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Flexural Analysis of Aluminum/Carbon-Epoxy Fiber Metal Laminates

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ABSTRACT

Background: Fiber metal laminate (FML) is one of the new hybrid materials and advanced composite materias, which consisting of thin metal sheets and fiber/adhesive layers. FML is quickly being a better alternative for metal structure especially in aerospace, aircraft and car applications. This is due to the special ability in terms of mechanical properties of FML. The flexural properties of FML such as flexural strength and flexural modulus are investigated which focused on the consistency of maximum load applied on the workpieces. Flexural properties of the resulting FML are evaluated using three point bending configuration in accordance of ASTM D790 standard. **Objective:** The main objective of this study is to investigate the response of aluminum/carbon epoxy FML to flexural testing and consistency of each sample. **Results:** From this study, the mean of flexural strength obtained is 566.706 MPa and flexural modulus obtained 38.577 GPa. **Conclusion:** The analysis found that the flexural properties are consistent for all workpiece tested due to the small S.D value.

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INTRODUCTION

Fiber metal laminates (FML) are the hybrid composite materials which generated from weaving layers of thin metals like aluminum alloy and fiber reinforced plastic (FRP) layers. These two combinations of metal and polymer composite can produce a synergistic effect on some properties such as physical and mechanical properties. FML offers the excellent damage tolerance, fatigue and impact properties with a relatively low density (Song *et al*. 2010). FML take advantages of metal and FRP by offering better mechanical properties compared to the conventional laminate which consisting only FRP ply or monolithic metal (usually aluminum or titanium) sheet. Previous researchers found that the FML are characterized by high strength properties that included static strength mainly in relation to density and fatigue resistance(Vogelesang& Vlot 2000; Sinmazçelik *et al*. 2011). The autoclave method used to manufacture the FML offer the better properties of FML (Bieniaś 2011).

Glass fiber reinforced aluminum laminate (GLARE) and aramid fiber reinforced aluminum laminate (ARALL) are commonly used extensively as structural materials in aircrafts. Numerous publications describe their excellent mechanical properties and performance(Asundi& Choi 1997; Roebroeks 1994; Laliberte *et al*. 2000; Cocchieri *et al*. 2006). Composite laminates which combine the aluminum and carbon fiber composite or also known as carbon fiber reinforced aluminum laminates (CARALL) still not widely used in industry and the research on these materials are still ongoing. These laminates provides higher strength properties compared to other types of FML which more efficient for aerospace applications.

This paper presents the response of aluminum/carbon-epoxy FML to flexural testing. Analysis of flexural properties is one of the important areas of research since the development of laminated composite. The flexural strength and flexural modulus of the FML are investigated. The used of carbon fiber reinforced polymer (CFRP) showed that aluminum/CFRP composites had good performance in energy absorption compared to aluminum material only and the performance is dependent on the lay-up sequence of CFRP and aluminum(Kim *et al*. 2013).

Methodology:

The FML composite is composed by a thin aluminum layer sheet with carbon fiber reinforced polymer (Al/CFRP). Aluminum alloy 2024-T3 sheets with the thickness 1.2 mm and impregnated carbon unidirectional (UD) tape, grade 190 and type 3 are

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used in this study. Grade 190 is grades specify areal weight of carbon in g/m^2 and type 3 refers to nominal resin content 37% by weight. The nominal cured ply thickness is 0.0078 in or 0.2 mm. The UD carbon prepregs are laminated in 0°, 45° and 90°directions and layered with Al 2024-T3 alternately. The sample consists of 18 layers of UD carbon prepregs and two pieces of Al 2024-T3. The layup composition and arrangement is shown in Fig. 1 and Table 1.

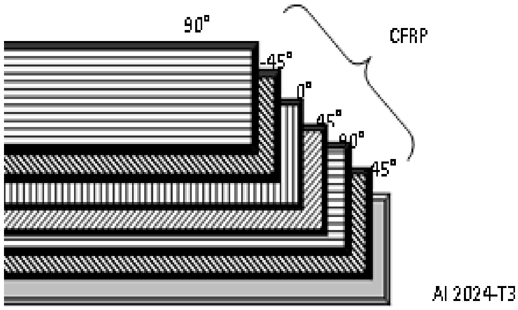

Fig. 1: Scheme of Al/CFRP laminate.

