Asian Review of Mechanical Engineering (ARME)
Vol.2.No.1 2014 pp 19-23.
available at: www.goniv.com
Paper Received :08-03-2014
Paper Accepted:22-03-2013
Paper Reviewed by: 1. R. Venkatakrishnan 2. R. Marimuthu
Editor : Prof. P.Muthukumar

MODE-I INTERLAMINAR FRACTURE BEHAVIOUR ANALYSIS OF FRP COMPOSITES UNDER MOISTURE AGING CONDITION

Prasanth C [#1],Saavan Ravindranath[#2], A.Samraj[#3],Pandian.M[#4],T.Manikandan [#5]
Aeronautical EngineeringDepartment,
Jeppiaar Engineering College,
Chennai.
Prasanth31092@gmail.com

ABSTRACT

The objective of the research endeavour is to characterize the fracture toughness behaviour of glass-epoxy and glass-carbon hybrid fiber reinforced composites under adverse moisture aging conditions. The Double Cantilever Beam (DCB) test is conducted to predict the inter laminar fracture toughness of both normal and exposed specimens at different moisture absorption characteristics on exposure to different solutions of varying concentration.Mode-I Interlaminar Fracture Toughness G_{IC} and strain energy release rate G_I of FRP composites under moisture absorption conditions. The moisture ageing of FRP composites under acidic and basic solutions of three different concentrations (0.01,0.05 and 0.1N) are exposed to 240 hours and 480 hours. The results also indicate that moisture absorption rate is more in glass-carbon hybrid composites than in glass-epoxy composites. After the 480 hours of ageing the energy release rate of aged glass-carbon hybrid composite decreases 10-15% to that of aged glass epoxy composite.

Keywords: DCB, energy release rate, FRP composites, acidic and basic solution, aging, energy release rate decreses

1. INTRODUCTION

The role of advanced composites in the fabrication and design of Aircraft components have been an inevitable one, off late. GFRP and CFRP Composites have manifested a trait of high durability against adverse environmental conditions and maintain their mechanical properties. To exemplify such scenarios, the body parts of ice terrain vehicles, pipelines carrying oil through desserts, underwater cables in the sea bed for telecommunication and so on. However, on prolonged exposures they show an ineptness towards flaw initiation and propagation and it is a characterised as the material's fracture toughness[8],[9],[10].The major causes for fracture in a material may be attributed to the presence of microscopic discontinuities or imperfections[17] in the material. Quasi-static mechanical properties of Fiber reinforced polymer composites are profoundly affected by environmental factors such as moisture and temperature.Absorption of moisture tends because plasticization and hence a reduction in the glass transition temperature[18]. Owing to the diminishment of the glass transition temperature T of the resin due to moisture absorption, the resin is considerably compromised. Diffusion is the root cause of moisture invasion into composite materials[1]. Solution diffuses directly into the matrix majorly and only a slight proportion into the fibers. Initially the molecules are absorbed at the fiber/matrix interface and in time it diffuse into the resin. Micro cracks and voids play a major role in both transportation and storage of the solution molecules[15].

The mode-I interlaminar fracture toughness test was carried out using Double Cantilever Beam (DCB)[4] technique employing UTM. Two types of composites namely glass epoxy and glass carbon hybrid composites and two types of solutions one of an acidic and of a basic nature, at three different concentrations (0.01N, 0.05N and 0.1N) were used. The tests were carried out in an unaged as well as aged condition [11] of two intervals (240 hours and 480hours). The energy release rate G_I for different conditions were determined and compared. Thus the paper highlights the influence of moisture in glass-epoxy and glass-carbon hybrid composite specimens under different aging conditions. Hence for this reason it has become quite vital to determine the interlaminar fracture behaviour of laminated composites [6] from a design perspective. The data on the repercussions of long term exposure of composites to moisture levels[7] compared to service environments has been quite a remote one.

2. EXPERIMENTAL WORK

A.Material geometry:

The fabrication of GFRP composite laminates were carried out by hand lay-up process followed by compression moulding where each plate composed of 12 plies of unidirectional glass fiber with epoxy LY556 resin and hardner HY951 in the ratio of 10:1. The Teflon tape (20µm) of length 55mm was placed at the midplane of the composite plate. According to ASTM D5528 the specimens of dimensions 130mm x 25mm x 3-3.5mm were cut from the plate by diamond saw cutting tool. The fiber volume fraction of the corresponding specimens of 54% were determined by burn-off method.... composite materials are regarded important parameters in the study of composites. The matrix volume fraction and fiber volume fraction were determined by the matrix digestion method.

