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NUMERICAL ANALYSIS OF TENSILE MECHANICAL PROPERTY OF GLASS FIBER REINFORCED EPOXY

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Abstract— **In this paper a study has been carried out to find the characteristic relation between experimental and numerical analysis of tensile properties of glass fiber reinforced epoxy composite materials, which are subjected last before to tensile test using the universal testing machine. The numerical results obtained by finite element analysis were compared with available experimental data in literature for the tensile strength. The comparison shows that the results of tensile strength are in agreement with available experimental data published in literature. It was confirmed and enhancing validity of tensile properties of experimentally tested composite materials.**

Keywords: **Glass Fiber, Stress Strain Relationship, mechanical properties, finite element analysis.**

I. INTRODUCTION

The composite materials has widely developed in last decades to obtain excellent properties such as decrease the weight, stiffness and offer better mechanical properties for using in various application [1].

The content of engineering composite materials is continuous fibres of glass, or carbon, reinforcing an epoxy polymeric matrix. When the epoxy polymerized, that makes it an amorphous and an extremely cross-linked material. The resultant in microstructure of epoxy polymer is a many beneficial properties to the composite materials as high modulus and failure strength, low creep, etc., but else conducts to an unwanted property in that it is comparatively brittle. These reverse fractures properties could be affect the overall tensile and fracture performance of the FRP composites. The failure of the tensile in laminated composite materials is a quite prevalent failure mode in

the most of the fiber reinforced polymer (FRP). Usually, the tensile failure is compensated over designed to lead
an increase in the weight. The investigation of tensile failure is an important for composite material laminate design [2].

The glass fibers are the mostly applying as reinforced fibers for polymeric matrix composites (PMC). The major advantages glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties. There are two types of glass fibers used in the fiber reinforced plastics which are E-glass and S-glass. The E-glass is widely applied in the fiber reinforced plastic because it has advantage such as the lowest cost of all commercially available reinforcing fibers. The forms of glass fibers are a continuous strand roving, chopped strands and woven roving. The average of glass fiber tensile strength could overtake 3.45 N/mm2. The glass fiber surface damage and presence of water could be reduction of tensile strength.

The mechanical properties of fiber reinforced composites are based on the constituent materials properties which are type, quantity, fiber distribution, fiber orientation, and void content. Moreover those properties, the nature of interfaces bonds and the ways of load transmit at the interphase. In this present paper, the tensile, flexure, impact and Brinell tests were implemented and their performances were estimated [3]

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II. LITERATURE REVIEW

The analysis of experimental results shows that high strain rates have a significant effect on the properties of unidirectional GFRP composite. The most important of this are: the behaviour of material under quasi-static and dynamic loading conditions is linear elastic up to the failure and its character does not change;

To determine mechanical properties and ultimate caring capacity six specimens were tested to failure at quasi-static strain rate. The tests showed linear elastic behaviour and brittle-like type fracture for the unidirectional composite material accompanying instant multiple failures with [4]. Typical strain-stress curve of experimental results is represented in Figure (7) in red colour.

The glass fibre reinforced epoxy composite was manufactured into six different parts each having ratios of glass fibre to epoxy resin as 0:100, 20:80, 40:60, 60:40, 80:20, 100:0 respectively and were compared for ultimate tensile strength, impact strength and flexural strength of the material by conducting experiment such as tensile test, flexural test and impact test. The tensile strength results show higher tensile strength with the percentages increase in glass fiber [5].

Al-Mosawi, A. I. (2009) was et all discussed about reinforcing by fibers this property will be improved greatly, where the fibers will withstand the maximum part of loads and by consequence will raise the strength of composite material. The tensile strength will be increased as the fiber percentage addition increased, where these fibers will be distributed on large area in the resin [6].

