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Mechanical Characterization of Adhesive in Lap Joint Under Tensile Load

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Abstract

The present work gives details of adhesive characterization in lap joints under quasi static tensile failure load. Rivets are major threat for an aircraft structure because of high stress concentration at lesser area ease to failure and also causes drag in aerodynamic perspective. Researchers are searching for a different method to avoid the stress concentrations in lesser area. The use of adhesives instead of rivets is most feasible solution for reducing stress concentration and aerodynamic drag. To investigate the strength of structures at joints, lap joint is made with adherends of Aluminium 8011, Mild steel 2062 and Glass fibre reinforced plastic is bonded with epoxy adhesives like Araldite AW 106 IN, Araldite AV 138 IN, Hindustan Speciality Chemicals HSC 7112. Tensile test on lap joint were carried out to find the ultimate static failure load of an adhesives. The ultimate failure loads were compared for the different adherends and adhesives to establish the best combination among them. The Load VS Displacement plots were also compared to establish the characteristics of adhesive joints. The results show that Araldite AV 138 IN for GFRP adherends gives higher failure strength compared to other adhesives and adherends. Hence the use of AV 138 IN adhesives at the joints will give better strength to the structures.

Keywords: Adhesive characterization, adherends, adhesives, tensile test, mechanical properties

INTRODUCTION

Recent years in aerospace industry, joining the components by adhesives are extensively being used. Boeing 737 of Aloha airline met in an accident at an altitude of approximately 7315.2 m, where an aircraft fuselage skin was ripped off, later in investigation it is found the failure was caused by a crack, were those cracks initiated at rivet holes in the lap joint. 70% of the failure of structures are initiated from the joints. To ensure the safety of joints, stress distribution analysis on joints is necessary. Stress concentration on the riveted joints is high, so the failure takes places quickly at the riveted joints. Adhesive bonded joints having advantages like higher strength, low production cost, less in weight and more importantly reduced stress concentration at the joints. Hence study on these adhesive bonded joints is important to have a safe structural joint.

Moreira and Nunes investigated the mechanical behaviour of a flexible adhesive joint in the overlap region [1]. The test result shows that the shear strain distribution in the adhesive layer decreases at the overlap ends. Grant et al., carried out series of tensile tests using toughened epoxy as adhesive and a grade of mild steel as adherend at temperatures ranging from–40 to +90 c◦ and the failure envelope moving up and down as the

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temperature increases or decreases respectively [2]. Ghanbari et al., investigated the load-carrying capacity of single-lap joints bonded with different adhesives under diverse room temperatures [3]. It is observed that the load-carrying capacity of single-lap joints decreased when the temperature is increased for two different adhesives that have approximately similar mechanical properties. Pinto et al., established the tensile strength of single lap joints between similar and dissimilar adherends bonded with an acrylic adhesive [4]. Reis et al., tested the tensile shear strength of single lap joints and found that the shear strength of joints was significantly influenced by adherend stiffness [5]. The superposition length influences the shear strength in different ways depending on the different adherend materials.

Yi Hua et al., investigated the performance of recessed single-lap joints with dissimilar adherends and spew fillet [6]. Shiuh-Chuan investigated about the adhesive bonded joint for single and double-lap joint [7]. The varying thickness of adherend and adhesive has an effect on high stress concentration on the free ends of adhesive bonding region and initiates the failure caused due to shear stress and transverse normal stress. Pires et al., supported the stress concentration towards the ends of a bonded lap joints to the relative stiffness of the adherend [8]. Lucas et al., exhibited that the lap shear strength is proportional to the overlap length and increases as adherend yield strength increases [9]. Lucas et al., investigated the supremacy of adhesive on the adherend and showed that the values on the lap shear strength depends on the overlap length followed by the type of adherend [10]. Han et al., carried out to examine the effect of specimen dimensions on mechanical behaviour of RSW welded joints and aluminium alloy AA5754 sheet in different thickness and the shear strength perceived was useful in assisting structural and manufacturing engineers in design and development [11].

