Effect of Different Environmental Conditions on Moisture Absorption of GFRP Laminates- A Comparative Study

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Abstract- *The designers are in search of materials which withstand the effect of all variety of loading conditions and at the same time at a very competitive price. The composites are complex material and their properties vary as the constituents change in any of its parameters like fiber orientation, stacking sequence, fiber volume fraction or the matrix and the method of fabrication. Hence, in the present paper an effort is made to review the effect of environmental conditions on glass/fiber reinforced composites.*

Keywords- Natural frequency, stiffness, resonance, spring

I. INTRODUCTION

Composite materials are finding applications in many high tech areas like aerospace, automotive, marine, transportation and bridges in civil engineering etc. Composite is a mixture of two or more constituents of fiber and matrix with different physical/chemical properties at the macroscopic or microscopic scale. Fibers are the principal load-carrying constituents while the surrounding matrix helps to keep them in desired location and orientation and also act as a load transfer medium between them. The effect of environmental conditions on GFRP laminates investigated by various researchers.

P. Sampath Rao et.al. [1], investigated the effect on weight and mechanical property of GFRP laminated composites subjected to different environmental conditions.

The Percentage weight gain was determined by,
M= (Weight of specimen – Weight of dry specimen)X100
(Weight of dry specimen)

The researchers carried out the test for different environments such as when exposed in water, salt water and NaOH solution for 0,3,6,9,12,15 & 18 days, and observed that weight gain is maximum in water compared to NaOH & salt water. Further analysis shows that there is significant decrease in tensile strength of GFRP laminates when exposed in these solutions.

Takafumi Kawaguchi et.al. [2], the toughening mechanisms in three types of glass-filled epoxy composites subject to fatigue loading were studied by several different microscopy techniques. The observed toughening mechanisms were then related to the macroscopic fatigue crack propagation behavior. The role of matrix-reinforcement adhesion was systematically investigated. Scanning electron microscopy (SEM) and transmission optical microscopy (OM) studies revealed that toughening mechanisms such as micro-cracking, crack pinning, shear yielding, fiber bridging, and fiber debonding and pull-out were dependent on the surface treatment of the reinforcements as well as the shape of reinforcements. The nature of the toughening mechanisms observed agreed with the fatigue crack propagation behavior predicted by crack tip shielding concepts. Interestingly, matrix shear yielding turned out to be the prevalent toughening mechanism in those mechanisms subjected to moisture exposure. In dry as-molded composites, a careful investigation involving SEM, OM, fluorescent microscopy, and atomic force microscopy (AFM) indicated that the particular micro mechanisms observed were indeed micro cracks and not micro-shear bands as had been suggested by other researchers.

Takafumi Kawaguchi et.al. [3], the fatigue crack propagation behavior of glass-filled epoxy composites with three different types of reinforcements was characterized. Moreover, the underlying mechanisms operating in fatigue were identified using da/dN vs. ΔK curves according to the model proposed by other investigators. The effect of moisture was studied. In particular, the role of adhesion promoters in fatigue crack propagation behavior was determined by treating the glass reinforcements with silane-based adhesion promoters. The fatigue crack propagation behavior with moisture exposure was strongly dependent on the surface treatment of the reinforcements and poor matrix–particle adhesion resulted in better fatigue crack propagation resistance.

An investigation revealed that the specific toughening mechanism contributing to fatigue crack propagation behavior depended on the type of reinforcement and the surface treatment. Glass spheres treated with n-butyltrimethoxysilane exhibited crack tip shielding mechanisms involving shear yielding whereas short glass fiber treated with aminopropyltrimethoxysilane exhibited contact shielding mechanisms involving fiber bridging and wedging due to asperities generated between fracture surfaces. Interestingly, the type of adhesion promoters had a significant influence on the type of toughening mechanism observed.

Jang-Kyo Kim et.al. [4], the moisture diffusion and barrier characteristics of epoxy-based nanocomposites containing organoclay are investigated. The effects of different types of organoclay modified with different compatibilizers, including a quaternary alkylamine-modified montmorillonite (KH-MT), a quaternary ammonium-modified montmorillonite (Cloisite 20A) and an octadecylamine-modified montmorillonite (I30P), on moisture barrier and thermo mechanical properties are specifically studied. The moisture absorption and diffusion behaviours were different depending on the type of organoclay: the moisture absorption rates of the Cloisite and I30P systems were much lower with associated lower diffusivity than the KH-MT system or the neat epoxy, due to the higher interlayer distance and more uniform distribution of organoclays, which in turn allowed a longer diffusion path of water molecules in the nanocomposite. The moisture diffusivity of nanocomposites decreased with increasing clay content for all organoclays. The corresponding moisture permeability was lower in the order of nanocomposites containing I30P, Cloisite and KH-MT organoclays.

