REVIEW ON MECHANICAL BEHAVIOR OF CARBON/EPOXY LAMINATE COMPOSITE IN HYGRO- THERMAL ENVIRONMENT

M.Ramarao[1], Dr.K.L.Narayana[2], Dr.B.Durga Prasad[3]
[1]Research Scholar, Department of Mechanical Engineering, JNTUA, Ananatapuramu, India
[2]Professor, Department of Mechanical Engineering, SVCET, Chittoor, India
[3]Professor& HOD, Department of Mechanical Engineering, JNTUACEA, Ananatapuramu, India

Abstract
This paper presents the recent trends in the mechanical characterization of composite systems under consideration for Marine Hydro Kinetic (MHK) applications exposed to salt water environments. Carbon/Epoxy laminate composites are used as building material in high strength to weight ratio applications. In real engineering applications Carbon/ Epoxy laminate composites are subjected to many mechanical and thermal loads. The combinations of mechanical and thermal loads may cause catastrophic failure. In order to reduce the risk of failure a detailed thermo mechanical analysis is required. In this paper, a detailed literature review is carried on mechanical behavior of Carbon/Epoxy Laminate Composite at Hygro-Thermal Environment.

Key Words: Carbon/Epoxy Laminate Composite, Mechanical Properties, Hygro-Thermal Properties.

I. INTRODUCTION

Fiber reinforced composites are considered to replace metallic components in many industries for past several years. Because, compared to conventional metals fiber reinforced composites have low density, high specific strength and stiffness, higher corrosion resistance and improved fatigue performance. Performance of these fiber reinforced composites under various loading condition; such as axial, torsion and impact is very crucial for used structural components. Mechanical properties of fiber reinforced polymer composites depend on the fiber, matrix and the interface between them. The core benefits of the composite materials have their strength and stiffness for example carbon fiber have great specific strength, high modulus, good in fatigue resistance and dimensional stability and lower density fibers. Composite materials have high strength and stiffness, combined with low density, when compared with bulk materials allowing for a weight reduction in the finished part.(1)

Fiber reinforced polymer (FRP) composites are used in many primary structural applications within the transport sector, for their ability to provide a good compromise between light weight and damage tolerant design . Nevertheless, these materials, during their operating life, are often subjected to changes of their properties due to the environmental conditions to which they are exposed. One such condition, able to trigger severe ageing phenomena, is exposure to solvents, and water or moisture in particular. The composite material industry, nevertheless, is novel. It has technologically advanced speedily in the last 35 years through the improvement of fibrous composites: to begin through glass fibered reinforced polymers (GFRP) and more recently, carbon fiber reinforced polymers (CFRP). Their use in boats and their growing replacement of metal in ground transport systems is an uprising in material usage which is still accelerating. It finds application in composite, automotive, sports goods, medical equipment and packaging industry. (1)

Water uptake in FRP composites is activated by three main mechanisms: water diffusion in glassy polymer matrices , water diffusion at fiber/matrix interfaces , and water uptake by mesoscale voids ; while diffusion into glass or carbon fibers is usually negligible. The latter two mechanisms, in particular, characterize FRPs, due to the presence of a mesoscopic free volume, which is mainly reached and filled by capillarity, and is responsible for a final relative water uptake higher than that absorbed by an equivalent weight of bulk matrix resin. The action of water in these fibre/matrix and matrix mesoscale voids can also provide the onset for further damage, and favour non-fickian diffusion behaviour or pseudo-equilibrium stages with the progression of absorption .

Among all fiber reinforced composites, carbon fiber reinforced polymers are emerging because of remarkable properties of carbon fibers and polymer matrix combination. Properties of these CFRP can be enhanced by using several additives. Carbon fiber reinforced polymers (CFRPs) are one the stiffest and lightest composite materials, they are much convincing than other conventional materials in many fields and applications. Use of composites is limited due to their higher price and lower formability.

The mechanical properties of carbon fiber reinforced polymer composites depend upon fiber-matrix interfacial properties. Carbon fiber reinforced polymer composites have been extensively used in a wide range of applications such as aerospace, automotive, wind energy, marine turbine blades and sports sector because of their superior strength to weight ratio, high thermal stability and excellent corrosion resistance. Their low fabrication cost, ease of handling and fatigue damage resistance owe to metal counterpart in various applications. The mechanical properties of carbon fiber reinforced polymer composites also depends upon the interfacial interaction of fiber and epoxy matrix. Interlaminar shear strength (ILSS) is one of the best desirable measurement for finding out the interfacial interactions.

