DEVELOPMENT AND STUDY OF THE MECHANICAL PROPERTIES, THERMAL DEGRADATION AND ELECTRICAL BEHAVIOUR OF BAMBOO FIBRES REINFORCED PLASTIC (BFRP) COMPOSITE

by

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CERTIFICATE

This is to certify that the thesis entitled "**DEVELOPMENT AND STUDY OF THE MECHANICAL PROPERTIES, THERMAL DEGRADATION AND ELECTRICAL BEHAVIOUR OF BAMBOO FIBRES REINFORCED PLASTIC (BFRP) COMPOSITE**", submitted by **SEEMA JAIN**, to the Indian Institute of Technology, Delhi, for the award of the degree of **DOCTOR OF PHILOSOPHY** is a record of the bonafide research work carried out by her. Seema Jain has worked under our guidance and supervision and has fulfilled the requirement for submission of the thesis, which to our knowledge has reached the requisite standard.

The results contained in this thesis are original and have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

A new class of fibres which hold great promise as a reinforcement in the FRP industry are the natural ligno-cellulosic fibres. These natural fibres like jute, coir, straw, banana, bamboo etc. are renewable and cheaper substitutes to a number of synthetic fibres.

The main thrust of the work reported in this thesis was to develop bamboo fibres reinforced plastic (BFRP) composite by reinforcing bamboo in fibre form in polymer resins and to study its various mechanical properties (tensile, flexy\ural and impact strengths), thermal degradation and electrical properties. Some possible uses of BFRP composites as structural and as insulating materials have also been explored.

The present work establishes bamboo as a superior natural fibre among other known natural fibres (like Jute, coir, straw, sisal etc.) on the basis of its anatomical properties, ultra structure and experimental findings.

$BFRP_{epoxy}$ and $BFRP_{USP}$ composites have been developed by reinforcing epoxy and polyester resins with bamboo fibres. Unidirectional, bidirectional and multilayered composites, with different fibre orientations, have been made using hand layup technique.

Under tension, the behaviour of bamboo and BFRP composites is linearly elastic and it has a brittle fracture. In general BFRP composite follow rule of mixture. The high impact strength (> 20 kJm^{-2}) of BFRP composite puts it in the category of tough engineering materials.

SEM studies on the fractured BFRP samples reveal that epoxy resin impregnates inside bamboo fibres making a perfect bonding with it. However, the bond between USP resin and bamboo is not as strong.

Strain contours and strain concentration factor around a hole with and without an oversize inclusion in an infinite BFRP composite plate under uniaxial tension have been

studied. An optical non-destructive technique, High Resolution Moire' Photography (HRMP) was successfully employed. The fringe patterns revealed that macroscopically BFRP composite behaves as a homogeneous material with no inherited defects and irregularities like voids and cracks.

Studies on the thermal degradation of bamboo have been carried out by thermogravemetric analysis. The thermal degradation of bamboo fibre strarts at approximately 270 °C. Both epoxy and USP resins degrade between 330 to 350 °C. This indicates that BFRP composite can be used upto a maximum temperature of 135 °C.

Different electrical properties like, dielectric breakdown voltage, insulation resistance, dielectric constant and dielectric loss at different frequencies (100 Hz - 1 MHz) and temperatures (20 - 180 °C) have been measured for BFRP composite. The dielectric breakdown voltage for $BFRP_{epoxy}$ is 14 Kv/mm and for $BFRP_{USP}$ is 12 kV/mm. Insulation resistance of BFRP composite is greater than 100 Mega ohms. The insulating properties of BFRP composite falls in the range of medium class insulating materials, which are subjected to severe mechanical forces.

Based on the experimental findings it can be concluded that bamboo fibres can be a commercially viable replacement to glass fibre as a reinforcement in fibre reinforced plastic (FRP) industry for a variety of applications.

Following papers have been published from the part of the thesis work.

1. A study of the mechanical behaviour of bamboo and bamboo composites.

   Authors : Seema Jain, U.C. Jindal, Rakesh Kumar

   Reference : Jl. of Material Science (UK), 27 (1992) 4598-4604.

2. Development and fracture mechanism of the bamboo / polyester resin composite.

   Authors : Seema Jain, U.C. Jindal, Rakesh Kumar

   Reference : Jl. of Material Science Letters (UK), 12 (1993) 558-560.

3. Development and strength of polymer composite reinforced with bamboo fibres.

   Authors : Seema Jain, U.C. Jindal, Rakesh Kumar

   Reference : Presented in "The International Conference on Advances in Composite Materials". Organised by ASM International, during January 15-18, 1990 at Bombay.

4. High Resolution Moire' Photography (HRMP) for strain concentration around a hole in an infinite bamboo fibres reinforced plastic (BFRP) composite under uniaxial tension.

   Authors : Rakesh Kumar, Seema Jain, U.C. Jindal

   Reference : Presented in "CANCOM' 91". Organised by Canadian association for composite structures and materials, during 4-6 September, 1991 at Montreal, CANADA.

5. Processing of bamboo composites

   Authors : Seema Jain, Rakesh Kumar

   Reference : Accepted for publication in "Materials and Manufacturing Processes", U.S.A.

SYMBOLS AND ABBREVIATIONS

BFRP	bamboo fibres reinforced plastic
USP	unsaturated polyester
SEM	scanning electron microscopy
OTF	optical transfer function
E_c	Young's modulus
E_f	Young's modulus of microfibril
A	cross - sectional area
A_f	the cross-sectional area of the fibres ,
A_m	the cross-sectional area of the matrix .
V_f	fibre volume fraction
BE_f	Bamboo fibre epoxy composite
BE_m	Bamboo mat epoxy composite
BP_m	Bamboo-mat polyester composite
P	maximum load at rupture, (N)
L	support span length, (m)
D	Maximum deflection at the centre of specimen, (m)
R	distance from the exit pupil to the image plane
S	ratio of the span length to thickness (S=L/t)
P(u,v)	pupil function
M(u,v)	two-dimensional optical transfer function (OFT)
UTS	Ultimate tensile strength
ΔZ	focus error
Θ	filamentary winding angle
ϵ_1	first modulus of composite in the fibre direction
σ	average stress
σ_f	average sterss acting on the fibre
σ_m	average stress acting on matrix
ϵ	Young'smodulous
ρ_m	density of matrix
ρ_c	density of composite
ρ_f	density of fibres

b	width of specimen, (m) measured at centre of support span
p	pitch of the grid pattern applied on the specimen.
t	depth or thickness of specimen, (m) measured at centre of support span.
m	slope of the tangent to the initial straight line portion of the load-deflection curve, (N/m)
u,v	variable, represent the measured spatial frequencies
η,ξ	co-ordinates which denote position in the plane of the exit pupil
u	tuned frequency
λ	effective wavelength set by the film and illumination,
d	slot separation viewed from the image plane,
f	focal length of the lens
δ_x	moire' fringe spacing measured in the x direction
$\tan\delta$ (ϵ")	AC-loss factor
(ϵ')	Dielectric constant

LIST OF CONTENTS