The moisture permeability showed a systematic decrease with increasing clay content, which agrees well with the prediction based on the simple tortuous path model. Increase in effective penetration path due to the very large aspect ratio of the silicate layers was responsible for the reduced moisture permeability. The glass transition temperature was much higher for the I30P nanocomposite than the neat epoxy resin, whether dry or wet condition. It decreased linearly with increasing moisture content. The CTE decreased with increasing clay content for all conditions studied.

C.P.L. Chow et.al. [5], in this study, sisal fibre reinforced polypropylene (SF/PP) composites were prepared by injection moulding using a pre-coating technique that we have developed earlier. The composite specimens were subjected to hot water immersion treatment at 90 °C for different durations. The effects of the immersion treatment on the tensile and impact fracture characteristics were investigated. The apparent weight gain and weight loss curves were constructed. From the weight loss curves for the individual composites, the weight loss within the induction period was negligible. At the end of the induction period, the weight loss increased sharply. Due to the weight loss and the formation of additional moisture diffusion paths as immersion treatment proceeds, the apparent weight gain was non-Fickian.

Both the tensile modulus and tensile strength of the SF/PP composites decreased continuously with increasing water immersion time. On the contrary, the Izod impact strength increased initially with immersion treatment. After reaching the maximum impact strength, the impact strength was found to decrease with further increase in immersion time. These contradictory behaviours between the tensile and impact properties were explained by the plasticization of the SF/PP interface and the swelling of the reinforcing sisal fibres.

W. Wang et.al. [6], Moisture absorption of natural fiber plastic composites is one major concern in their outdoor applications. Traditionally diffusion theory is applied to understand the mechanism of moisture absorption; but it cannot address the relationship between the microscopic structure-infinite 3D-network and the moisture absorption. The purpose of this study is to introduce percolation theory into this field and conduct some preliminary work. First, two new concepts, accessible fiber ratio and diffusion-permeability coefficient, were defined; secondly, a percolation model was developed to estimate the critical accessible fiber ratio; finally, the moisture absorption and electrical conduction behavior of composites with different fiber loadings were investigated.

At high fiber loading when accessible fiber ratio is high, the diffusion process is the dominant mechanism; while at low fiber loading close to and below percolation threshold, percolation is the dominant mechanism. The over-estimate of accessible fiber ratio led to discrepancies between the observed and model estimates.

Selvum Pillay et.al. [7], the present work addresses the effects of moisture and ultraviolet (UV) exposure on the static and dynamic mechanical properties of carbon fabric reinforced, thermoplastic polyamide 6 matrix panels processed using VARTM. Moisture diffusion and hygrothermal aging in bismaleimide matrix carbon was applied to evaluate the moisture uptake for the C/PA6, fully immersed in distilled water at 100 °C. SEM results show that moisture exposure result in surface micro-cracks compromise of the fiber–matrix interface.

The flexural strength is lowered by 45%, after exposure to moisture at 100 °C. UV exposure up to 600 h causes yellowing of the samples and an increase in crystallinity from 40% to 44%.

Y.Z. Wan et.al. [8] In this work, bacterial cellulose (BC) nanofibres were used as the biodegradable reinforcement. The BC nanofibres were incorporated in the starch plasticised with glycerol via a solution impregnation method. Tensile properties of the BC/starch biocomposites were tested and compared with those of the unreinforced starch. Moisture absorption of the biocomposites under 75% RH at 25 °C was analysed. The kinetics of sorption–diffusion process was investigated and typical kinetic parameters D, k, and M∞ were determined. Additionally, the BC/starch biocomposite (15.1 wt.% BC) and starch were submitted to biodegradation by soil burial experiments in perforated boxes. Tensile strength after exposure to moisture and microorganism attacks was measured.

It is found that the moisture sorption mechanism in the BC starch biocomposites follows a Fickan diffusion mode. The presence of BC nanofibres improves the tensile properties and the resistance to moisture and microorganism attacks.

