ISSN 2321-807X
Volume 12 Number17
Journal of Advances in chemistry

GFRP - FAILURE CHARACTERISTICS ANALYSIS

A. S. Nandakumar[1], B. T.Sasikumar[2]

[1]Department of Mechanical Engineering, Lord Jegannath College of Engineering and Technology, Nagercoil, Tamilnadu, India, [2]Department of Mechanical Engineering, Lord Jegannath College of Engineering and Technology, Nagercoil, Tamilnadu, India.

drphd88@gmail.com

Abstract

The objective of this paper is to predict the ultimate failure load and also is to characterize the failure modes in GFRP composite coupons using Multi linear regression. IBM SSPS20 version is used to predict the ultimate failure load using Multi linear regression with failure loads as dependent variable and the load range of 10kg each and its corresponding hits as independent variable. The three point bending test was conducted on the GFRP composite coupons till failure of the GFRP composite coupons. Based on the effect of various failure modes the ultimate failures of the specimen were also predicted by means of multi linear regression method.

Keywords

Glass Fiber reinforced polymer coupon, Failure mode characterization, Multi linear regression

INTRODUCTION

Acoustic emission technique is one of the frequently adopted practical methods for ensuring the integrity of the FRP composite structure. For the evaluation of the structural integrity of FRP composites, the key AE parameters are in the form of amplitude, hits, energy and duration. The mode of failures in FRP composites are matrix cracking, fiber fracture, fiber-matrix de-bounding, de-lamination and fiber pullout. Multi regression analysis is one of the most powerful statistical tools widely used to determine the goodness fit of the data and accuracy of the model. In multi regression analysis, five steps has to be followed are model building, model adequacy, model assumptions like residual tests and diagnostic plots, potential modeling problems and solutions and model validation.

EXPERIMENTAL WORK

Fabrication of GFRP Composite Flexural Coupons.

GFRP composite laminate is fabricated by hand-lay-up using a E-glass woven glass fiber of average thickness 0.28mm. The laminate plate is fabricated by hand-lay-up method with seven layers using LY556 epoxy and hardener HY951 of dimensions 80x200x2.3mm. The laminate is then compressed in a compression molding machine with a compression pressure of 30kg/cm^2 in order to remove the excess resin from the laminate. The laminate is cured for a period of 24 hour. Eight flexural coupons are cut from the lamina laminate of dimension 80x25x2.3mm as per ASTM D790 [13] using a diamond cutter to avoid any structural degradation.Fig.1Shows the GFRP flexural coupons.

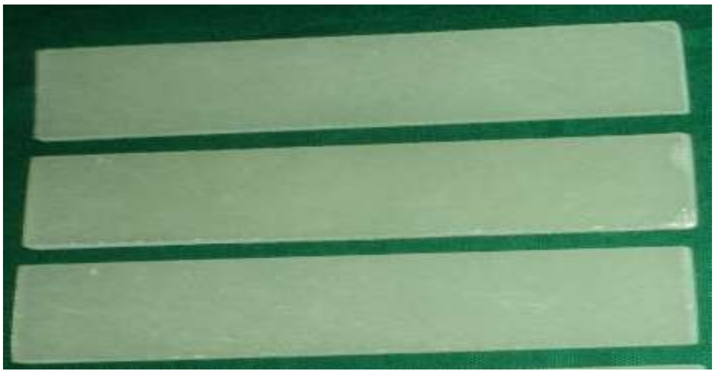

Fig.1. Flexural GFRP composite Coupons.

Flexural testing procedure

The flexural loading using a 100 KN Universal testing machine with data acquisition system. The test coupons were loaded with a three point bending as per ASTM D 790 [13] with a supporting span of 60mm apart as in fig-4 were loaded at the middle of the coupon with cross head motion of 2.4mm/min in a 10 ton capacity testing machine till the coupons fail and the corresponding AE signals are recorded. This is repeated for all the eight coupons.

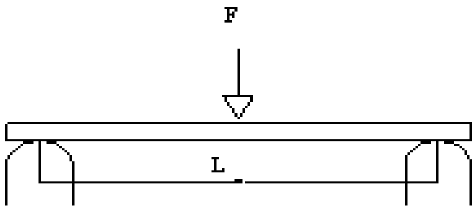

Fig.2. Schematic diagram of three point bending as per ASTM D 790

RESULT AND DISCUSSION

In FRP composites, the primary failure modes are matrix cracking, fiber breakage and de-lamination. Among the three failure modes, the least and most damaging failure modes are the matrix cracking and fiber breakage. The matrix cracking occur throughout the cycle while the de-lamination takes place due to shearing of the lamina. The breaking of fiber occurs due to the interfacial de-bonding of matrix from the fiber, which leads to uneven distribution of load to the fiber.