M. S. EL-Wazery, M. I. EL-Elamy, and S. H. Zoalfakar(2017) was et all discussed about E-glass fiber with random oriented reinforced polymer composite was developed by hand lay-up technique with varying fiber percentages (15%, 30%, 45%, and 60% by weight percentage). The influence of glass fiber percentage on the mechanical properties such as tensile strength, bending strength and impact strength was investigated. Hardness of composites was evaluated by using Brinell hardness tester. The results showed remarkable improvement in the mechanical properties of the fabricated composite with an increasing in the glass fiber contents. Tensile strength varies from 28.25 MPa to 78.83 MPa, flexural strength varies from 44.65 MPa to 119.23 MPa and impact energy at room temperature varies from 3.50 Joules to 6.50 Joules, as a function of fiber weight fraction. The hardness value will greatly increase from 31.5 BHN to 47 BHN. The best mechanical properties obtained at 60 wt.% of glass fiber of fabricated composites. From various studies shows that Mechanical Behavior of E-Glass and S-Glass fiber reinforced with polyester resin is not studied yet.so in our present work is I, E-glass and S-glass random fiber reinforcement in pol yester resin matrix was produced by hand lay-up technique with varying fiber percentages (15%, 3 0%, 45%, and 60% by weight percent). The tensile, flexure, impact and Brinell hardness tests were carried out and their performances were evaluated [7].

Davallo, M. and Pasdar, H. (2009), Flexural properties of continuous random glass-polyester composites formed by resin transfer moulding (RTM) and hand-lay up (HLU) moulding have been studied to determine the effects of glass content, composite thickness, reinforcement geometry and type of fabrication on damage developed during flexure tests. Flexural parameters derived from the force-deflection data of composites containing 20 % and 30 % continuous random fibre showed mean values of flexural strength and modulus of 84 MPa, 7 GPa, 110 MPa and 10 GPa for the HLU composites (Cx20 and Cx30 test groups), respectively and similarly, the mean values of flexural strength and modulus of 96 MPa, 7.6 GPa, 120 MPa and 11 GPa for the RTM composites (Cx20 and Cx30 test groups), respectively [8].

Estabraq T. Abdulla(2013) was et all discussed about In this study two commercial types of reinforced glass fibers were studied: chopped and 0/90 fiber glass composted with unsaturated polyester resin. The composites were prepared by hand lay-up method in three layers. The flexure properties were studied by using three-point bending test. The results showed that pure unsaturated polyester UPE is fractured when it reach the maximum point. Different behavior was shown for the fiber/polyester composite depending on the type of the fiber [9].

III. NUMERICAL PROCEDURE

Typical example of quasi-static test specimens with identical physical and mechanical properties E-glass/epoxy 5-ply ([05] - unidirectional) laminate panel was manufactured using vacuum bag forming from E-glass pre-preg with epoxy matrix curing at the high temperature in oven. The nominal fibre volume fraction V_f was about 60%. The prepreg material was unidirectional E-glass SP Systems SE84LV/EGL/300/400/37 type. The panel sizes after trimming was rectangular 600 x 500 mm. The unidirectional samples of size 250 mm lengths, 15 mm width, 1.2 mm thickness were then cut from the plate using a high-speed circular diamond saw with water-cooled blade. Specimen dimensions are shown in Fig.1 and conditions for quasi-static tests were chosen according to the ISO Standard, [7].

A. Material Modelling

The composite material selection was E-glass/Epoxy reinforced composite material with the volume of fraction 60%. Tensile stiffness of laminates applied in number of six test specimens was estimated at the thickness 1.2 mm. these specimens were designed according to the ASTM standard D638-14 [10]. where the specimen length half the experimental specimen length were implemented in the experiment (main paper) to apply the constraints on the test specimen in the finite element analysis such as the tensile load along the test specimen on one side and the opposite side of test specimen is a fixed support. The geometry test specimen model was designed by surface design mode in the CATIA V5R20 software and according to the standard dimension of the specimens in the reference [10]. The dimension of these specimens is described in the (figure 1). The geometry of the specimen was imported to the finite element analysis as shown in the (figure 1) to perform the tensile stiffness for the six test specimens. Composite material layup sequence is five ply with thickness for each 0.2 (mm) and the fiber angle 0 ° were used in Finite Element Analysis.