Table 1: The Layup Orientation

Ply Sequence	Ply Direction
1	90°
2	-45°
3	0°
4	45°
5	90°
6	-45°
7	Al 2024-T3
8	-45°
9	90°
10	45°
11	0°
12	-45°
13	90°
14	Al 2024-T3
15	90°
16	-45°
17	0°
18	45°
19	90°
20	-45°

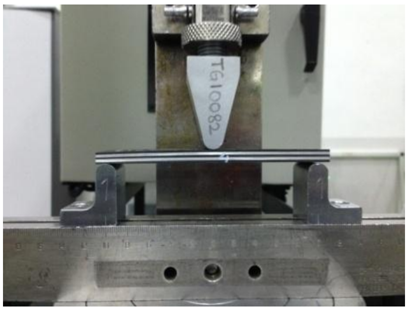

Fig. 2: Flexural testing procedure.

The laminates are produced by autoclave method with the following parameters; pressure 85 + 15/-0 psi, vacuum 22 Hg, temperature 355 °F, curing time 120-135 min and heating and cooling rate 0.3-4.0 °C/min.

Flexural testing was carried out according to ASTM D790 using universal testing machine INSTRON 5582 with a load cell of 10kN and a cross head speed of 1 mm/min. A support span-to-depth ratio of the composite laminate sample was set at 16:1. The composite laminate panels were cut into rectangular bars with dimension 110 mm x 25 mm x 6mm. A bar of rectangular cross section rests on two supports and loaded by means of a loading nose midway between the supports as shown in Fig.2. Total of five specimens of composite panels were tested and the average reading was taken for record.

Results:

The effect of aluminum /carbon-epoxy FML on the flexural strength and flexural modulus are presented in Table 2. The estimated of maximum load is found to be almost constant in range 3.2 kN to 3.7 kN as presented in Fig. 3.

Table 2 shows the flexural properties of aluminum /carbon-epoxy FML.Flexural strength is the maximum stress in the outermost fiber and calculated using equation 1. Flexural modulus is defined as a tendency of material to bend and determined from the slope of stress-strain curve. Flexural modulus also can be calculated using equation 2. Then, the mean values of flexural properties are calculated.

The flexural strength and modulus are then plotted on graph as shown in Fig. 4.

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Table 2: Flexural Properties of Aluminum/carbon-epoxy FML

Sample	Width (mm)	Thickness (mm)	Support Span (mm)	Flexural Strength (MPa)	Flexural Modulus (GPa)
1	24.170	5.890	94.240	617.727	39.067
2	24.220	6.210	99.360	578.737	44.545
3	24.360	6.240	99.840	585.201	36.095
4	24.470	6.250	100.000	521.144	36.793
5	23.232	6.200	99.200	530.719	36.385
Mean	24.323	6.158	98.528	566.706	38.577
S.D	0.20	0.15	2.40	40.19	3.54

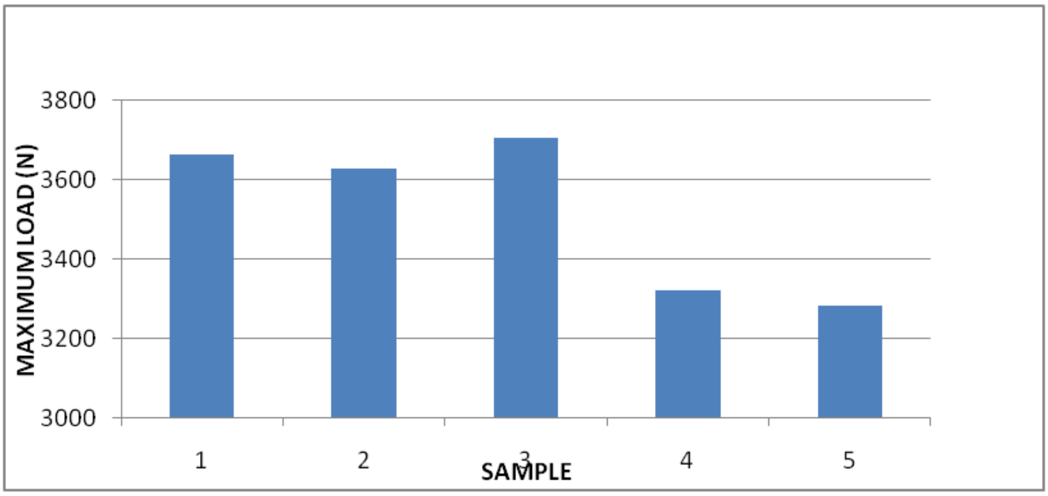

Fig. 3: Maximum load applied on the workpiece.