BW*, (Kg)	CP+ - I	CP - II	CP - III
0-10	565	415	1249
10-20	1953	2170	1445
20-30	423	420	431
30-40	418	426	450
40-50	552	548	487
50-60	460	464	469
60-70	463	440	428
70-80	267	210	131
FL, Kg	75	74.2	72.5

Table. 1. AE hits for each bandwidth for three coupons (* BW- Bandwidth. +CP- Coupons)

The AE parameter like amplitude duration and energy are recorded till coupon fails and corresponding data are segregated as hits due to matrix cracking, fiber breakage and de-lamination for each bandwidth of 10 kg each. Table –I shows the total AE hits recorded on each bandwidth for three coupons. From table-1, and from the fig- 5 it is seen that at the initial bandwidth of 0-10kg where the number of hits is less for matrix cracking. Fiber breakage has more load bearing capacity than with more number of hits for matrix cracking and fiber breakage when compared, where the failure load is 75 kg and 72.5 kg respectively. De-lamination also plays a vital role in the earlier failure of the coupon. The number of de-lamination hits in the initial in the intermediate load range also plays a vital role is the low load bearing capacity of the coupon.

Prediction of failure load using Multi-linear regression

IBM SSPS 20 Version software is used for predicting the ultimate failure load. For the analysis, the variables dependent and independent variables are the ultimate failure load of the coupons and hits in the various bandwidths for matrix cracking, fiber breakage and de-lamination respectively. The table-2 shows the correlation coefficient and coefficient of determination for the eight coupons and the corresponding predicted failure load. The table-3 shows the percentage of error for the predicted failure load with respect to actual failure load.

Sl.no	Specimen	R	R2	Predicted failure load(Kg)
1	Sp-I	0.999	0.998	71.3
2	Sp-II	0.828	0.686	70.83
3	Sp-III	0.946	0.895	70.99

Table: 2. Regression analysis for predicted failure load

Sl.no	Specimen	Actual failure load	Predicted failure load	% of error
1	Sp-I	75	71.3	-5.189
2	Sp-II	74.2	70.83	-4.757
3	Sp-III	72.5	70.99	-2.127

Table: 3. Regression analysis for percentage of error between the predicted and actual failure load

Conclusion

The experimental results clearly states that less fiber failure and early stage of loading will widely affect the ultimate failure from prediction for reducing the percentage of error will be obtained by more number of coupons.

REFERENCES

[1] NatAtivitavas, Thanyawat Pothisiri and Timothy J. Fowlwer. Identification of fiber-reinforced plastic failure Mechanism from acoustic emission data using Neural Network-Journal of composite materials, vol.40. No.3, 2006.

[2] PasiAlander, Lippo V.J. Lassila, Arzu Tezvergil, Pekka.K. Vallittu. Acoustic emission analysis of

fiber reinforced composite in Flexural testing, Dental Materials vol.20, pp 305-312, (2004).

[3]S.Rajendraboopathy,T.Sasikumar,K.M.Usha, S.Vasudev. Failure strength prediction of unidirectional tensile coupons using acoustic emission peak amplitude and energy parameter with artificial neural networks, Composites science and technology Feb10 2009.

[4]S.Rajendraboopathy,T.Sasikumar, ,K.M.Usha, S.Vasudev. Artificial neural network a tool for Predicting failure strength of composite tensile coupons using acoustic emission technique, Int. J. Adv. Manufacturing technology, Dec. 2008, Open access Springer link.com

[5] Edward C. Fatzinger Jr, Eric V.K. Hill. Low proof load prediction of ultimate loads of fiber/Glass/ Epoxy resin I- Beams using acoustic emission, Journal of testing and evaluation, Vol.33, No.5 Sep 2005.

[6] Thomas M. Ely, and Eric V.K Hill. Longitudinal splitting and fiber breakage characterization in graphite epoxy using acoustic emission data, Material evaluation/, page 228-294, Feb1995.

[7] James L.walker and Eric V.K. Hill. Acoustic emission of testing of spheres and other pressure vessels, Acoustic emission testing Journal of Engineering Failure analysis.

[8] The steps to follow in a multiple regression analysis, Theresa Hoang Diem Ngo, Lapuente. Statistics and data analysis, SAS Global Forum, pp. 333-339, 2012.

[9] Edward Thomas. Advanced regression analysis, 2009 ed.

[10]J.T.Lin, T. Bhattacharyya, V. Keeman. Multiple regression and neural network analysis in composite machining, J. Composites science and technology. vol 63, pp 539-548, 2003.

[11]James L. Walker, Eric V.K. Hill. Back, propagation neural network for Predicting ultimate strength of unidirectional graphite/ epoxy tensile specimen. Advanced performance material. vol.3, pp 75-83, 1996.

[12] Marcus E. Fisher and Eric V.K. Hill,. Neural network burst pressure prediction in fiber glass epoxy pressure vessel using acoustic emission, J.Materialevaluation,Vol.56,pp.131401.Dec1998.

[13]ASTM D -790-03 Standard test methods for flexural properties of an reinforced and reinforced plastics and electrical insulating materials.