The carbon fiber laminated composites are liable to crack initiation and Propagation through various modes of failure. The delamination is one of the major crack Growth mode, which causes critical depression in in-plane strength and stiffness . Another problem is the surface inertness of carbon fiber which exhibits poor interfacial interactions with Polymer matrix. All above drawbacks are potentially lead to catastrophic failure of the whole Composite structure.

In this present paper, influence of Hygro-Thermal environment on mechanical behavior of carbon/Epoxy laminate composites is reported. Defects and failure analysis are presented.

II. CARBON/EPOXY LAMINATE COMPOSITES FOR HYGRO-THERMAL MEDIUM

2.1. Fiber

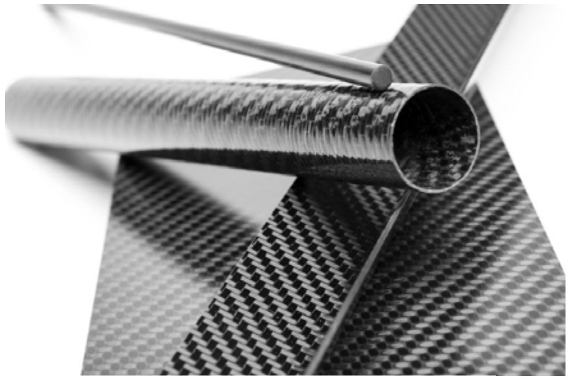
Fiber is the second most important component of the composite. The functions of fiber are:

1. To contribute high strength and stiffness to the composites
2. To carry the majority of the loads

A fiber has a diameter that is much smaller than its length.The length to diameter (l/D) ratios is identified as the aspect ratio and can differ significantly. Continuous fibers have their long aspect ratios, where as discontinuous fibers have small aspect ratios. Continuous fibers composite fibers generally have a desired orientation, although discontinuous fiber composite materials usually have a random orientation (1).

Carbon fiber was initially developed in the late 19th century as filament material for electric light bulbs. High strength and modulus carbon fibers were developed by the Royal Air Craft Establishment Farnborough, united kingdom in 1953.

Carbon fiber is also called graphite fiber, although in reality they are two different materials. Carbon fiber is stronger than Graphite fiber but in the composite community they are referred as the same materials. Carbon fibers are originally used as reinforcement of composite in Aerospace industry. Now the applications are extended to other industries, such as marine and automotive. It has high tensile strength and modulus, high fatigue strength and high thermal conductivity. The strength and stiffness carbon fibers are higher than glass and aramid fibers.(2)



2.2. Matrix

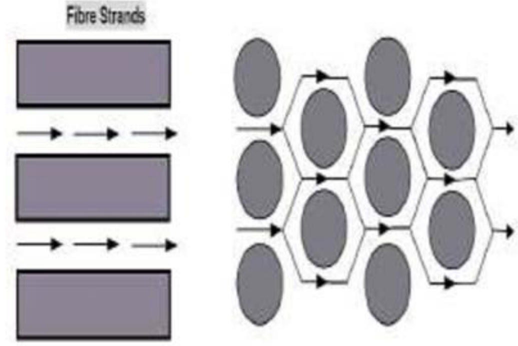
Polymer used as matrix in composites is also known resin. The function of polymer matrices are

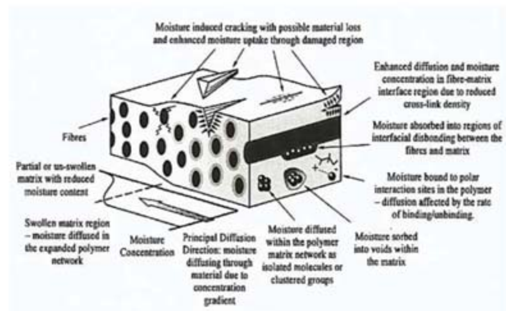
1. To help in distributing or transferring loads.
2. To assist in controlling the chemical properties of composites.
3. To carry inter laminar shear.
4. To hold all reinforcement together as a binder, thus allowing the applied force to be transmitted to the reinforcement
5. To protect and prevent the fibers from mechanical damage due to crack propagation within the material during fabrication and in the finished component.

