Evaluation of Adhesive Failure in Similar And Dissimilar Single Lap Joint

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Abstract: Single-lap joints made of aluminium and aramid fibre adherends are tested to understand better the behaviour of such dissimilar joints. Peeling and shearing strains are investigated, emphasizing that peeling is important in the region where failure is initiated, towards the extremity of the overlap region. Ansys was used to simulate the behaviour and strength of dissimilar single-lap adhesively bonded joints.Experiments show that the use of dissimilar stiffness of the joints aluminium-aramid and aramid-glass adherends is reducing the strength and as the delamination and pull-out of the aramid fibres compromises their integrity.

Keywords: Aluminium , glass/Kevlar composite, epoxy resin, adhesively-bonded joints, tensile test, FEA.

1.Introduction

During the past three decades, the application of composite materials has continuously increased from traditional application areas such as military aircraft and commercial aircraft to various engineering fields, including automobiles, robotic arms and even architecture. Due to their superior properties, composites have been one of the materials used for repairing existing structures[1]. In such applications, they are used for joining various composite parts and are fastened together using either adhesives or mechanical fasteners. In order to understand the mechanical behaviour of adhesively-bonded joints, many studies have been carried out, different models have been proposed and different methods have been used. One of these methods is based on the strength of Materials. One of the key areas in composite structural design involves the joint strength. Adhesively-bonded lap joints are most preferred because they develop a smooth load transfer and have fewer points of stress concentration when compared to fastened joints, where the failure prediction of such joints is extremely important since their failure might lead to catastrophic failure in aircraft during its service period. Adhesively-bonded structures are used to obtain lighter weight and efficient structures. In adhesively-bonded aircraft, metals and composite structures such as stringers, ribs and sandwich skin panels and channel sections are bonded to the fuselage or wings to increase strength and rigidity. The bonded structure has the advantage of light weight and is cost-effective. The structure consists of an assembly of sub-structures properly arranged and connected to form a load transmission path. Such a load transmission path is achieved using joints. Joints constitute the weakest zones in the structure. Failure may occur due to various reasons, such as stress concentrations, excessive deflections or a combination of these. Therefore, to utilise the full potential of composite materials, the strength and stress distribution in the joints has to be understood so that a suitable configuration can be chosen for various applications. The shear strength decreases considerably as the binding area expands, which could be the result of the fact that the deformation resistance occurring in small areas was more than in large areas and two different failures at single lap joints were caused by the peel stress and shear stress.

Fig 1.GLASS FIBRE

Fig 2.KEVLAR FIBRE

The aim of the present paper is to investigate the characteristics of failure modes and the strength of composite bonded lap joints at two different overlap thicknesses with zero degree fibre orientation using acoustic emission data and finite element analysis.

1.1 classification of failure mode:

Seven typical characterised modes of failure in fibre-reinforced polymer bonded joints are

1.ADHESIVE FAILURE.

2.COHESIVE FAILURE

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3.THIN LAYER COHESIVE FAILURE

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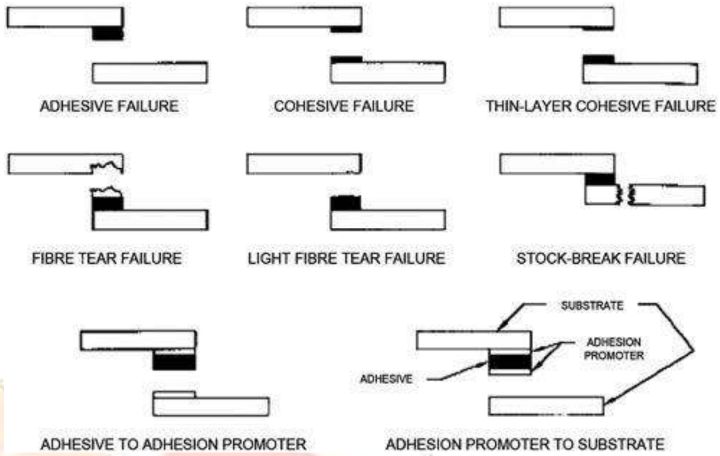
4.FIBRE TEAR FAILURE.

