STUDY ON TENSILE BEHAVIOUR OF CARBON JUTE ALUMINIUM-FIBRE METAL LAMINATES

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Abstract— Fibre Metal Laminates (FML) is a new family of Hybrid Composite materials which consists of a thin metal layer bonded together between the intermediate Fibre and Epoxy layers. FML have the properties of both metals and fibre with high mechanical strength with less weight. The present work focuses on the Tensile behaviour of a FML. Fibres that are used in this FML are Carbon (300 Gsm) and Jute (200 Gsm). Aluminium sheet of thickness 0.2 mm is used in this combination. The Epoxy Ly556 (Araldite) and Hardener Hy 951 are mixed in the ratio of 10:1. The fibre metal laminates are made by hand layup technique and are cured for four hours and then compressed at a pressure of 0.8 Mpa using Compression Molding machine at a temperature of 70 degrees c for 10 minutes. Three specimens of FML are prepared with two different layer orientation as per ASTM D 3039 standards. The Modulus of Elasticity and Tensile strength of the FML for different layer orientation have been evaluated. Here the parameters such as number of layers and stacking sequence of the fibre and metal are varied and their effects on the above properties are studied.

Keywords— Fibre Metal Laminates, Tensile behaviour, hand layup technique, Modulus of Elasticity, Tensile strength, stacking sequence.

I. OVERVIEW OF FIBRE METAL LAMINATES

The Fibre Metal Laminates (FML) is a new type of hybrid composites developed at the Delft University of Technology. FML consists of thin sheets of Aluminium bonded with fibre adhesive layers. This laminated structure behaves much as a simple metal structure, but with considerable specific advantages regarding properties such as metal fatigue, impact, corrosion resistance, fire resistance, weight savings and specialized strength properties. This first hybrid metal laminate is known as ARALL (Aramid Reinforced ALuminum Laminate). ARALL showed the damage tolerance and fracture toughness known from the metal laminates together with the strength and crack growth resistance brought in by the fibres. GLARE (GLAss REinforced fibre metal laminate), using glass fibres, was then introduced in 1991, due to the good compressive properties of glass.

These compressive properties lead to a better loading flexibility of GLARE compared to ARALL since aramid fibres show a very poor behaviour under compressive loading. GLARE is now an accepted Material in the aircraft Industry. While the 20 percent weight reduction was the prime driver behind the development of this new family of materials, it turns out the additional benefits like cost reduction, weight reduction and improved performance.

II. ORIENTATIONS OF FIBER METAL LAMINATES

The Schematic Diagram of Orientations of the Fiber Metal Laminate is Shown in Figure Below.

III. FABRICATION AND EXPERIMENTATION

Materials Used in Fibre Metal Laminate Preparation were
1. Carbon fibre (240 gsm)
2. Jute fibre (200 gsm)
3. Aluminium2024 T3 (0.19mm)
4. Epoxy (LY 556)
5. Hardener (HY 951)

IV. TENSILE TEST SPECIMEN GEOMETRY OF FML

The Tensile test specimen geometry of FML was prepared by following the American Society of Testing Methods (ASTM D 3039) Standards. The geometry of the CAJALL specimen was shown in Figure 2.
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V. MANUFACTURING OF FIBRE METAL LAMINATES

The conventional method of manufacturing Fibre Metal Laminate include hand layup, filament winding, fibre placement, compression molding, pultrusion, prepreg lay-up, resin film infusion and resin transfer molding. The resin transfer molding requires a mould to be prepared to form the laminate. Material consolidation is generally obtained by the application of heat and pressure which aids curing of the resin also. In this work the Fibre Metal Laminates were prepared by hand layup method.

VI. STEP BY STEP PROCEDURE OF SPECIMEN PREPARATION

The Fibre Metal Laminate was prepared by hand lay-up method by the following procedure. Initially place a glass plate with a Teflon sheet over it. Apply a layer of wax polish over the Teflon sheet, which will act as a relieving agent. Fix the metal/ wooden stencil over the Teflon sheet. Apply a layer of matrix material, which is a combination of epoxy (LY556) and hardener (HY951) mixed in the weight ratio 10:1. Place the mat layer of Carbon fibre at the required ply angle and dimension. Rolling operation is performed to remove air bubbles and voids. Apply the matrix material coating (resin) with hand brush to wet the carbon fibre mat. Place the mat layer of Jute fibre at the required ply angle and dimension. Rolling operation is performed to remove air bubbles and voids. Apply the matrix material coating (resin) with hand brush to wet the Jute fibre mat. Place the aluminium sheet as per the standard dimensions.