The geometry of the specimen with aluminium entapped as shown in fig 1. The curing of resin was carried out at room temperature. The specimens were prepared by hand lay-up process followed by compression moulding. From plates measuring 300x300mm with a thickness of 3 to 3.5mm specimen were cut into sizes as per ASTM standard of 130mm x 25mm of thickness varying from 3 to 3.5mm.

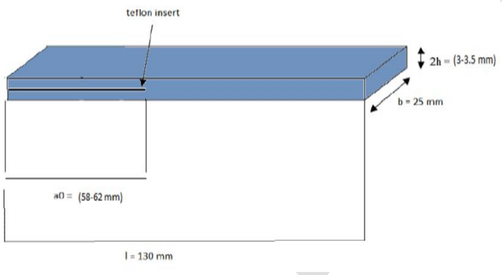

Figure 1: Material geometry of FRP composite for DCB test

B. Environmental condition:

Before the specimen was subjected to moisture conditions for ageing a pre moisture test was carried out in order to drive out any moisture absorbed during the preparation of the specimens. The Specimens are immersed in concentrated solution of H_2So_4 and NaOH of three different normalities (0.1N, 0.01N, 0.05N). Ageing took place for a period of 240 hours and 480 hours at room temperature. According to ASTM D5529 the specimens were concealed by aluminium foil at the four corners for the preventions of high moisture absorption at the edges.

Fig ure2a: specimens immersed in H_2So_4 solution of different concentration for aging

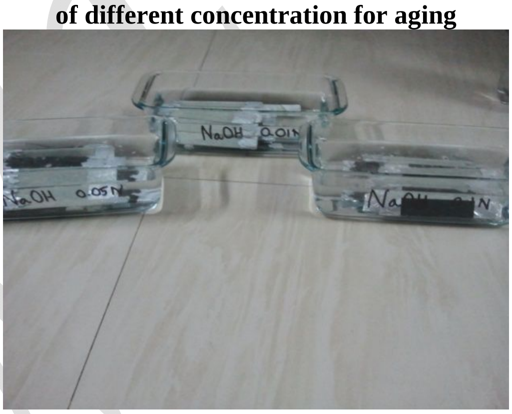

Figure 2b : specimens immersed in NaOH solution of different concentration for aging

C. Test method:

Mode I interlaminar fracture toughness of unidirectional fiber- reinforced polymer matrix composites was conducted as prescribed in ASTM D5528-01 standard. Piano hinges attached to the DCB specimen were fixed to the universal testing machine. The constant displacement rate of universal testing machine used for testing was 2.5 mm/min. The applied load vs opening displacement is recorded on a XY recorder in instaneous delamination front locations are marked on the chart at intervals of delamination growth. The mode-I interlaminar fracture toughness is calculated by using the modified beam theory.

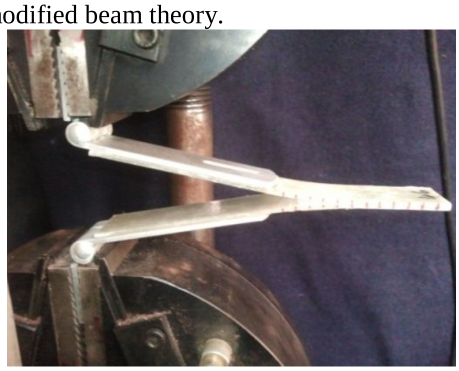

Figure 3a : crack propagation in glass-epoxy composite under DCB test

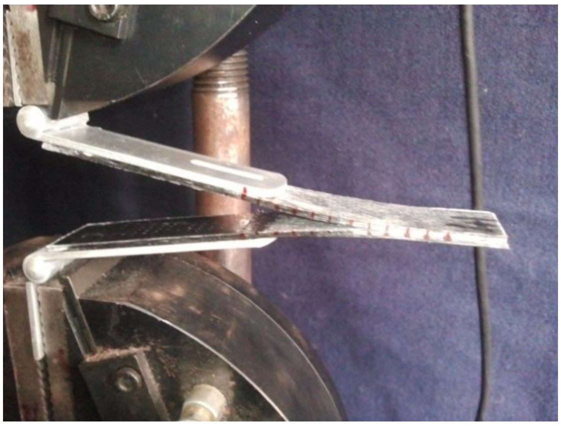

Figure 3b : crack propagation in glass-carbon hybrid composite under DCB test

3. RESULT AND DISCUSSION

The absorption rate of acid the (H_2SO_4) and base (NaOH) solution at different concentration are measured under two different ageing periods of 240 hours and 480 hours. The Change in weight percentage of the specimen after moisture absorption, under the various condition of ageing are as shown.