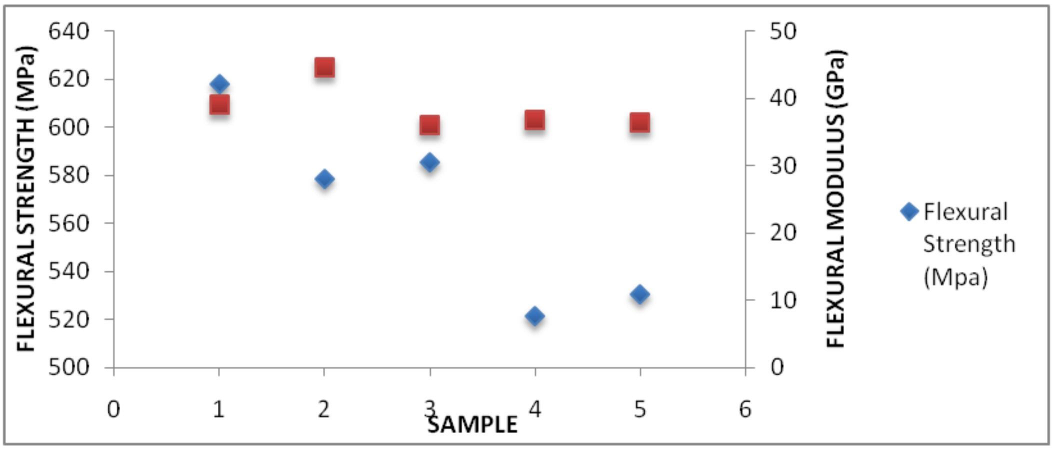

Fig. 4: Flexural strength and modulus.

Flexural strength

$$\sigma = \frac{3FL}{2bt^2} \quad (1)$$

Flexural modulus

$$E = \frac{L^3F}{4bt^3d} \quad (2)$$

Where F is the load at fracture point, L is length of support span, b is width of specimen, t is thickness or height of the specimen and d is deflection due to the load applied.

Figure 5 shows the original and deformed shape of FML samples after testing. It can be observed that FML composite gives good yield stress and stiffness in bending with the presence of metal element (aluminum) in the laminate.

Discussion:

From the obtained results, there are different flexural strength and modulus between the same batches of the composite laminates due to the errors during manufacturing of the laminates. The errors maybe cause by the fabrication and processing errors, porosity, incompletely cured matrix due to the incorrect curing cycle, ply misalignment that change the overall strength and stiffness of the composite laminates and bonding defects (Berglund & Kenny 1991; Wang *et al*. 1997; Olivier *et al*. 1995). The flexural strength and modulus as plotted on graph in Fig. 4 shows that the flexural properties are consistent for all specimens where the difference for each specimen is small. The consistency also proved by the S.D values where the values are small compared to the flexural strength and modulus values.