Temiz et al., established that the use of curved end at lap joint increased the load-carrying capacity and the displacement capability of single lap joints [12]. Kocabas et al., investigated the material behaviour under static tensile strength and established that the critical overlap length depends on adherend yielding point [13]. Tomas et al., investigated the influence of adherent surface in the lap shear strength of adhesive bonded single lap joint [14]. Mechanically roughened and abrasive blasted surface gave quite good results compared to other types of surfaces. Mridusmita Roy and Kishore have found the width of the specimen for tensile failure load and type of bonding material for compressive failure load affecting the performance of the adhesively bonded joint [15]. Xiao et al., showed that the failure of the bond usually occurred at the interface of bond and bond types, length and thickness have significant effects on the failure of bond [16].

Researchers have conducted different testing on adhesive lap joints by using various adhesives and different material combinations[17-25], but still the different adherends on a single lap joint with different adhesive was inadequacy in literature. In this study, failure load of single-lap joint bonded with three different adhesive (AW106, AV136 and HSC7112) types have been determined in order to compare the effect of adhesive properties on the load-carrying capacity. Comparisons of different adherend and peel strength of the selected adhesives on the joint strength are the critical output of this study.

ARALDITES

Araldite AW 106 IN, Araldite AV 138 IN, Hindustan Speciality Chemicals HSC 7112 are a type of epoxy resin, and it is commonly used as an adhesive in various mechanical bonding applications. All these araldites are often used for structural bonding applications where a strong and durable bond is required. It can be used to join various materials, including metals, plastics, ceramics, and composites. Adhesive failure occurs at the interface between the adhesive and one of the adherends (the materials being bonded). In adhesive failure, the bond between the adhesive and the substrate is weaker than the cohesive strength of the adhesive itself. The failure typically happens within the adhesive layer, and the surfaces of the adherends may show minimal or no signs of bonding material. Cohesive failure occurs within the adhesive itself, meaning the adhesive material breaks apart internally. In cohesive failure, the bond within the adhesive is stronger than the bond between the adhesive and the adherends. The failure happens within the bulk of the adhesive, and both adherends may still have adhesive material attached to their surfaces. Adhesion refers to the attraction or bonding between molecules of different substances. It is the force that holds different materials together at their interface. Adhesion is crucial for joining dissimilar materials. It allows materials with different compositions to stick together, forming adhesive bonds. Cohesion refers to the attraction or bonding between molecules of the same substance. It is the force that holds similar or identical molecules together. Cohesion is essential for maintaining the structural integrity of materials. It is responsible for the internal strength and stability of substances.

EXPERIMENTAL DETAILS

Three different adherends (GFRP woven glass fabric of 400 GSM, Mild Steel IS 2062 grade and Aluminium 8011 alloy) and three different adhesives (AW106, AV136 and HSC7112) with hardeners (HV953, HV998 and HSC 8112) respectively were used to manufacture the single lap joints (SLJs). The investigation was to assess the effect of adherends and adhesives bonding strength of the SLJ, adherends with different yield behaviour and yield strength were needed. The selected materials are combined according to different sets of combinations as follows:

- Mild steel 2062–Mild steel 2062
- Aluminium 8011–GFRP
- GFRP–GFRP
- Aluminium 8011–Aluminium 8011
- Mild steel 2062–GFRP

The first set of combination the Araldite (AV 106) and hardener (HV953) mixed in the ratio of 10:08 was used as matrix material, second set of combination uses the Araldite (AV 138M) and hardener (HV998) mixed in the ratio of 10:04 and the last set of combination uses Araldite (HSC 7112) and hardener (HSC 8112) mixed in the ratio of 10:04. The adherends are prepared as per the ASTM 1002D testing standards. All the adherends are prepared identically of same geometry dimensions of 100 mm × 25 mm × 1.5 mm. The mixture with epoxy and hardener is then prepared and used on the adherends at the lap joints for a thickness of 1 mm, later allowed for 24 hours curing with hand wise clamped at the lap joints for all the test specimens. The typical test specimen dimensions are shown in Figure 1 and sample of the prepared specimens for the test are shown in Figure 2. The properties of the araldite are compared and shown in Table 1.

