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Effect of Fiber-Reinforced Type on the Dynamic Behavior of Composite Plate

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Abstract— an experimental investigation had been done to demonstrate the effect of fiber-reinforced type on the dynamic behavior of composite plate. The composite plates are manufactured at (2, 4, and 6 layers), from unsaturated polyester as a matrix with the fiber at (30%) volume fraction. Three type of fibers reinforcement are used; i) E-glass woven roving, ii) E-glass mat chopped, and iii) carbon. The tensile strength and Charpy impact tests are used to evaluate the mechanical properties. In fatigue tests, the specimens are investigated to estimate the basic S-N Curve and deduced there relations. The plate was fixed from all sides. Two steel balls of 16g and 23g were freely dropped from height of 0.5 m. The dynamic response of the plate was measured using vibration data collector (TVC 200). The results showed that the mechanical properties and the endurance limits increased while the deflection decreased with using carbon fibers-reinforced in compare with using E-glass fibers-reinforced.

Keywords—composite laminate plate, fatigue, dynamic response.

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1. INTRODUCTION

FIBER reinforced composite material are known by their higher strength / weight and stiffness / weight ratios than metals; therefore, they are used in numerous light weight engineering applications, particularly in aircraft design. However, the impact loads of external objects are still a major concern for such laminates in comparison to similar metallic structure that can cause internal material damage. Typical impact scenarios in aircraft design range from a tool dropped on the laminate surface, over runway debris thrown up by tires or hail to bird strike during flight. In this study the dynamic response test, fatigue test and Charpy impact test are used to demonstrate the dynamic behavior of laminated composite material experimentally. In the literature there are many studies concern with the impact load on the composite structure, Alpaydin and Turkmen [1], were investigated the dynamic behavior of sandwich panels subjected to the impact load experimentally and numerically, they investigated the dynamic response of the panel by measuring strain on a particular location on the panel. Vogler, et al [2], reported that the dynamic behavior of a tungsten carbide filled epoxy composite under planner loading condition. Planar impact experiments were conducted to determine the shock and wave propagation characteristics of the material. Jaafer [3], studied the effects of fiber on damping behaviors of composite materials with volume fraction (Vf=1%, 2% and 3%). It was concluded that the stiffness, natural frequency, vibration damping and damped period increased with the increases of volumefraction of reinforcement material. Heimbs, et al [4], were studied (experimentally and numerically) the influence of a compressive preload on the low velocity impact behavior of a carbon fiber – reinforced composite plate (CFRP). They were developed modeling strategies for low velocity impact simulation of CFRP plate under compressive preload with LS – DYNA with emphasis on the laminate delimitation and preload modeling. Sinan [5], demonstrate the effect of filler on the dynamic behavior of sandwich panel, and present that the deflection decrease with the graphite filler increase up to 7.5%. The main objective of this study is to investigate, experimentally the effect of fiber on the behavior of composite laminate plate under dynamic load.

2. MATERIALS AND EXPERIMENTAL PROGRAM

The materials used in this investigation are the fiber and unsaturated polyester of (1.4g/cm3) density as a matrix. The fibers, which are compatible to unsaturated polyester resin, were used as the reinforcement. The fibers are carbon, E-glass woven roving and E-glass mat chopped. All the composite laminated plates were manufactured by dry hand lay-up procedure. The unsaturated polyester resin was mixed with the hardener in the ratio 100:2 by weight. The stacking procedure of fiber-polyester composites was constructed by placing the fiber ply one above the other with the resin mixed well to spread between the plies by using mould of (300×200×20) mm. This process was repeated with a constant volume fraction of (30%) [6]. The inside wall of the frame was covered by a nylon paper to prevent the adhesion between the mould and the specimen. A steel cover was applied to prevent any shrinkage and removing any air bubbles trapped under the reinforcement during the curing process. The curing process was completed in 24 hours at room temperature. After complete solidification of composite sheet specimen, the product laminate was left for 3 hours in oven at 70 ◦C in order to achieve a sufficient curing. The product is a composite plate of (300×200)

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mm with (2, 4 and 6) layers. To produce the test samples required, the plate was cut into the appropriate dimensions using a tipped cutter.

2.1 Mechanical properties:

The mechanical properties demonstrated by using the tensile strength test and Charpy impact test. The tensile test specimens are manufactured according to ASTM D3039 standards [7], as shown in Fig. 1. While the Charpy test specimens are manufactured according to ISO-179 [8]. The test results are listed in Tables 1 and 2.