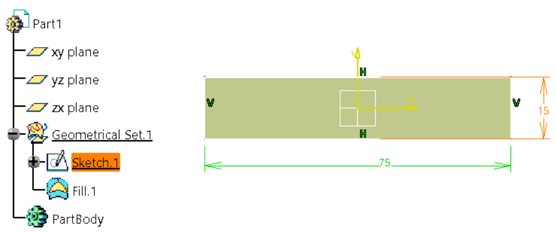


Figure 1. Test Specimen Geometry

B. Finite Element Analysis

Once the geometry of test specimen is imported into the finite element analysis, the composite material properties are defined for the E-glass/Epoxy and applied the proper mesh for the specimen as it describes in the (figure 2). Moreover, the composite layup is defined and the lamina thickness, etc. (Figure 3) demonstrates the ANSYS Composite Pre-post (ACP) composite model with the fiber direction of 0 ° ply.

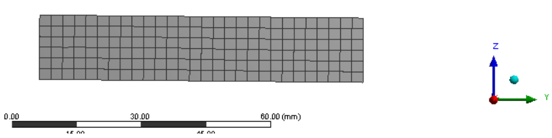


Figure 2. Test Specimen Mesh

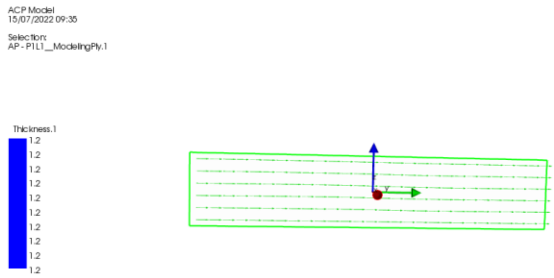


Figure 3. The ACP Composite Model with Fiber Direction (Y axis) Test Specimen

The definition steps were finished of the ACP for laminate composite, then the finite element analysis is utilized to estimate the stress and tensile stiffness, the finite element analysis setting was applied of the specimen. The simulation was implemented for the six test specimens.

IV. RESULTS AND DISCUSSION

In order to estimate the stress and tensile stiffness of laminate, the finite element analysis was performed for the six specimens which was implemented experimental tests up to tensile failure as mentioned in Literature Review [4], these results of maximum tensile stresses demonstrate in (table 1). The simulation results of maximum stress obtained by finite element analysis are described in the (table 2) according to load applied on the same specimens in literature review; the results obtained of maximum stress for the six test specimens are fluctuated from 937.02 (MPa) to 1017.3 (MPa), while the yield stress of the lamina composite is 1035 (MPa) and the average maximum stress for the six test specimens are 982.09 (MPa). On the other hand, these results for the maximum stress and tensile stiffness are agreed with the experimental results.

Table 1, Experimental Results of Tensile Failure

Specimen No.	Stress (MPa)	Stiffness (GPa)	Ɛ (%)
1	948	40.934	2.315
2	934	41.095	2.278
3	958	39..243	2.446
4	887	40.838	2.176
5	963	40.720	2.368
6	888	39.331	2.389
Average	930	40.360	2.33

Table 2. Tensile Results of Finite Element Analysis

Specimen No.	Stress (MPa)	Stiffness (Gpa)	Ɛ (%)
1	1001.5	43.261	2.315
2	986.67	43.313	2.278
3	1012.0	41.374	2.446
4	937.02	43.062	2.176
5	1017.3	42.960	2.368
6	938.07	41.109	2.389
Average	982.09	42.513	2.33

The (figures 4 and 5) show the experimental results and finite element analysis of the stress-strain curve for the six test specimens, respectively. These relations are demonstrated a linear elastic behaviour. The results of maximum stresses are fluctuated through the test specimens, where the fifth test specimen raises the maximum stress which is equal 1017.3 (MPa) among results, while the fourth specimen drop to minimum value through the test specimens and it is equal 937.02 (MPa). The (figure 6) illustrates the stress distribution for the six test specimens.