Rolling operation is performed to remove air bubbles and voids. Apply the matrix material coating (resin) with hand brush to wet the metal sheet. The above steps are repeated to complete the fibre metal laminates. Then place another Teflon sheet followed by a glass plate. Allow the Fibre metal laminates to cure in atmospheric condition for about 4 hours. Then the laminates are compressed, using compression molding machine at 70 kg/cm², 70°C for 10 minutes.

VII. COMPRESSION MOLDING MACHINE USED FOR CAJALL SPECIMEN PREPARATION

The FML fibre metal laminate is compressed by Flowmech Compression molding machine. The photograph of Flow Mech Compression molding Machine used for FML Specimen Preparation is shown in Figure below.

VIII. TENSILE TESTING

Tensile elongation and Tensile modulus measurements are among the most important indications of strength in a material, and are the most widely specified properties of polymer materials. The tensile test, in a broad sense, is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking. Tensile modulus, is an indication of the relative stiffness of a material, can be determined from a stress-strain diagram. The generally accepted standard test method for high strength composites is the ASTM D 3039. The Instran 3369 Universal Testing Machine shown in figure was used for performing the tensile test. The test specimen was positioned vertically in the grips of the testing machine. The speed of the testing was the relative rate of motion of the grips or test fixtures during the test. The testing speed of the crosshead was 1.27mm/min. The grips were tightened evenly and firmly to prevent any slippage. The speed of testing was set at the proper rate and the machine was started. As the specimen elongates, the resistance of the specimen increases, and it was detected by a load cell. An computer connected with the testing machine was utilized. The machine also records to capture the data, the maximum (peak) load obtained by the specimen, which can be recalled after the completion of the test. The elongation of the specimen was continued until rupture was observed. The load value at break was also recorded. The tensile strength at break (ultimate tensile strength) was calculated.

IX. FML ORIENTATION SET UP FOR TENSILE TEST

The orientation of the FML tensile test specimen containing 8 layers of alternate fibre and metal is (0°/0°/0°/0°/90°/0°/0°/0°) which is shown in Table 1.
The orientation of the FML tensile test specimen containing 13 layers of alternate fibre and metal is \((0º/0º/0º/0º/90º/0º/0º/0º)\) which is shown in Table 2.

### Table 1 CAJALL FML Orientation for 8 Layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>FIBRE Material</th>
<th>Orientation Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>2</td>
<td>Ca</td>
<td>0º</td>
</tr>
<tr>
<td>3</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>4</td>
<td>Ju</td>
<td>0º</td>
</tr>
<tr>
<td>5</td>
<td>Ju</td>
<td>90º</td>
</tr>
<tr>
<td>6</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>7</td>
<td>Ca</td>
<td>0º</td>
</tr>
<tr>
<td>8</td>
<td>Al</td>
<td>0º</td>
</tr>
</tbody>
</table>

### Table 2 FML Orientation for 13 Layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>FIBRE Material</th>
<th>Orientation Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>2</td>
<td>Ca</td>
<td>0º</td>
</tr>
<tr>
<td>3</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>4</td>
<td>Ju</td>
<td>0º</td>
</tr>
<tr>
<td>5</td>
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<td>90º</td>
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<td>6</td>
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<td>0º</td>
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<td>7</td>
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<td>Al</td>
<td>0º</td>
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<td>9</td>
<td>Ju</td>
<td>90º</td>
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<tr>
<td>10</td>
<td>Ju</td>
<td>0º</td>
</tr>
<tr>
<td>11</td>
<td>Al</td>
<td>0º</td>
</tr>
<tr>
<td>12</td>
<td>Ca</td>
<td>0º</td>
</tr>
<tr>
<td>13</td>
<td>Al</td>
<td>0º</td>
</tr>
</tbody>
</table>

X. EXPERIMENTAL SETUP FOR TENSILE TEST

The ruptured specimens view after conducting tensile test of 13 layered Fibre Metal Laminate specimen set up is shown in Figure 4.