2.2 Fatigue test:

Fatigue is the failure or decay of mechanical properties after repeated applications of cycle stress lower than ultimate tensile stress of material [9]. Using an alternating-bending fatigue testing machine shown in Fig. 2, which performed at stress ratio of (-1). The equation of power law regression trend is a typical for composite fatigue data [10]. The regression constants (a, & b) and the correlation coefficient (R2), that represent the fatigue trends results are given in Table (3).

2.3 Dynamic response:

The composite plate of (200×200 mm) has been fixed from all sides using eight bolts and an accelerometer has been glued at the center of the sheet in the back side. A metal pipe is fixed by a suitable structure over the sheet. This structure was used as a guide to be able to drop the steel ball on the center of the plate from a height of 0.5 m. The structure setup is shown in Fig. 3. Spherical steel balls of 16g and 23g were freely dropped on the top side of the composite plate. The strain is digitized and transferred to the vibration data collector (TVC 200) device. The data transferred to a computer by connect the (TVC 200) to it. The data was analyzed by utilizing MCM3 software program to represent the dynamic response (deflection and frequency) of the tested plates.

3. Results and discussion

The mechanical properties test results are listed in tables (1&2). The results show that the mechanical properties improved with the layer increased. With using carbon fiber reinforced the mechanical properties increased rather than that of using E-glass. At six layers composite plate, the modules of elasticity, tensile strength and toughness of carbon fiber are increase by 300%, 200% and 110% respectively rather than of using E-glass woven roving fibers. In fatigue tests, the specimens are investigated to estimate the basic S-N Curve (fatigue only).The results with the deduced relations for the effect of layers and fiber reinforced are shown in Figs. (4, 5, 6 and 7). The endurance limit for using E-glass mat chopped fiber reinforced at 106 is 5, 10 and 35 Mpa for 2, 4, and 6 layers respectively. While the endurance limit for using carbon fiber reinforced at 106 is 12, 19 and 54 Mpa for 2, 4, and 6 layers respectively. At 6-layers, the endurance limits of carbon fibers and E-glass woven roving fibers are increased by 50% and 28% rather than of using E-glass mat chopped fiber reinforced as shown in fig. 7. The deflection in z-direction was measured at the center on the back side of the plate. Figs. 8, 9 and 10 represent the behavior of E-glass mat chopped, woven roving and carbon fibers laminated plates respectively with impact loads of (16 & 23) g. The results showed that the laminated plates have the same deflection behavior but differ in magnitude. The deflection increased as the impact load increased due to the momentum increased. In general the deflection of 6-layers plate was decreased by 11% in comparison to the 2-layers. The deflection of the carbon fibers and E-glass woven roving fibers are less than the deflection of E-glass mat chopped fibers by 12% and 6% respectively, as shown in figure 8. Due to have a higher toughness than the E-glass mat chopped fibers plate.

4. Conclusions

The following conclusions can be drawn:

1. The mechanical properties of are greater than of using E-glass fibers.
2. The endurance limits of using carbon fibers are increased rather than of using E-glass fibers.
3. The deflection of 2-layers using carbon fibers increased by 11% than that of 6-layers.
4. The deflection of the carbon fibers is less than the deflection of E-glass fibers.

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Table- 1: Tensile test results

No. of layers	E-glass (mat chopped) fibers		E-glass (woven roving) fibers		Carbon fibers	
	E1 (Gpa)	σt (Mpa)	E1 (Gpa)	σt (Mpa)	E1 (Gpa)	σt (Mpa)
2	2.215	85.09	4.410	132.90	11.602	302.198
4	3.125	93.50	5.157	160.57	19.186	486.731
6	3.289	96.15	6.163	174.66	25.851	654.84

Table- 2: Charpy Impact test results

No. of layers	E-glass (mat chopped) fibers	E-glass (woven roving) fibers	Carbon fibers
	K (MPa√m)	K (MPa√m)	K (MPa√m)
2	20.802	28.57	55.313
4	25.874	34.678	67.254
6	31.873	38.416	83.507

Table-3: Regression parameters of fatigue data.

NO. of layers	E-glass chopped			E-glass woven			Carbon		
	a	b	R^2	a	b	R^2	a	b	R^2
2	-0.22609	4.48446	0.947685	-0.123102	3.95514	0.98261	-0.116239	5.12588	0.994718
4	-0.178339	4.42729	0.986505	-0.114402	4.12329	0.986795	-0.0991045	5.07742	0.986169
6	-0.131254	4.11148	0.922938	-0.106179	4.31618	0.976405	-0.0965047	5.20172	0.993862

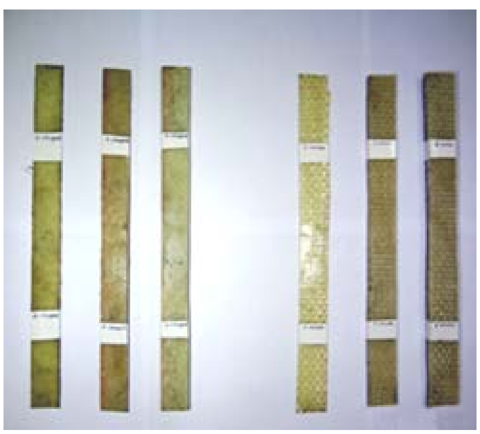

Fig. 1: Tensile test specimen (ASTM-D3039).