There are two major types of polymers used as matrices in composite, namely thermo plastic and thermo setting polymers when composites were introduced in the 1940s. Thermo setting polymers such as polyester, Epoxy and Phenolic were mainly used.

2.3. Hygro-Thermal Medium

Improved properties of fibrous composites have led to enhanced its use in different important Applications. These composites are affected by heat and moisture during operation under severe Environmental conditions. They absorb moisture and expanded gradually with time. These will in turn reduce the failure time. Since the composites contain epoxy matrix and fibrous material, the moisture is absorbed by epoxy, and no moisture will be absorbed by fibers as Shown in figures





2.4. Mechanical Properties influenced by hygro-Thermal Medium

Paepegem and Degrieck [5] had investigated the bending fatigue. The materials used are plain woven glass/epoxy specimens in two configurations: [#0º] and [#45º]. Experiments show that these two specimen types, although being made of the same material, have a quite different damage behavior and that the stiffness degradation follows a different path. Next a numerical model is presented which allows one to describe the degradation behavior of the composite specimen during its fatigue life. This model has been implemented in a mathematical software package and proves to be a useful tool to study the fatigue degradation behavior of composite materials.

Paepegem and Degrieck [6] presented the fatigue behavior of plain woven glass/epoxy composites. Bending fatigue tests were used to yield the experimental data. With the aid of an advanced phase-shift shadow Moiré technique, an out-of-plane displacement profile during fatigue life of the composite specimens was recorded at a number of intervals, as well as the bending force history. A residual stiffness model which describes the fatigue damage behavior of the composite material was adopted. Next a new finite element approach was developed to implement the fatigue damage model in a commercial finite element code that proves to be capable of simulating the observed experimental results.

Paepegem et al., [7] presented a phenomenological residual stiffness model which predicts the stiffness degradation as well as final failure of the composite component. The reserve to failure has been evaluated by means of a modified use of the Tsai-Wu static failure criterion. The fatigue damage model has been applied to displacement-controlled bending fatigue experiments of plain woven glass/epoxy specimens. The damage and stress (re)distribution, as well as the force-cycle history have been simulated and compared to experimental results. Due to the consistent integration of continuum damage mechanics and the residual stiffness approach, the implementation of the fatigue model in a commercial finite element code has been possible, which allows for an accurate simulation of the successive damage states during fatigue life.

Ganapathi et al., [8] studied static and dynamic characteristics of thick composite laminates exposed to hygrothermal environment, which was studied using a realistic higher-order theory developed recently. The formulation accounts for the nonlinear variation of the in-plane and transverse displacements through the thickness, and abrupt discontinuity in slope of the in plane displacements at any interface. The analysis is carried out employing a C0 QUAD-8 isoperimetric higher-order finite element. It is shown that the shear deformation theory without accounting for the thickness-stretching effect and slope discontinuity in the in-plane displacements may not be adequate for the analysis of fairly thick composite laminates exposed to hygrothermal loading. The significance of retaining various higher-order terms in the present model, in evaluating the deflection, buckling and natural frequency for composite laminates at different moisture concentration and temperature, is brought out through parametric study Differently, the lowest Tg being recorded for samples exposed to up-thermal shock after hygrothermal conditioning. Scanning electron micrographs reveal the mode of failure which includes fiber fragmentation, fiber pull-out and fiber matrix debonding.

Papanicolaou et al., [9] aimed to investigate the effect of damage due to hygrothermal fatigue on the mechanical behavior of CFRP (Carbon Fiber Reinforced Polymer) laminates as well as on the skin-core interfacial stress field in sandwich structures having CFRP laminates as core material and aluminum as skin. The above behavior was both experimentally and analytically studied using a model recently developed by the CMG group at University of Patras. Levon Minnetyan [10] investigated the influence of hygrothermal environmental conditions on the load carrying ability and response of composite structures via computational simulation.

An integrated computer code is utilized for the simulation of composite structural degradation under loading. Damage initiation, damage growth, fracture progression, and global structural fracture are included in the simulation.Results demonstrate the significance of hygro-thermal effects on composite structural response, toughness, and durability.

