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Fabrication and tensile testing of composite hybrid joints

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ABSTRACT

The composite joint strength to weight ratio was found based on actual joint arrangements in the aircraft structure and the test results were helped to the research to composite joint design and analysis. The experimental study, conventional hybrid and hybrid joints with curved attachments of different angles (12°, 16°, 24°) are designed fabricated and tested using UTM Machine which has the maximum capacity of 600 kN until the catastrophic failure of the joints. The results obtained tensile strength and failure modes are compared to find the better joint configuration. The joint has 117% more strength than the conventional joints.

Peer-review under responsibility of the scientific committee of the International Conference on Recent Trends in Nanomaterials for Energy, Environmental and Engineering Applications.

1. Introduction

Nanotechnology the principle of combining different joining methods and materials is often referred to as hybrid joining [1]. In this paper different joining methods are used, with adhesive and mechanical fastener are used together [2–4]. In hybrid joining, mechanical fastener acts as a fail-safe design, because until the adhesive joint fails fasteners do not contribute to the tensile strength [5].

The adhesive joint failure, mechanical fastener will act as additional weight structure. To overcome that, attachments are helped in order to supply alternate load paths to forward the load to the fastener [6–7]. The fasteners will give strength to the joint when the structure is loaded. The attachment would also reduce the amount of load induced in the adhesive joint and increase the overall strength of the hybrid joint [8].

2. Fabrication of specimens

For analysis, two different types of joints in composite materials such as conventional hybrid joint, hybrid joint with curved attachment consisting of three different angles (120, 160, 240) are prepared. The specimen dimensions are taken according to ASTM D1002 [9]. Twelve specimens of three in each joint for tensile testing have been prepared by hand lay-up process. Hand lay-up is a molding process where fiber reinforcements are placed by hand then wet with resin [10,11]. The manual nature of this process allows for almost any reinforcing material to be considered, chopped strand or mat [14–19]. The material of adherent plates, adhesive and fastener are likely Glass/Epoxy composites, Epoxy resin and stee [12] l. (see Fig. 1.1).

2.1. Conventional hybrid joint

The specimen dimensions are taken according to ASTM D1002. Fig. 2.1 represents the conventional hybrid joint. The bolt diameter is chosen to be approximately same as the thickness of the joint [13]. Hybrid joints include a combination of two different fusion processes or a combination of two different types of adhesive (see Fig. 2.2,).

Angle is calculated by using the above triangle, the angle of the attachment is calculated as follows.

$\theta = \tan - 1$ (h/d)where,

h – Load transfer height

d – Load transfer distance

By varying the load transfer distance of the attachments, different angle of the attachments are calculated as shown in the triangle. Similarly hybrid joint with curved attachments of angle 160 and 240 are also fabricated by hand lay-up process.

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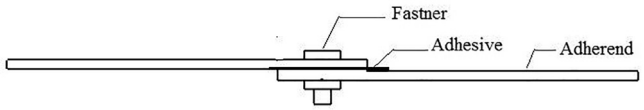

Fig.1.1. Conventional Hybrid Lap Joint.

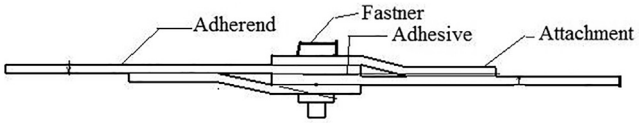

Fig.1.2. Hybrid Lap Joint with Curve Attachments.

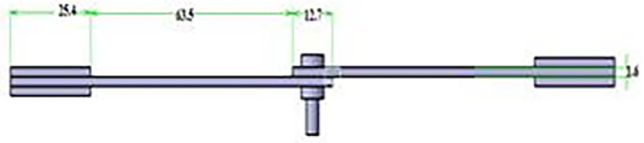

Fig. 2.1. Two dimensional view of Conventional Hybrid Joint.

3. Specimens fabricated for testing

3.1. Conventional hybrid joint (H1, H2, H3)

3.1.1. Hybrid joint with curved attachment (12°) (C1, C2, C3)

Three hybrid joint with curved attachment with angle 12° is fabricated and is represented as C1, C2, C3 are shown in Figs. 3.1–3.3.