5.LIGHT FIBRE TEAR FAILURE.

6.STOCK BREAK FAILURE.

7.MIXED FAILURE.



2. Specimen preparation

Composite panels were prepared through a hand lay-up process.The unidirectional glass fibre is placed over the resin (LY 556 with hardener HY951) and with a stippling action using a resin wetted brush, the resin is squeezed onto the top surface. After the first layer is laid up, subsequent layers are laid up in a similar manner. This procedure was repeated until the required thickness had been built up. The specimens of size 100 × 25.4 × 3 mm were cut using water-jet cutting to avoid machining defects and to maintain a good surface finish from the fabricated laminates.The adherend surfaces cleaned with acetone were bonded for a single lap joint specimen.. A total of 30 specimens were prepared.Which contains 15 of glass , 15 of Kevlar. The use of bonded joints in primary load-bearing structures makes it important to understand their failure and maximum joint strength.

2.1Method of fabrication:

Hand lay method:

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment.

PROCESS:

Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness.

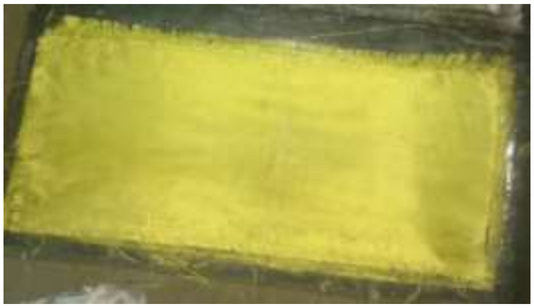


Fig 3. LAMINATION OF KEVLAR FIBRE

Fig 4. LAMINATION OF GLASS FIBRE

After cutting the laminates:

Fig 5. SPECIMEN OF KEVLAR

Fig 6.SPECIMEN OF GLASS

Fig 7.SPECIMEN OF ALUMINIUM

3.Fillers

Aluminium oxide 1.5% (Al_2o_3) , Calium Carbonate 1.5% (Caco$_3$) , Silicon Dioxide 1.5% (Sio$_{2)}$. All the three fillers are mixed with the epoxy resin of 1% and some amount of hardner (HY 951) added to the combination.

3.1 Configuration

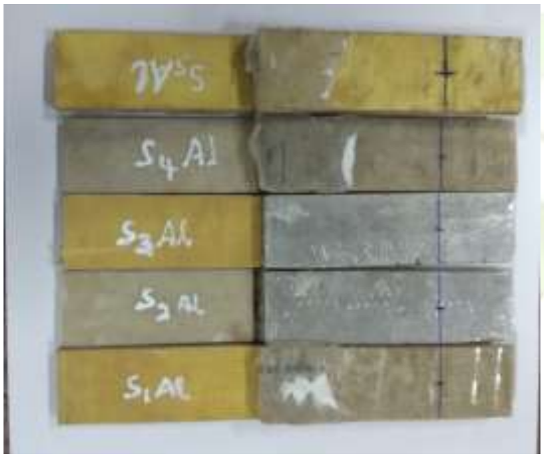


Fig 8.ALUMINIUM FILLER LAP JOINT

Fig 9.SILICON DIOXIDE FILLER LAP JOINT

Aluminium Oxide

Al2o$_3$-Kevlar and Kevlar
Al2o$_3$-Glass and Glass
Al2o$_3$-Kevlar and Aluminium
Al2o$_3$-Glass and Aluminium
Al2o$_3$-Kevlar and Glass

Silicon Dioxide

Sio$_2$-Kevlar and Kevlar
Sio$_2$-Glass and Glass
Sio$_2$-Glass and Kevlar
Sio$_2$-Aluminium and Kevlar
Sio$_2$-Aluminium and Glass