Z.D. Xiang et.al. [9], The moisture absorption of a carbon-fibre-reinforced polymer composite, with a bismaleimide-modified epoxy resin matrix, was studied under constant hygrothermal conditions and under a series of thermal-spike conditions, in an attempt to understand the so-called enhanced moisture absorption phenomenon. The spiking temperatures ranged from 100 °C to 160 °C, which are above and below the glass-transition temperature (Tg) of the matrix in the 'wet' laminate. An enhancement to the moisture absorption was observed which depended strongly on the spiking temperature. For the laminate conditioned under 96% relative humidity (RH) and 45 °C, rapid enhancement occurred at approximately 110 °C, and for the laminates conditioned at 75% RH and 45 °C, it occurred at approximately 120 °C. Laminates with different configurations were also studied, which allowed assessment of the effects of thermal residual stresses and stress distributions induced by fibre configuration. It was observed that laminate configuration had a profound effect in determining the moisture absorption characteristics under thermal-spike conditions.

The glass transition temperature of the matrix was further reduced by the enhanced moisture absorption. A higher spiking temperature was observed to cause a larger reduction in Tg, even though it may not induce a stronger enhancement in moisture absorption. It was thus suggested that the reduction in Tg depended on the degree of plasticization and hydrolysis of the polymer matrix. The latter was probably more important when the laminates were conditioned under high humidity environments and spiked at high temperatures.

T. Glaskova et.al. [10], the peculiarities of moisture absorption of epoxy–nanoclay composite are estimated in the paper. Second Fick's law of diffusion was used to predict moisture diffusivity and equilibrium moisture content using accelerated analytical procedure. It was experimentally confirmed that sorption process in NC passes more slowly than in pure epoxy resin, for the highest filler content diffusivity reduces about half of diffusivity as for epoxy resin. The deviation from mixture rule was obtained for the equilibrium moisture content and the estimation of inter phase content in composite was undertaken. It was determined that the higher content of interphase consistently leads to greater moisture absorption.

Yihui Pan et.al. [11], developed a constitutive model of short natural fiber reinforced composites (SNFRCs), with the consideration of nonlinear constitutive relation and large deformation induced by moisture absorption. This model accounts for the processes of moisture absorption and mechanical degradation in SNFRCs by a single internal variable, since these two thermodynamic processes are found correlated with each other. This internal variable is introduced to modify the Neo-Hookean model, from which the evolution equations of these two processes are derived by specifying a suitable energy dissipation function. Both the moisture absorption and the mechanical degradation are shown sensitive to the fiber content and could be enlarged with exposure time in a humid environment.

The theoretical predictions of the evolution of the internal variable are compared with experimental results of short sisal fiber reinforced polypropylene and it is shown a good agreement between them. Moreover, this model is used to give a reasonable prediction of the degraded Young's modulus of SNFRCs.

Yihui Pan et.al.[12], the method of hybridization by adding synthetic hydrophobic fibers into the natural fiber reinforced composites is used to reduce moisture absorption and mechanical degradation of the composites. A linear constitutive model for this hybrid fiber composite is proposed to study the effect of hybridization on the mechanical properties of the composites. The natural fibers absorb large amounts of water when exposed to the humid environment, which causes remarkable modulus loss and interface damage between natural fiber and matrix. Based on the Rule of Hybrid Mixture (RoHM), the overall mechanical properties of the hybrid short fiber reinforced composites are obtained, in which one internal variable is introduced to reflect both the modulus loss of natural fibers and the interface damage.

From the thermodynamics modeling, the evolutions of moisture absorption and mechanical degradation are derived. Compared with the experimental results of hemp and glass fiber reinforced composites, a good agreement is obtained.

S. Saravanan et.al. [13], in this study, mesoporous silica–cyclic olefin copolymer nanocomposite films were fabricated by solution casting. With an increase in silica loading, the stiffness of the matrix increased. The nanocomposite film shows increased strain to failure with moisture after aging by matrix plasticization. The storage modulus and loss factor for samples with silica content show better results compared with pristine polymer, as indicated by dynamic mechanical analysis. The interaction between filler–polymer chain exhibit hydrophobicity compared to the neat polymer. Water absorption studies at room temperature and near the Tg of the polymer (~64 °C) were carried out. The nanocomposites up to 4 wt% filler reduces the water diffusion by forming hydrogen and chemical bonding.

The result by calcium degradation test method for moisture permeability and Schottky structured organic device encapsulation under weathering condition confirms the effective reinforcement effect of silica particles in the matrix.

II. CONCLUSION

Based on the comparative study made [1-13], the following conclusions are drawn

- The review showed that due to moisture absorption there is a remarkable reduction in mechanical strength (tensile modulus) of GFRP Composites which are exposed to different water salinity and at room temperature for different exposure time.
- The Composite material moisture absorption is more.
- The presence of moisture or water particles in the matrix, fiber-matrix interface of composite materials attack on the glass fibres, all these are the reason for the reduction of mechanical properties.

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