Table 4a:Percentage of weight change in glass epoxy composite (GFRP) due to moisture aging

INTERVALS	1ST INTERVAL	2NDINTERVAL
H_2SO_4(0.01N)	0.033%	0.960%
H_2SO_4(0.05N)	0.756%	1.360%
H_2SO_4(0.1N)	0.987%	1.674%
NAOH(0.01N)	0.649%	0.844%
NAOH(0.05N)	0.935%	1.3987%
NAOH(0.1N)	1.059%	1.788%

Table 4b: Percentage of weight change in glass-carbon composite (GCFRP) due to moisture aging

INTERVALS	1ST INTERVAL	2ND INTERVAL
H_2SO_4(0.01N)	0.765%	1.041%
H_2SO_4(0.05N)	1.1518%	1.4286%
H_2SO_4(0.1N)	2.035%	1.852%
NAOH(0.01N)	0.972%	0.972%
NAOH(0.05N)	1.337%	1.967%
NAOH(0.1N)	1.588%	2.595%

From the table it may be concluded that the moisture absorption rate is of an elevated magnitude in the basic solution (NaOH) than in the acidic solution (H_2SO_4) and in addition the moisture absorption rate of hybrid composites (glass-carbon hybrid) is slightly higher than that of glass epoxy composites. Theenergy release rate $(G_I)$is calculated using modified beam theory method.

Energy Release Rate , $G_I = \frac{3}{2}$ – – joules/m^2

The energy release rate (G_I) for the unaged specimen is slightly greater than that of specimens which were moisture aged. The load absorption by glass carbon hybrid specimen is 20-30% is higher than that of the glass-epoxy specimen. The load percentage decreases to 30-40% both in glass epoxy and carbon glass hybrid fibers subjected to different aging conditions, hence the energy release rate decreases to 20-40% of both the specimens in comparison with that of the corresponding unaged specimens.

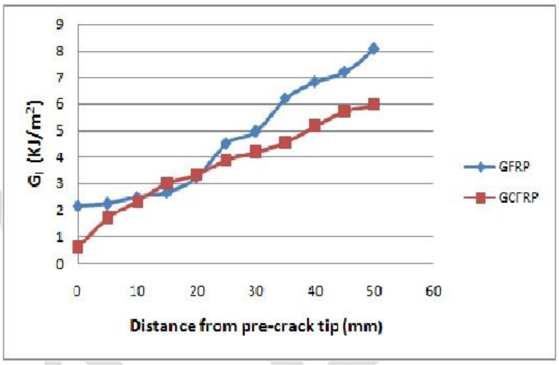

Figure 4 : comparison of unaged glass-epoxy and glass-carbon hybrid composites.

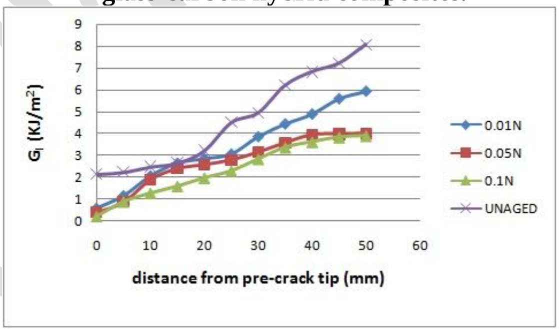

Figure 5: 480 hours aged-glass epoxy composite in H2So4o that of unaged glass-epoxy composite.

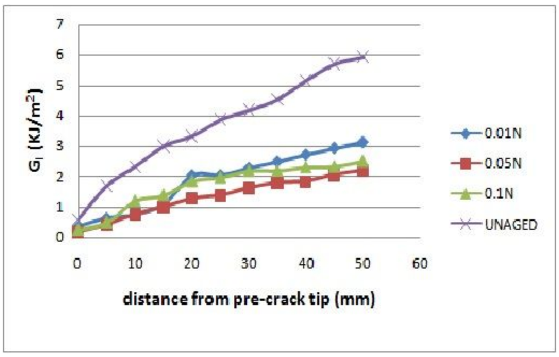

Figure 6: 480 hours aged glass-carbon hybrid composite in H2So4 to that of unaged glass-carbonhybrid composite.

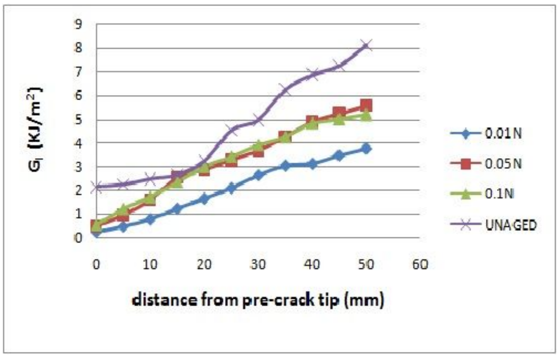

Figure 7: 480 hours aged-glass epoxy composite in NAOH to that of unaged glass-epoxy composite.