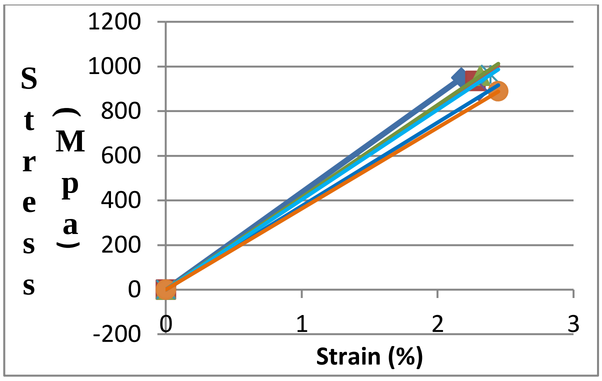


Figure 4. Experimental Stress Strain Relation of Six Test Specimens

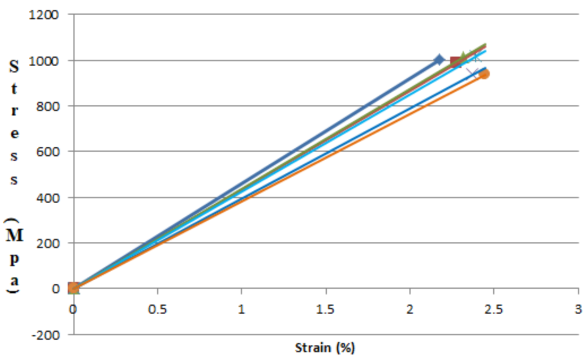
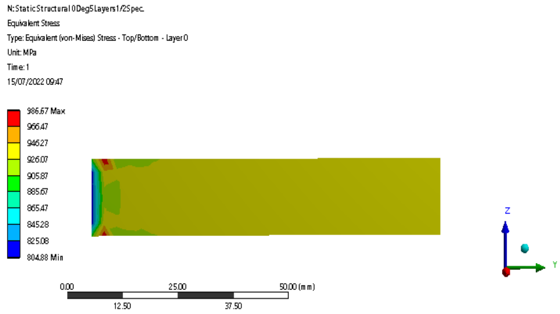
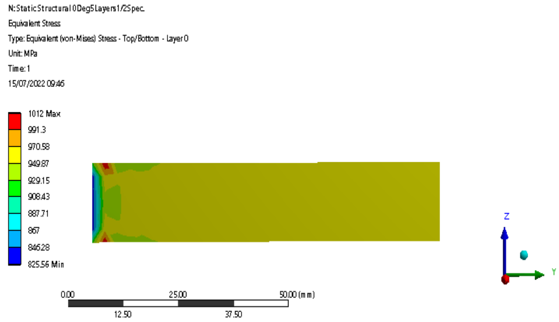
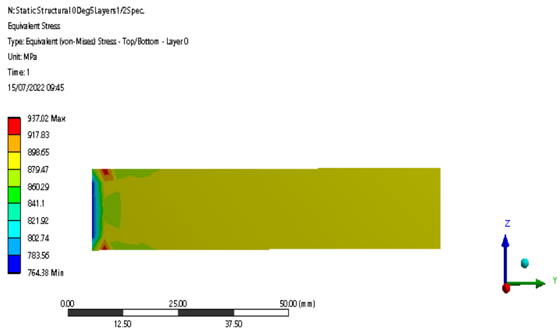
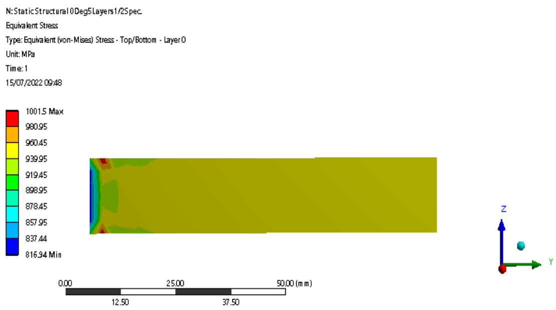