![Figure 4 Eight Layer CAJALL Specimen after Rupture](image)

The ruptured specimens view after conducting tensile test of 13 layered CAJALL Fibre Metal Laminate specimen set up is shown in Figure 5.

![Figure 5 Thirteen Layer CAJALL Specimen after Rupture](image)

XI. RESULTS AND DISCUSSION

The average values of Tensile Strength, Yield Strength, Young’s modulus, Maximum displacement and Maximum Load for thirteen layered FML specimens are calculated. The Tenile Strength and Tensile Modulus for the eight layered FML specimen is calculated by the formula given in Equations 11.1 and 11.2.

\[
\text{Tensile Strength} = \frac{\text{Maximum load recorded}}{\text{cross sectional area}} \quad \text{(11.1)}
\]

\[
\text{Young’s Modulus} = \frac{\text{Difference in stress}}{\text{Difference in corresponding strain}} \quad \text{(11.2)}
\]

\[
\begin{align*}
1. & \quad \text{Maximum load applied} = 1520N \\
2. & \quad \text{Maximum extension achieved} = 5.010mm \\
3. & \quad \text{Thickness of the specimen} = 5.5mm \\
4. & \quad \text{Gauge length} = 150mm \\
5. & \quad \text{Width of the specimen} = 25mm \\
6. & \quad \text{Area of the specimen} = 0.025x0.0005m^2 \\
= & \quad 1.25 \times 10^{-4}m^2 \\
\text{Tensile Stress} & = \frac{\text{Load Applied}}{\text{Area}} = \frac{1520}{1.25 \times 10^{-4}} = 1.216GPa \\
\text{Strain} & = \frac{\text{Change in length}}{\text{Original length}} = \frac{5.010}{150} = 0.0333 \\
\text{Young’s modulus for eight Layers} & = 20 \times 0.00835 = 0.167GPa
\end{align*}
\]

The values of maximum load, maximum displacement, Yield Strength, Tensile Strength and Tensile Modulus for the thirteen layered FML specimens are calculated.
Young’s modulus for eight layered and thirteen layered FML specimen are tabulated in Table 3.

**Table 3 Comparison of Tensile properties of 8-layered and 13-layered FML**

<table>
<thead>
<tr>
<th>SLNo.</th>
<th>Description</th>
<th>8 Layers</th>
<th>13 Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum Load (KN)</td>
<td>15.12</td>
<td>19.65</td>
</tr>
<tr>
<td>2</td>
<td>Maximum Displacement (mm)</td>
<td>5.101</td>
<td>7.324</td>
</tr>
<tr>
<td>3</td>
<td>Yield Strength (Mpa)</td>
<td>34.44</td>
<td>28.25</td>
</tr>
<tr>
<td>4</td>
<td>Tensile Strength (Mpa)</td>
<td>174.10</td>
<td>131.02</td>
</tr>
<tr>
<td>5</td>
<td>Youngs modulus (Gpa)</td>
<td>2.367</td>
<td>4.024</td>
</tr>
</tbody>
</table>

**XIII. PLOTS IN THE TENSILE TESTING**

The maximum load and number of layers was plotted for the eight and thirteen layered FML specimen and shown in Figure 6.

The Figure 6 shows the plot of maximum load response of thirteen layered and eight layered FML specimen. From the plot we observe that the maximum load bearing capacity of thirteen layered specimen is greater than for eight layer FML specimen.

**XIV. THE TENSILE STRENGTH AND NUMBER OF LAYERS PLOT**

The Tensile Strength and number of layers plot is shown in Figure 8 for the eight and thirteen layered FML specimen.

The Figure 7 shows the plot of Tensile Strength of the thirteen layered and eight layered FML specimen. From the figure, we observe that the Tensile Strength of thirteen layer specimen is lesser than the eight layer FML specimen.

**XV. THE STRESS AND STRAIN PLOT OF EIGHT AND THIRTEEN LAYER FML SPECIMEN**

The stress and strain plot for the eight and thirteen layered FML specimen is shown in Figure 8.

From the above figure we note that the thirteen layered FML specimen has more strength than the eight layered FML specimen.

**CONCLUSION**

The tensile testing of the FML specimen is done and various properties such as Tensile strength, Young’s modulus, Maximum load, Yield strength, and Maximum Displacement are evaluated. Here the parameters such as number of layers and stacking sequence of the fibres and metals are varied and their effects on the above properties are studied.

**REFERENCES**


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