Fig 10. CALCIUM CARBONATE FILLER LAP JOINT

Calcium Carbonate
Caco$_3$-Kevlar and Aluminium
Caco$_3$-Kevlar and Glass
Caco$_3$-Kevlar and Kevlar
Caco$_3$-Glass and Aluminium
Caco$_3$-Glass and Glass

3.2 Testing

The specimens were subjected to uni-axial tension until they failed in a 50 kN universal testing machine (UTM) . The specimens were mounted on the UTM machine and the dimensions of the specimens were entered into the software. The crosshead speed was maintained at a rate of 1mm/min.

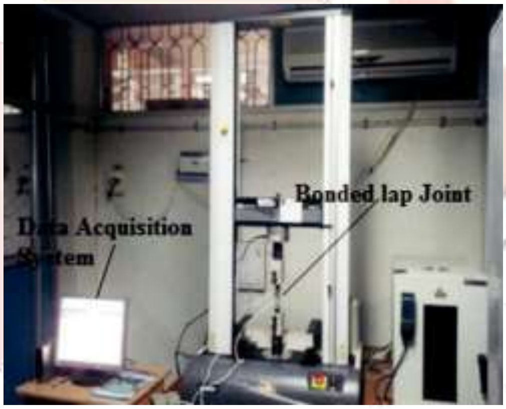


Fig 11. UNIVERSAL TESTING MACHINE

Fig 12. BREAKING OF SPECIMEN IN UTM