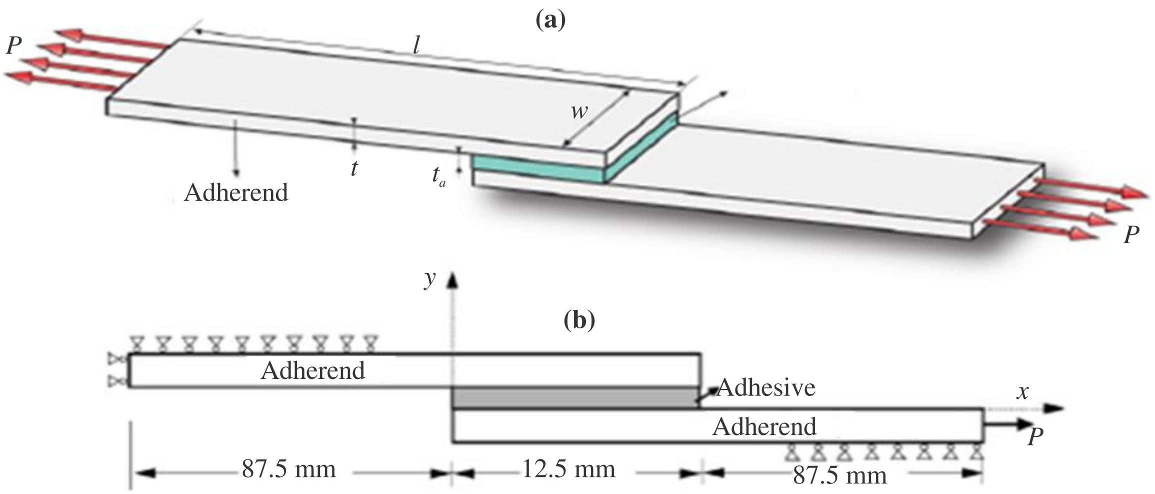

Figure 1. Typical test specimen dimensions. (a) Three dimensional single lap joint, (b) Boundary

conditions and geometric dimensions of bond joint [26].

Figure 2. Test specimens.

Table 1. Properties of araldite.

Properties	Araldite AW106	Araldite AV138	HSC 7112
Visual appearance	High-viscosity, opaque liquid	Beige	Milky paste
Viscosity at 25°C	25000–50000 (mPa.s)	Thixotropic	Thixotropic
Density at 25°C	1.2 (gm/cc)	1.7 (gm/cc)	1.7 (gm/cc)
Flash point	210(°C)	100(°C)	150(°C)

Tensile test was carried out in the hydraulic test machine as per ASTM1002D under constant rate 1.2 mm/min (quasi static condition). Wedge grips were used to clamp the specimens and all tests were displacement controlled, using the same conditions and a total of 45 specimens were tested.

RESULT AND DISCUSSION

The Stress versus stain curves of AA8011+ AA8011, MS-2062+MS-2062, GFRP+ GFRP, GFRP+ AA8011 and GFRP+MS-2062 bonded joints with araldite AW106, AV138 and HSC7112 were tested at room temperature are shown in Figure 3 to Figure 7 respectively. For each combination and with respective adhesive three sets of quasi-static tensile test were carried and their stress vs strain curves are plotted from the load vs displacement data obtained from the tests.

From the figures, the maximum and minimum failure load for three adhesives and metal-metal, metal-non-metal bonded strength was observed in the curve of joint tested at room temperature. For the test 2 of MS2062+MS2062 with HSC 7112 araldite has failed much earlier due to improper bonding, which is due to improper specimen preparation. So, in the adhesive joints it’s very important to prepare the material and their bonding carefully as per the testing standards. The average shear strength from the three-specimen test for AA8011+AA8011 adherend with three different araldites were found to be 6.104 MPa for AW106, 9.70 MPa for AV138 and 5.688 for HSC 7112 respectively. The shear strength for MS2062+MS206 adherend with three different araldites were found to be 8.40 MPa for AW106, 15.08 MPa for AV138 and 5.823 for HSC 7112 respectively. The shear strength for GFRP+GFRP adherend with three different araldites were found to be 12.134 MPa for AW106, 13.72 MPa for AV138 and 10.436 for HSC 7112 respectively.

The shear strength for GFRP+AA8011 adherend with three different araldites were found to be 5.134 MPa for AW106, 7.141 MPa for AV138 and 3.63 for HSC 7112 respectively. The shear strength for GFRP+MS206 adherend with three different araldites were found to be 9.498 MPa for AW106, 11.092 MPa for AV138 and 8.802 for HSC 7112 respectively. From the results it is observed that AV138 adhesive has better performance than other two adhesives. In metal-metal combination,