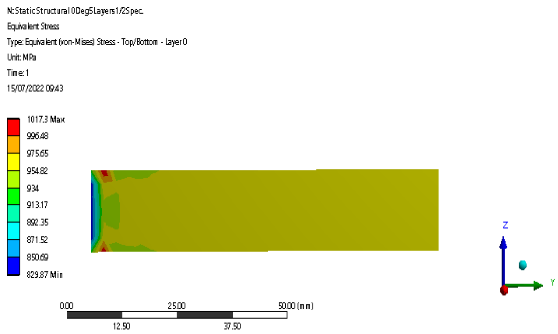
Figure 5. Numerical Stress Strain Relation of Six Test Specimens

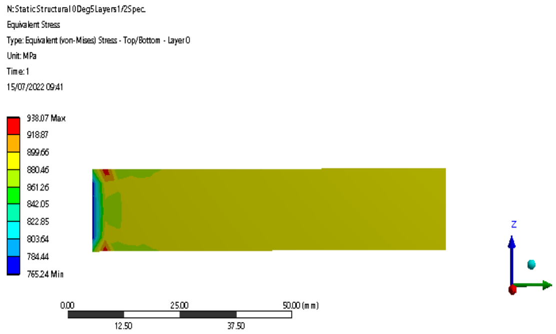

(b) Specimen 2


(c) Specimen 3


(d) Specimen 4


(a) Specimen 1


(e) Specimen 5



(f) Specimen 6

Figure (6) Stress Distribution Obtained by FEA

According to the experimental results as it is mentioned in the (table 1) can be calculated the average stress and average strain percentage which are 930 (MPa) and 2.33% respectively. However, the finite element analysis average results are 982.09 (MPa) and 2.33% respectively as it is mentioned in the (table 2). These results are plotted in the (figure 7) and the trend line of both results show match for the first part of results then it has been slightly raised the finite element analysis results than the experimental results.

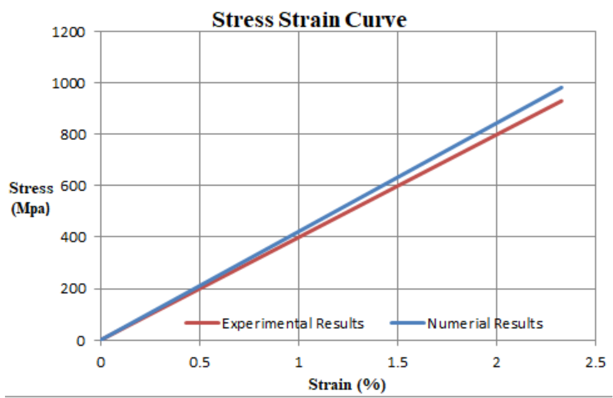


Figure 7. Experimental & Numerical Average Stress Strain Relationship

Referring to results of the experimental testing and finite element analysis results of tensile can be calculated the tensile stiffness of the six specimens, and these results of tensile stiffness are fluctuated for both the experimental tests and the finite element analysis among the six specimens test. These results of experimentally and numerically tensile stiffness are plotted for the six specimens test in the (figure 8).

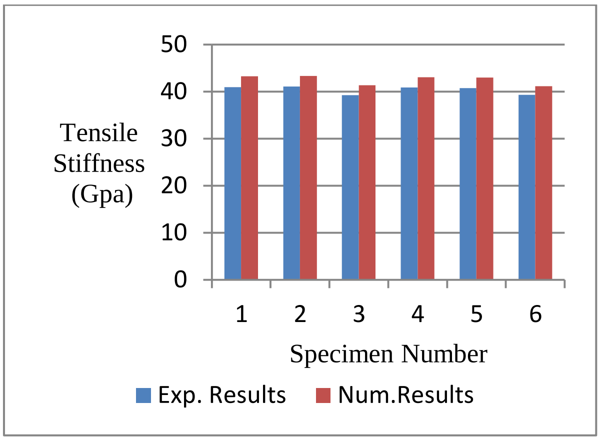


Figure 8. Tensile Stiffness for Experimental Test and Finite Element Analysis

V. Conclusion

This work shows that the comparison of the experimental and numerical results of tensile property of unidirectional glass fiber reinforced epoxy composite materials are:

- The tensile mechanical property of unidirectional glass fiber reinforced epoxy composite materials shows that it has linear elastic behaviour.
- The maximum stress of numerical results is fluctuated through the six test specimens from 937.02 (MPa) at fourth specimen to 1017.3 (MPa) at fifth specimen while the maximum yield strength of lamina is 1035.25 (MPa). On other hand, these results are agreement with the experiments ones. However, the numerical results of tensile strength agreed with experimental results.
- The results of finite element analysis of the stress distribution show position of the maximum stress at edges of each specimen that means the failure will occur at these positions.
- The results of tensile stiffness of both experimental and numerical are in agreement with each other.
- According to the numerical results were obtained by finite element analysis and which these results match with the experimental results. The finite element analysis can apply for such analysis and rely on of those results.

References

[1] T. Seshaiah & K. Vijaya Kumar Reddy "Effect of Fiber Orientation on the Mechanical Behavior of E-glass Fiber Reinforced Epoxy Composite Materials", International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 8, Issue 4- 2018, Pages: 379-396, DOI:10.24247/ijmperdaug2018- 40.

[2] A.Karthick, Karthik Prabu B, Johnson V, Karthik Praveen, Kiran P "Experimental Investigation of Glass Fiber Reinforced Polymer (GFRP) Composite Laminates", International Journal of Scientific Development and Research (IJSDR),Vol. 2, Issue 4, 2017, ISSN: 2455-2631.

[3] N.Saravana Kumara , G.VinothKumarb, C.VinothKumar , M.Prabhud aPG scholar, "Experimental Investigation on Mechanical Behavior of E-Glass and S-Glass Fiber Reinforced with Polyester Resin", SSRG International Journal of Mechanical Engineering (SSRG-IJME), Vol. 5, Issue 5-May 2018, ISSN: 2348-8360.

[4] G. Makarov, W. Wang & R. A. Shenoi, " Deformation and fracture of unidirectional GFRP Composites at high strain rate tension", School of Engineering Sciences, Ship Science, University of Southampton, SO17 1BJ, UK.

[5] T. Prasad, Dr. A Chenna Kesav Reddy, Dr.S.Madhav Reddy, N. Arjun, "Experimental Investigation of Mechanical Behaviour of Glass Epoxy", Journal of Manufacturing Engineering,Vol. 10, Issue 1, March 2015, pp 55-62

[6] Al-Mosawi, A. I. "Study of Some Mechanical Properties for Polymeric Composite Material Reinforced by Fibers", Al-Qadisiya Journal for Engineering Science, Vol. 2, Issue 1-2009, Pages:14-24, DOI:10.6084/mg.figshare.12573983.

[7] M. S. EL-Wazery, M. I. EL-Elamy, and S. H. Zoalfakar. "Mechanical Properties of Glass Fiber Reinforced Polyester Composites" International Journal of Applied Science and Engineering (IJASE), Vol. 14, Issue 3-2017, Pages: 121-131, DOI: 10.6703/IJASE2017.

[8] Davallo, M. and Pasdar, H. "Comparison of Mechanical Properties of Glass-Polyester Composites Formed by Resin Transfer Molding and Hand Lay-Up Technique". International Journal of ChemTech Research, Vol. 1, Issue 3-2009, Pages: 470-475.

[9] Estabraq T. Abdullah, "A Study of Bending Properties of Unsaturated Polyester/Glass Fiber Reinforced Composites". Journal of Al-Nahrain University-Science, Vol. 16, No.3, September 2013, Pages: 129-132, http://doi-org/10.22401/JNUS.16.3.18.

[10]www.dept.aoe.vt.edu/~aborgolt/aoe3054/manual/expt5/D638.38935.pdf