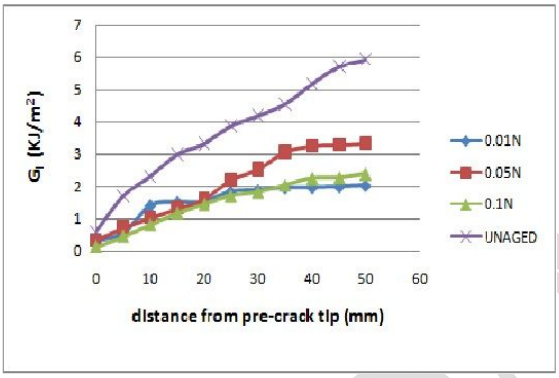

Figure 8: 480 hours aged glass-carbon hybrid composite in NAOH to that of unaged glass-carbonhybrid composite.

At unaged condition the energy release rate of hybrid specimen is 20-30% more than that of glass epoxy composites as evidenced from the above graph .After the first interval energy release rate is only 10-20% greater than that of glass epoxy specimen but that of glass carbon hybrid specimen decreases to 10-15%.Hence it can be concluded that the absorption rate is more in glass-carbon hybrid specimens than that in glass epoxy specimen as shown in the graphs below.

4. CONCLUSION

The unidirectional FRP glass-epoxy and glass-carbon hybrid composites were subjected to moisture ageing conditions of acidic (SO4) and basic(NaOH) solutions, each of three different concentrations (0.01N,0.5N,0.1N).The tests were instrumental in determining the effect of moisture absorption on mode-I fracture behaviour. The following conclusions drawn from the experimental studies are as follows.

1.The energy release rate (G_I) of unaged glass-carbon hybrid composite more when compared to that of unaged glass-epoxy composite.

2.On comparison of the tables 1 & 2 ,the moisture absorption rate is more in glass-carbon hybrid composite than in glass-epoxy composite

3.The energy release rate (G_I) of glass-carbon hybrid composite decreases more due to moisture absorption than that of glass-epoxy

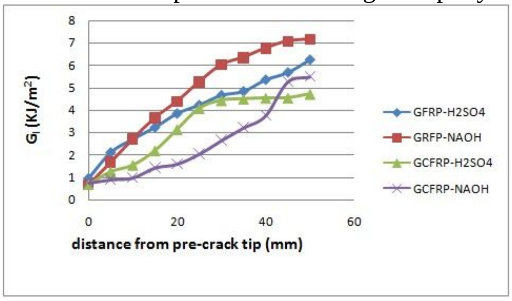

Figure.9: comparison of both composite material aged under high concentration (0.1N) of two different solution after 240hours

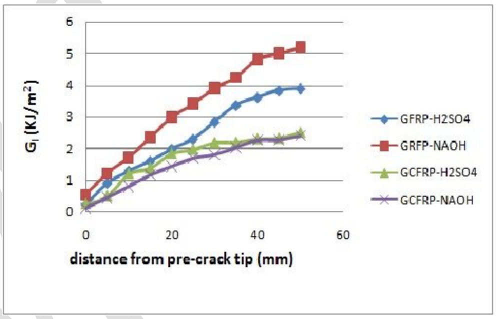

Figure10 : comparison of both composite material aged under high concentration (0.1N) of two different solution after 480hours

4.The moisture absorption of an increased order is seen in the basic solution(NaOH) than in acidic solution (H_2SO_4).

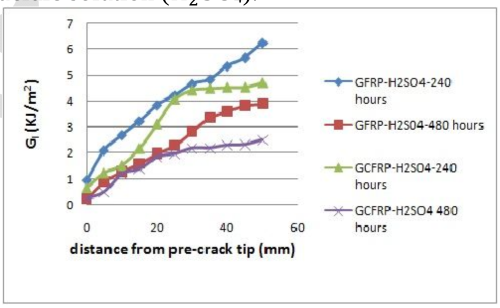

Figure.11 : comparison of both composite material aged under high concentration (0.1N) of H_2So_4 solution after 240 hours and 480hours

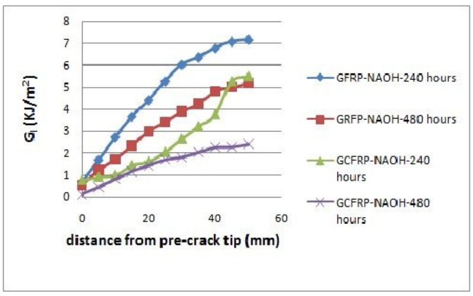

Figure 12: comparison of both composite material aged under high concentration (0.1N) of NAOH solution after 240 hours and 480hours

5.The moisture absorption depends upon the concentration of the solution and hence the moisture absorption rate increases as the concentration increases, irrespective of the solution.