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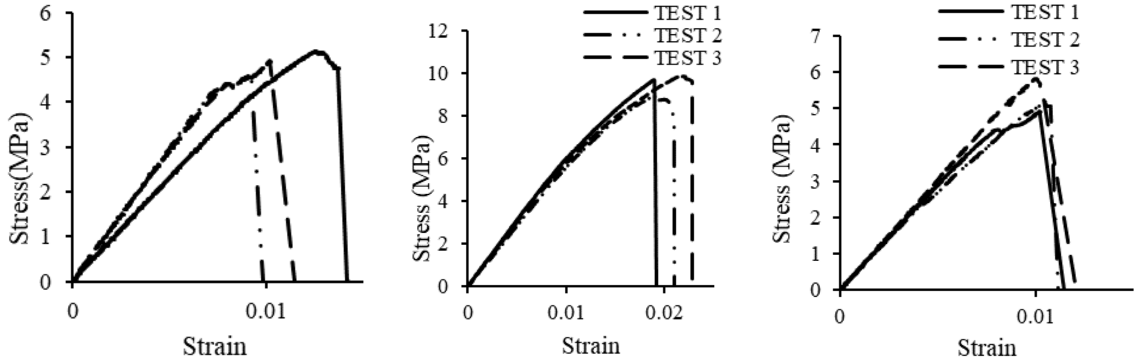
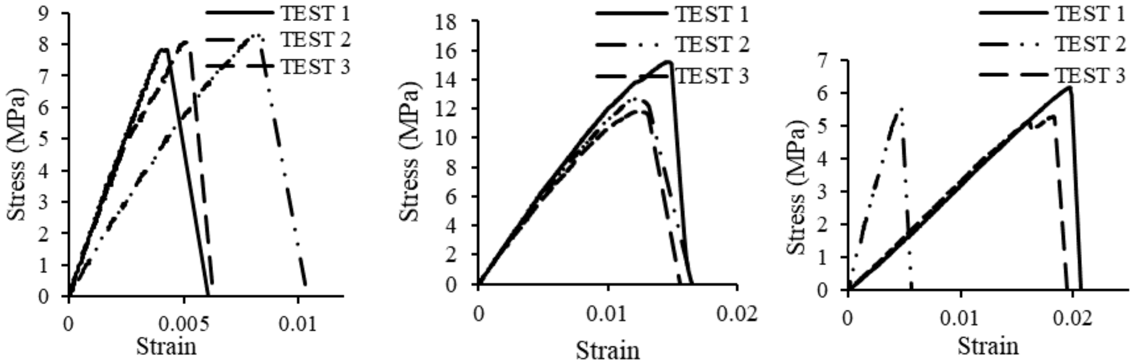


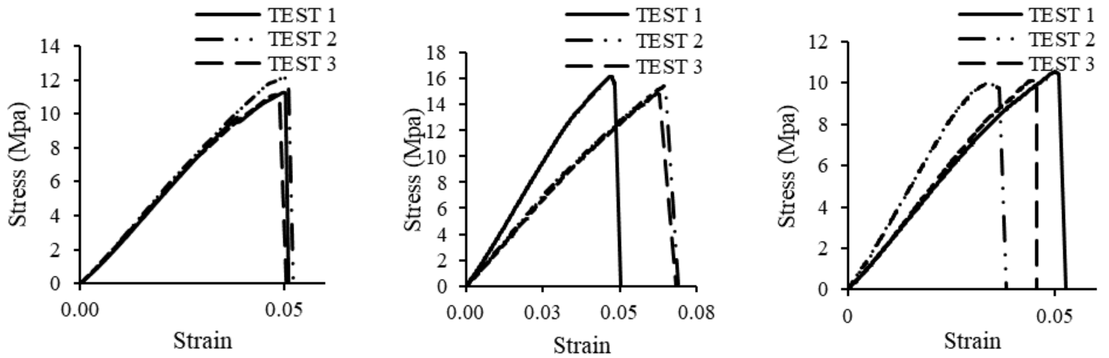
Araldite AW106 Araldite AV138 HSC 7112

Figure 3. Stress vs Strain curve of AA8011+AA8011.