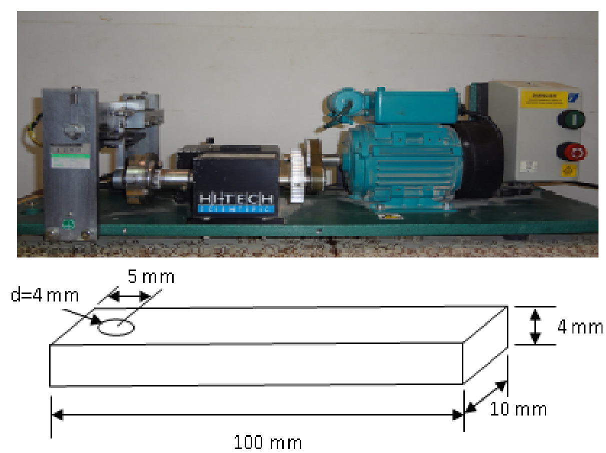

Fig. 2: Fatigue testing machine and specimen.

Fig. 3: The impact test setup.

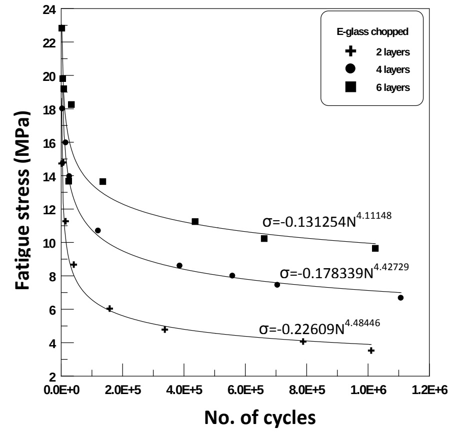

Fig. 4: Experimental S-N curves for E-glass mat chopped fiber composite plates at different layers.

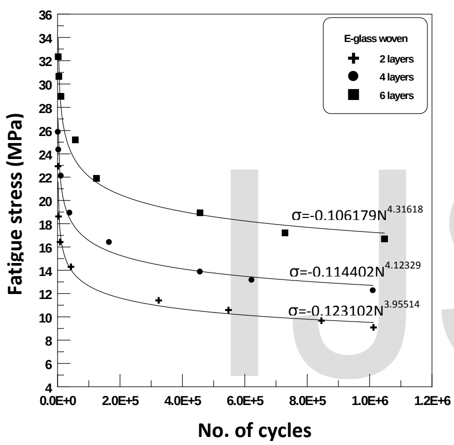

Fig. 5: Experimental S-N curves for E-glass woven roving fiber composite plates at different layers.

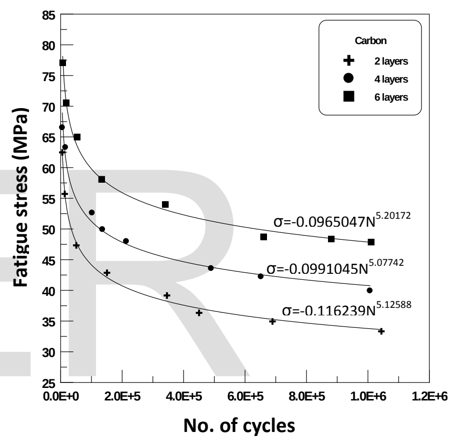

Fig. 6: Experimental S-N curves for carbon fiber composite plates at different layers.

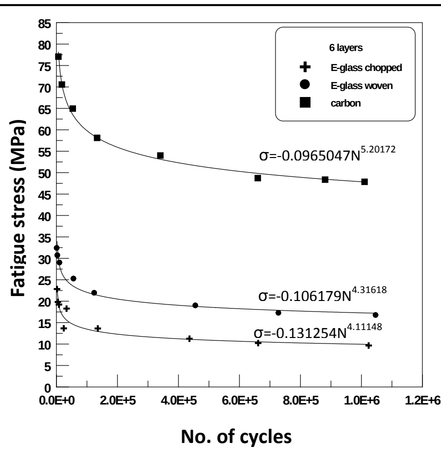

Fig. 7: Effect of fiber type on the S-N curve of composite plates.