REFERENCES

[1] Shivakumar S, Dr.Shivarudraiah : "Effect of Temperature on the Hygrothermal and Mechanical Behaviour of Glass-Epoxy laminates" *International Journal of Advanced Engineering Technology (2010) 225-231*.

[2] M. Akay, D.F. O'Regan : " Fracture behaviour of glass fiber reinforced polyamide moulding " *Elsevier science limited, polymer testing14 (1995)* 149-162.

[3] A. Haque , M.K. Hossain : "Effect of moisture and temperature on high strain rate behaviour of S2-glass-vinyl Ester Woven Composites*", journal of composite materials, sage publications (2003*).

[4] ASTM D 5528-01 "Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites**".**

[5] M.S. Sham Prasad, C.S. Venkatesha, T. Jayaraju : "Experimental Methods of determining Fracture Toughness of Fiber Reinforced Polymer Composites under Various Loading Conditions", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.13, pp.1263-1275, 2011

[6] A J Brunner, B R K Blackman and P Davies. "A status report on delamination resistance testing of polymer–matrix composites". *Engineering Fracture Mechanics.75: 2779–2794* (2008).

[7] XuJiang ,HenkKolstein, Frans S.K. Bijlaard. "Moisture diffusion in glass–fiber-reinforced polymer composite bridge under hot/wet environment ." *Elsevier science ltd., composites science and technology , part B 45(2013) 407-416*.

[8] Springer GS. "Environmental effects on composite materials", *vol. 1. Lancaster (PA): TechnomicPubnishing Company; 1981*.

[9] Springer GS."Enivormental effects on composite materials", *vol. 2. Lancaster (PA): TechnomicPubnishing Company; 1984*.

[10] Springer GS." Enivormental effects on composite materials", *vol. 3. Lancaster (PA): TechnomicPubnishing Company; 1987*.

[11] Earl JS, Shenoi RA. "Hygrothermal ageing effects on FRP laminate and structural foam materials". *Composites Part A – Appl S 2004;35(11):1237–47*.

[12] Haque A, Mahmood S, Walker L, Jeelani S. "Moisture and temperature induceddegradation in tensile properties of Kevlar graphite epoxy hybrid composites". *J ReinfPlast Composites 1991;10(2):132–145*.

[13] Mouzakis DE, Zoga H, Galiotis C." Accelerated environmental ageing study of polyester/glass fiber reinforced composites (GFRPCs)". *Composites Part B – Eng2008;39(3):467–475*.

[14] J.A.P. Cunhaa, M. L. Costab and M.C. Rezendec: "Study of the hygrothermal effects on the compression strength of carbon tape/epoxy composites" *Latin American Journal of Solids and Structures, 5 (2008) pp 157–170*.

[15] Shen CH, Springer G: " Moisture absorption and desorption of composite materials" *,Journal of Comp Materials, 10, 2-20, 1999.*

[16] P.SampathRao, Dr. M. ManzoorHussain ,R.Kishore : " Moisture Absorption Evolution GFRP Laminates Subjected To Different Environmental Condition" *IOSR Journal of Mechanical and Civil Engineering (2012) 33-38.*

[17] A. K. M. Masud, A. K.M. Kais Bin Zaman, Abdullah-Al-Khaled : "Effect of Environmental On Fracture Toughness of Glass Fiber/Polyester Composite" *Journal of Mechanical Engineering (2007) 38-43*

[18] G. Kotsikos, J.T Evans, A.G. Gibson, J.M. Hale :"Environmentally Enhanced Fatigue Damage in Glass Fibre Reinforced Composites Characterised by Acoustic Emission" *Elsevier Science Ltd (2000) 969-977.*

[19] A. Agarwal, S. Garg, P. K. Rakesh, I.Singh&
B.K. Mishra : "Tensile Behaviour of Glass Fiber Reinforced Plastic Subjected to Different Environmental Condition*" Indian Journal of Engineering & Materials Science (2010) 471-476*.

[20] P.K. Dash ,D.Singh : "Shear Characterisation of Woven Carbon/Epoxy Composites Under Various Adverse Environment*" Department of Aeronautical Engineering, Blackwell publishing Ltd. (2010) 1-11*.