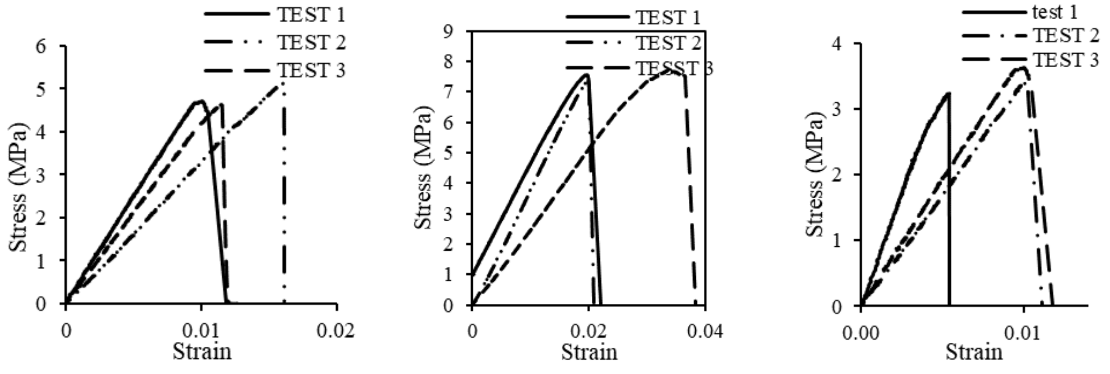
Araldite AW106 Araldite AV138 HSC 7112

Figure 4. Stress vs Strain curve of MS2062+MS2062.



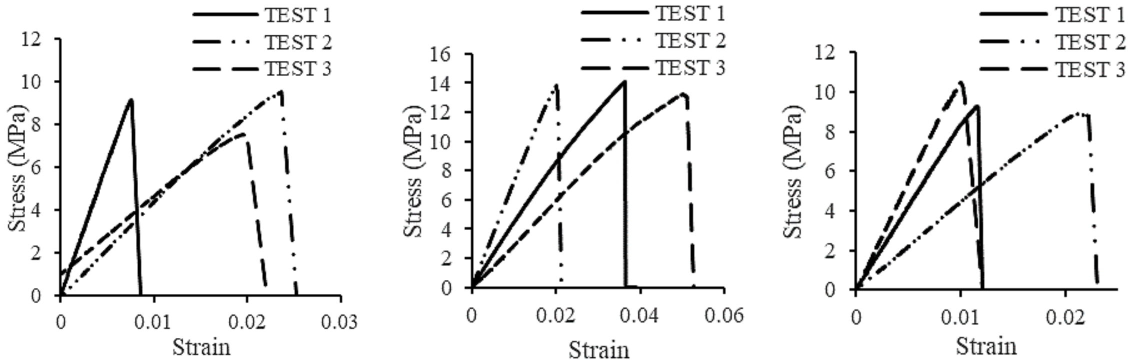
Araldite AW106 Araldite AV138 HSC 7112

Figure 5. Stress vs Strain curve of GFRP+GFRP.



Araldite AW106 Araldite AV138 HSC 7112

Figure 6. Stress vs Strain curve of GFRP+AA8011.



Araldite AW106 Araldite AV138 HSC 7112

Figure 7. Stress vs Strain curve of GFRP+ MS2062.

epoxy adhesive araldite AV138 in mild Steel shows the best results with the stress value of 13.23 MPa and the Strain value of 0.016. In non-metal-non-metal combination, epoxy adhesive araldite AV138 in Glass Fiber Reinforced Plastic-Glass Fiber Reinforced Plastic shows the best results with the stress value of 13.73 MPa and the Strain value of 0.063.

CONCLUSIONS

Adhesives bonded lap joints have wide range of application in the many industries because of the less stress concentration over a jointed area. Riveted joints failure contributes around 70% of the failures in the jointed structures. Hence, there is a need to study on adhesives at joints that are capable of withstanding higher loads for long duration. The following findings are derived from the investigation of adhesive lap joints under quasi static tensile load.

- In Metal-Metal combination, Epoxy adhesive Araldite AV138 in Mild Steel 2062 Mild Steel 2062 shows the best results with the stress value of 13.23 MPa and the Strain value of 0.016.
- In Non-Metal-Non-Metal combination, Epoxy adhesive Araldite AV138 in Glass Fiber Reinforced Plastic-Glass Fiber Reinforced Plastic shows the best results with the stress value of 13.73 MPa and the Strain value of 0.063.
- In Metal-Non-metal combination, Epoxy adhesive Araldite AV138 in Glass Fiber Reinforced Plastic-Mild Steel 2062 shows the best results with the stress value of 11.09 Mpa and the Strain value of 0.11.
- It is observed that AV138 adhesive has better performance than other adhesives.

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