the environment as well

as to the person handling those chemicals and this will negate the very purpose of using natural fibers as reinforcement.

Against this background the present experimental research work has been carried out to modify the surface of natural fibers with various eco-friendly chemicals in order to minimize hydrophilicity and enhance the strength, crystallinity, and surface roughness of the fibers so that the fibers can have efficient bonding with the polymer matrix. The complete experimental investigation is subdivided into four broad areas focusing on surface modification of the natural fibers, physical and thermal characterization of the surface modified fibers, fabrication of the natural fiber reinforced epoxy composites and the investigation of water absorption, mechanical and tribological properties of the composites.

The first phase of experimental investigation primarily deals with the usage of eco-friendly chemicals to modify the natural fiber surface. This research work involves the application of three different types of natural fibers namely hemp, sisal and jute. Hemp fiber was surface treated with sodium carbonate and hydrogen peroxide. Sodium hydroxide, glutamic acid, combination of alkali and glutamic acid, stearic acid and sodium citrate were used as chemicals to modify the sisal fibers' surface. Jute fiber surface was chemically modified with sodium hydroxide, sodium carbonate and sodium bicarbonate. In addition to the use of various chemicals, the hemp fiber surfaces were also coated with biodegradable polymers like Polylactic acid (PLA) and Polyhydroxybutyrate (PHB) to improve the fiber's compatibility with the polymer matrix. This offers an innovative approach to fiber surface modification other than chemical treatment.

The second phase deals with various physical characterization (SEM, FTIR, XRD) and thermal characterization (TGA/DSC) techniques employed for the evaluation of

surface roughness, chemical modification (functional groups), crystallinity and thermal properties of the natural fibers under investigation. Scanning electron microscopy (SEM) was used to investigate the morphological properties of the fibers, which demonstrated that the chemical treatment eliminated the contaminants from the fibers' surface. The reduction of hemicellulose and lignin contents of the fiber was confirmed by Fourier transform infrared (FTIR) analysis following chemical treatments. X-ray diffraction (XRD) analysis showed an increase in the crystallinity index of the surface modified fiber. Thermal stability of the treated fibers showed a slight reduction as revealed by Thermogravimetric analysis (TGA) and Differential scanning calorimetry (DSC).

The third phase involves the fabrication of various epoxy composites reinforced with natural fibers. Hemp/epoxy, sisal/epoxy and jute/epoxy composites were manufactured with the help of simple hand lay-up technique. After the fabrication of the composite plates, samples for various mechanical, water absorption and tensile tests were prepared according to the ASTM standards.

The fourth phase deals with the investigation of water absorption, mechanical (tensile, flexural, impact, interlaminar shear strength and micro-hardness properties) and tribological properties (wear and friction) of natural fiber reinforced epoxy composites. The experimental results revealed that both chemical treatment and polymer coatings of the fibers have resulted in improvement of water resistance and mechanical properties of the composites. Tribological test results also revealed that the surface modified fiber composites have improved wear and frictional properties in comparison to untreated fiber composites. Fractured and wear surfaces of the specimens were examined using Scanning Electron Microscope (SEM) to get insight

into the composite's fracture behavior and to better understand the fiber/matrix adhesion.

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