4. Testing

4.1. Determination of tensile strength of composite joints

All the specimens have been tested using the "UTE 40" which has a maximum capacity of 600kN until the catastrophic failure the joints occur.

The graph of 3 conventional hybrid joint samples is shown in Fig. 4.1

Using tensile test data of conventional hybrid joint, the average tensile strength of three specimens is obtained as 15 N/mm^2.

4.2. Hybrid joint with curved attachments

The graph shown in Figs. 4.2, 4.3, 4.4 represents the displacement vs load curve for hybrid joint with curved attachment of 12°, 16° and 24°. Fig. 1.2.

The average tensile strength of hybrid joint with curved attachment of 12° is obtained as 18.67 N/mm^2.

Fig. 3.1. Conventional Hybrid Joint Specimen.

Fig. 3.2. Hybrid joint with curved attachment (12°).

Fig. 3.3. Hybrid joint with curved attachment (24°).

5. Results and discussions

For comparison purposes, the bar chart representing tensile strengths of the conventional hybrid joint and hybrid joint with curved attachments of three different angles is shown in Fig. 5.1.

From the test data plotted in the above chart, it is clear that the tensile strength of 160 curved attachments is very high and load transfer to the bolt is good. Though the weight of attachment

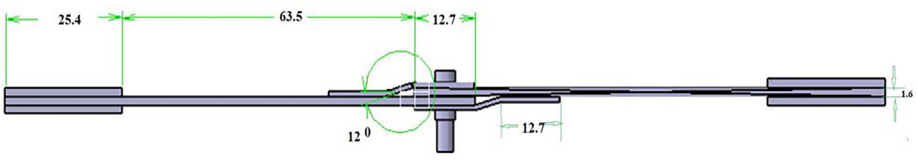

Fig. 2.2. Hybrid joint with curved attachment of 12°.

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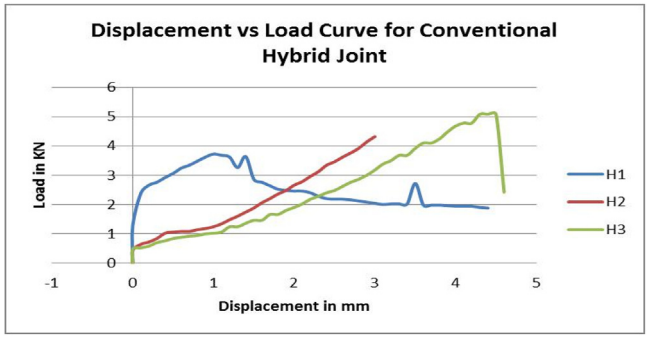

Fig. 4.1. Displacement Vs Load graph for Conventional Hybrid Joint.

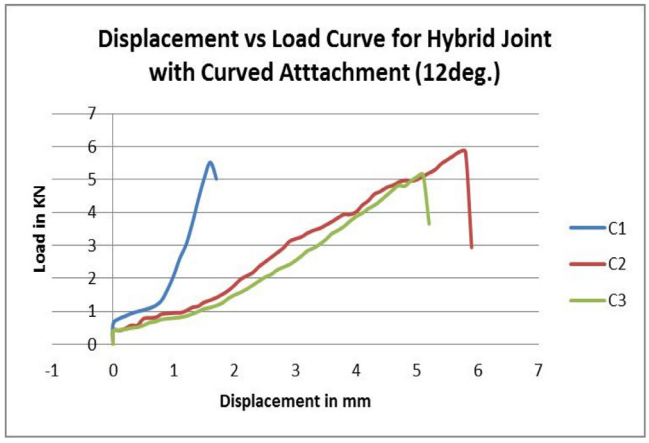

Fig. 4.2. Displacement Vs Load graph for Hybrid Joint with Curved Attachment (12°).