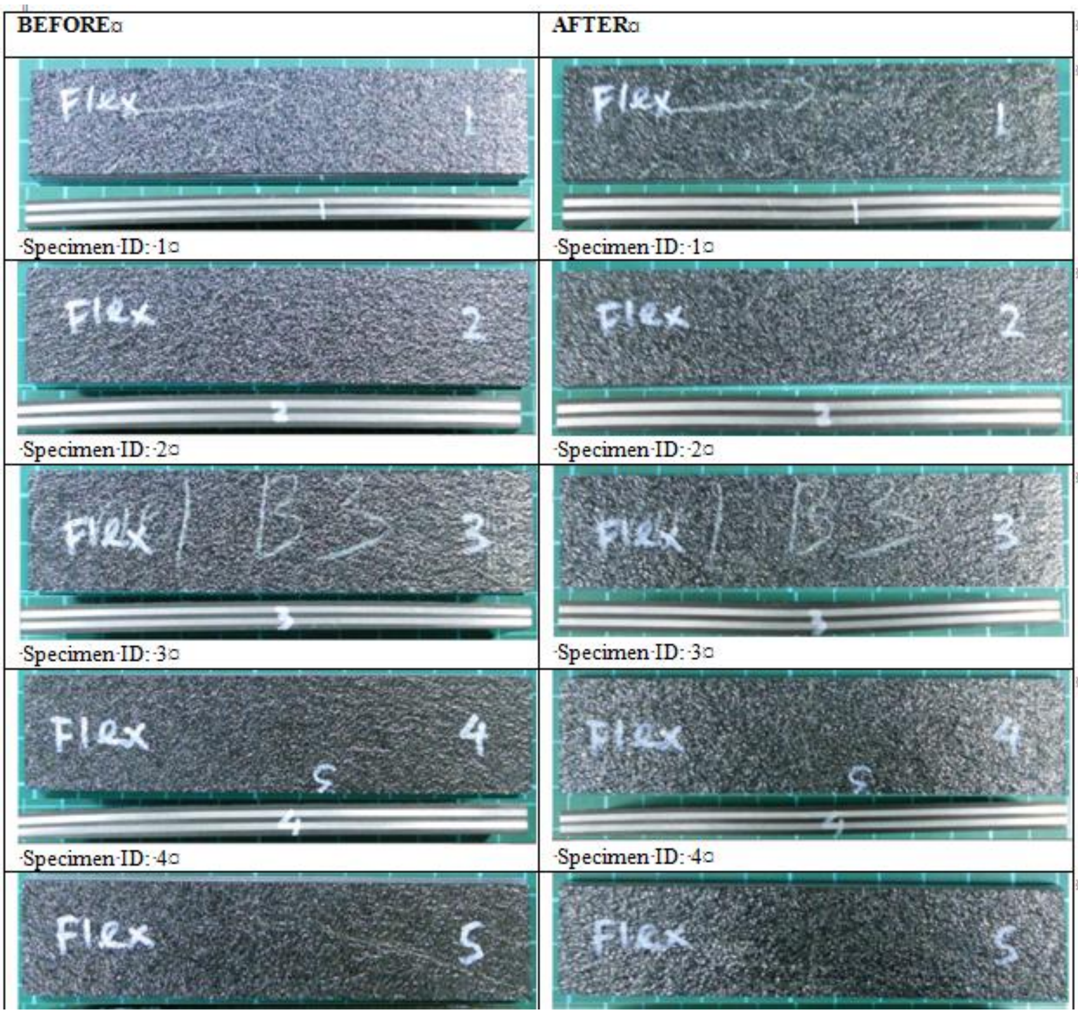

Fig. 5: Tested specimens for flexural properties.

Conclusion:

A new combination of metal and fiber composites which consist of aluminum and CFRP is reported for FML composite. The flexural behavior of aluminum/carbon-epoxy composite laminates is obtained using three-point bend configuration according to the ASTM D790 standard. With regards to the flexural strength, a mean value obtained is 566.706 MPa. The mean of flexural modulus obtained is 38.577 GPa. The consistency of each sample proved by the S.D value is small.

REFERENCES

Asundi, A., A.Y.N. Choi, 1997. Fiber Metal Laminates : An Advanced Material for Future Aircraft. *Materials Processing Technology*.

Berglund, L.A., J.M. Kenny, 1991. Processing science for high performance thermoset composites. *SAMPE Journal*, 27(2): 27–37.

Bieniaś, J., 2011. FIBRE METAL LAMINATES - SOME ASPECTS OF MANUFACTURING PROCESS , STRUCTURE AND SELECTED PROPERTIES. *Composites*, 1: 39–43.

Cocchieri, E., 2006. A Review on the Development and Properties of Continuous Fiber / epoxy / aluminum Hybrid Composites for Aircraft Structures 2 . The Production of Metal / laminate Hybrid Composites. *Material Research*, 9(3): 247–256.

Kim, H.C., D.K. Shin, J.J. Lee, 2013. Characteristics of aluminum/CFRP short square hollow section beam under transverse quasi-static loading. *Composites Part B: Engineering*, 51: 345–358.

Laliberte, J.F., 2000. Application of Fiber-Metal Laminates. *Polymer Composite*, 21(4): 558–567.

Olivier, R., J.P. Cottu, B. Ferret, 1995. Effects of cure cycle pressure and voids on some mechanical properties of carbon / epoxy laminates. *Composites*, 26(7): 509–515.

Roebroeks, G.H.J., 1994. Fibre-metal laminates: Recent Developments and Applications. *Fatigue*, 16(1): 33–42.

Sinmazçelik, T., 2011. A review: Fibre metal laminates, background, bonding types and applied test methods. *Materials & Design*, 32(7): 3671–3685.

Song, S.H., 2010. Experimental and Numerical Investigation on Impact Performance of Carbon Reinforced Aluminum Laminates. *Journal of Materials Science & Technology*, 26(4): 327–332.

Vogelesang, L.B., A. Vlot, 2000. Development of fibre metal laminates for advanced aerospace structures, 103: 3–7.

Wang, Q., 1997. Cure Processing Modeling and Cure Cycle Simulation of Epoxy-Terminated Poly (phenylene ether ketone). *Journal of Applied Polymer Science*, 66: 799–808.