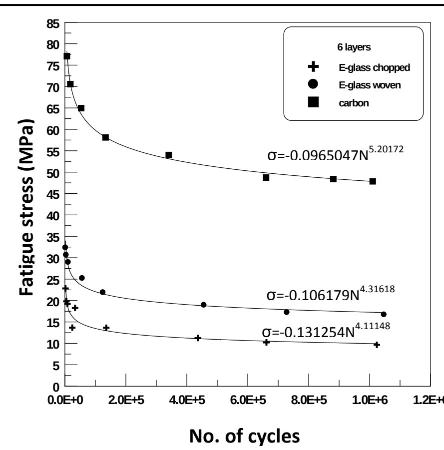

Fig. 8-a: Deflection behavior of E-glass mat chopped fiber composite plates at w=16g.

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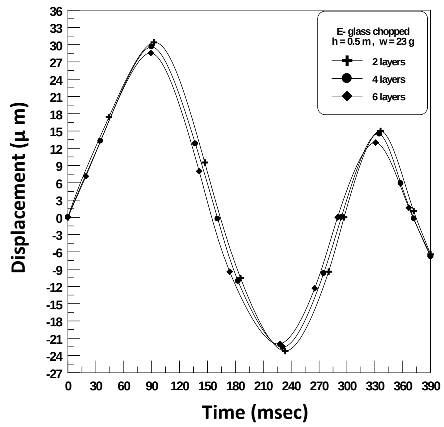

Fig. 8-b: Deflection behavior of E-glass mat chopped fiber composite plates at w=23g.

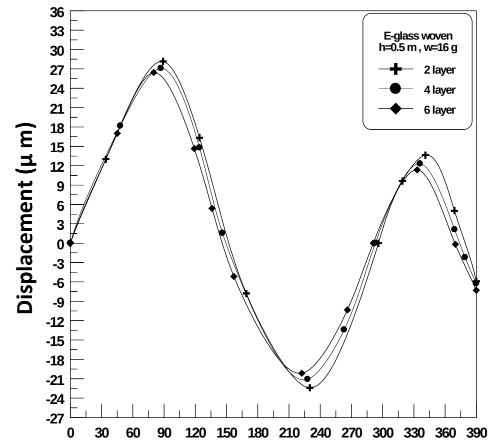

Fig. 9-a: Deflection behavior of E-glass woven roving fiber composite plates at w=16g.

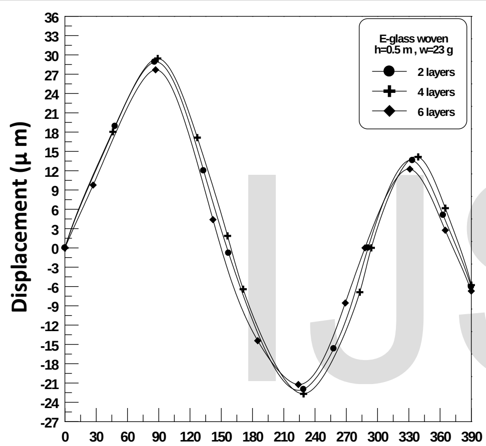

Fig. 9-b: Deflection behavior of E-glass woven roving fiber composite plates at w=23g.

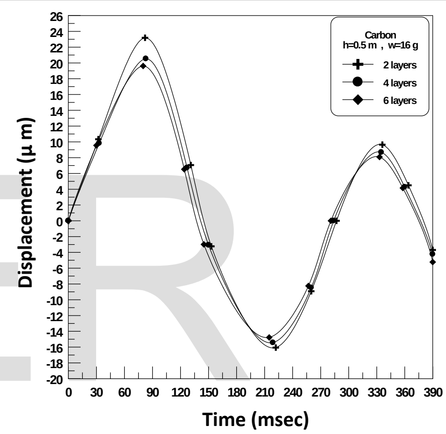

Fig. 10-a: Deflection behavior of carbon fiber composite plates at w=16g.

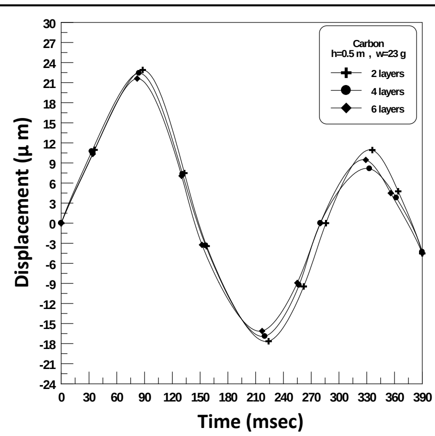

Fig. 10-b: Deflection behavior of carbon fiber composite plates at w=23g.