III. APPLICATIONS OF CARBON/ EPOXY COMPOSITES:

Some of the major important areas of Carbon/Epoxy Composite applications Aerospace applications: fuselage, wings, pressure bulk head etc., Wind power generation: blades, casing etc., Marine applications: boats, fish boats etc., Civil construction: building materials etc Telecommunication applications: signal towers, transmitter casings etc., Bio-Medical applications: prostatic body parts etc.,

IV. CHALLENGES AND PROSPECTIVES

1. Composite materials based on polymer matrices are widely used in different industrial sectors such as aerospace, automotive, and civil applications [1]. Because of growing environmental awareness, the use and disposition of composite structures typically produced with synthetic fibers such as glass fibers, have been criticized. The main problem is how to get rid of these materials at the end of their useful life. Today, one of the main research areas is the development of composites reinforced with natural/lignocelluloses fibers.
2. Carbon/Epoxy material structure has more complex mechanical characterization than a metal structure
3. Repairing process of Carbon/Epoxy is Complex as compared to that for Metals
4. Carbon/Epoxy materials do not have the of high combination of strength and fracture toughness compared to metals

5. High cost of fabrication of Carbon/Epoxy composite materials
6. It is not compulsory that Carbon/Epoxy give greater performance in all the properties used for materials selection: corrosion resistance, affordability, formability, join ability, strength and toughness

V. CONCLUSIONS AND FUTURE SCOPE

From various experimentation done by research team it is clear that addition of CNT or nanoclay which in this case is montmorillonite Nanoclay properties of CFRP are showing promising increase and enhancement. As well as for NDT testing the early stage of heating phase is suitable for carbon fiber mapping and that both latter heating phase and cooling phase can be used for impact characterization. Both results under reflection mode and transmission mode illustrate that the detection of impact is mainly based on the carbon structure broken and conductivity change but not the thickness change using eddy current pulsed thermography. Composite papers which are modified, shows better mechanical properties than unmodified. Tensile strength for both modified and unmodified papers first increases then decreases with increase in carbon fiber fraction. As far as the material is concerned, Carbon/Epoxy Composite have been equally investigated; however, epoxy resin is preferred as the matrix material. An effort towards this literature on Carbon/Epoxy mechanical properties in Hygro-Thermal medium will throw some light on researchers and scientists pursuing work on Carbon/Epoxy Composite technology.

REFERENCES

[1] piyoosh thori and pawan Sharma (Dec-2013), An Approach of composite materials inindustrialmachinery:Advantages,disadvantages and Applications.ElSSN:2319-1163/ plSSN:2321-7308.

[2]Barbero,e.j,1998 .Introduction to Composite materials design. Taylor & Francis,Philadelphia.

[3] Gourav Gupta and Ankur Kumar(May-2016) Application And Feature of Composite materials:ISSN:2319-8753.

[4]Dr. Noori Hassoon Mohammed Al-Saadi and Dr.Samheri A.(March-2016) An Experimental investigation of Moisture Effect On Fatigue Behaviour Of Composite materials.ISSN 2055-656X.

[5] W. Van Paepegem and J. Degrieck, (2001), "Fatigue Degradation Modeling of Plain Woven Glass/Epoxy Composites", Composites Part A, 32(10), 1433-1441.

[6] W. Van Paepegem and J. Degrieck, (October 2001), "Finite Element Approach for Modelling Fatigue Damage in Fiber-Reinforced Composite Materials", Composites Part B, 32(7), 575-588

[7] W. Van Paepegem and J. Degrieck, (April 2002), "Coupled Residual Stiffness and Strength Model for Fatigue of Fiber-Reinforced Composite Materials", Composites Science and Technology, 62(5), 687-696.

[8] B.P. Patel, M. Ganapathi and D.P. Makhecha, (2002), "Hygrothermal Effects on the Structural Behavior of Thick Composite Laminates Using Higher-Order Theory", Composite Structures, 56 (2002) 25–34

[9] A. G. Xepapadaki, George C. Papanicolaou1, P. Keramidas, Gabriel Jiga, (2010), "Effect of Hygrothermal Fatigue on the Mechanical Behavior of Polymeric Composite Laminates and Sandwich Structures", Material Plastic, Vol. 47, No.2.

[10] Levon Minnetyan, "Progressive Fracture In Composites Subjected To Hygrothermal Environment", NASA Technical Memorandum 105230, Prepared For the 32rid Structures, Structural Dynamics and Materials Conference Cosponsored by AIAA, ASME, ASCE, AHS.