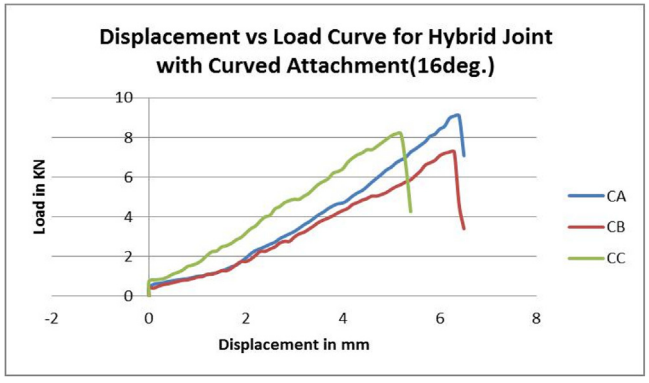

Fig. 4.3. Displacement Vs Load for 16 deg.

increases, the strength to weight ratio is observed to be high. Fig. 5.1 shows the bar chart representing the strength to weight ratio of all joint configurations. From the bar chart shown in Fig. 5.1, it is observed that hybrid joint with curved attachment of 160 possesses high strength to weight ratio compared to conventional hybrid joint and hybrid joint with curved attachment of 120 and 240. Hence taking all the results into consideration, hybrid joint with curved attachment of 160 is found to be more effective in all cases.

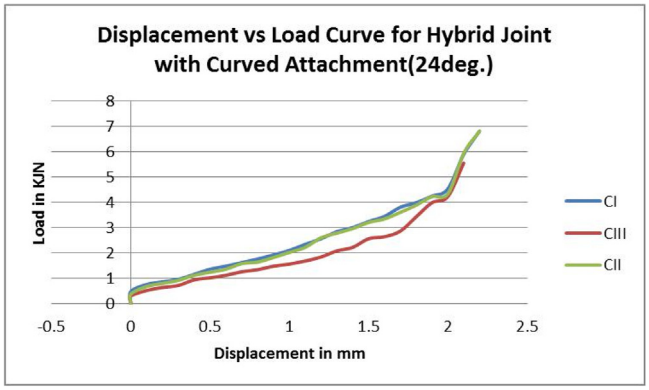

Fig. 4.4. Displacement Vs Load for 24 deg.

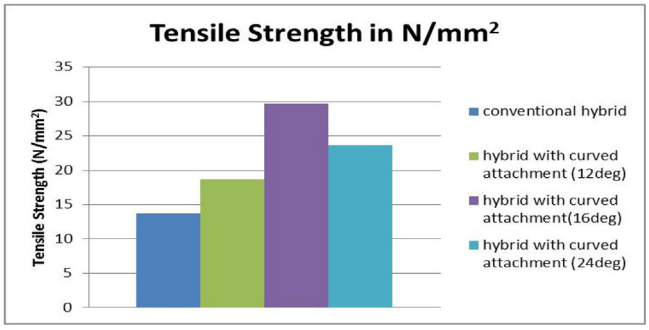

Fig 5.1. Bar chart representing tensile strengths of different joints.

6. Conclusions

According to the results obtained, from the tensile testing of the different specimens consisting of conventional hybrid joints, hybrid joints with curved attachments of angles 120, 160, 240, the hybrid joints with curved attachments shows a significant improvement in ultimate tensile strength when compared to the conventional hybrid joints, which is 36%, 117%, 72% increase over the conventional hybrid joints.

Once the adhesive joint failed the hybrid joint with curved attachments held at a higher load compared to the conventional hybrid joints. The results obtained shows that adding attachments to a conventional hybrid joint could improve the ultimate tensile strength of the hybrid joint and load transfer to the bolt is better. It is also observed that attachments would reduce the amount of load induced in the joint once the structure was loaded. Also the curved attachment of angle 160 has higher average ultimate tensile strength compared to the curved attachments of angles 120, 240.

The hybrid joint with curved attachments of angles 120, 160, 240 are on average 10.4%, 6.67%, 6.18% are heavier than the conventional hybrid joint. From the results obtained, it is clear that the hybrid joint with curved attachment of angle 160 has better strength compared to the other joint configurations and its increase in weight is acceptable because of its increase in tensile strength which is depicted by strength to weight ratio.

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