4.Graph

Aluminium Oxide

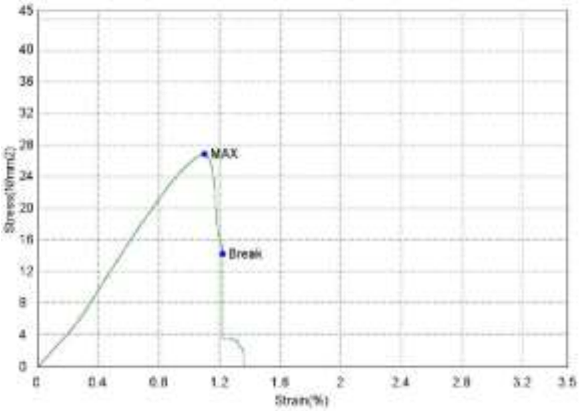


Fig 13. Al2o$_3$-Kevlar and Kevlar

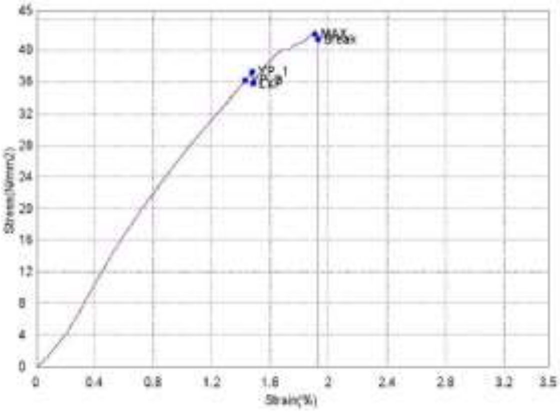


Fig 14. Al2o$_3$-Glass and Glass

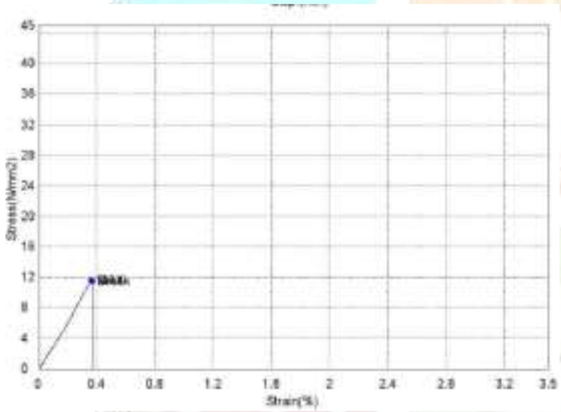


Fig 15. Al2o$_3$-Kevlar and Aluminium

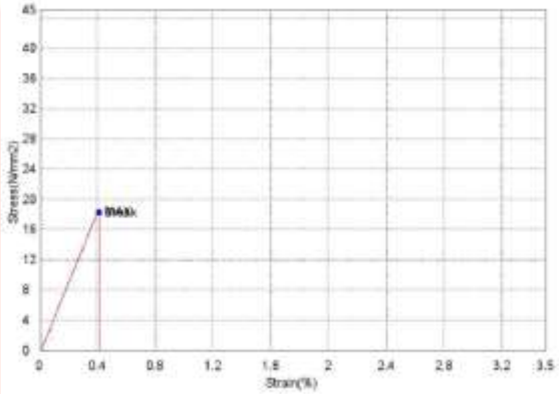


Fig 16. Al2o$_3$-Glass and Aluminium

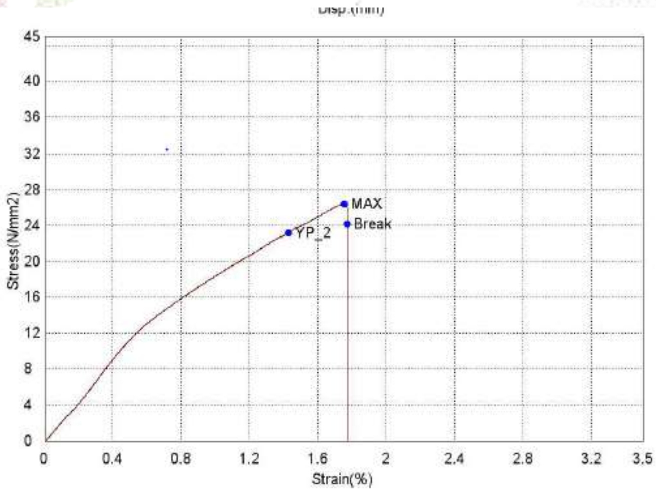


Fig 17.Al2o$_3$-Kevlar and Glass

Silicon Dioxide

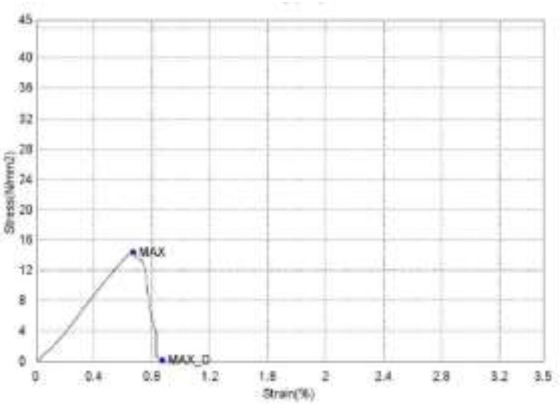


Fig 18. Sio$_2$-Kevlar and Kevlar

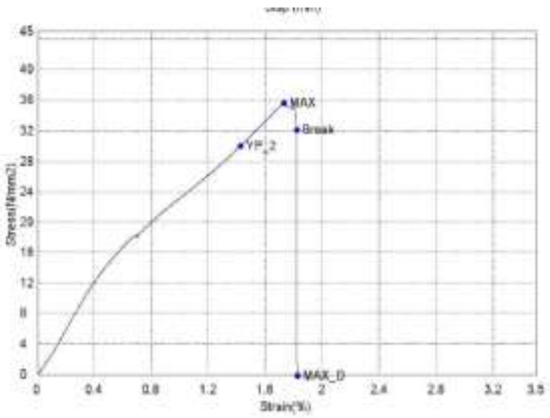


Fig 19. Sio$_2$-Glass and Glass

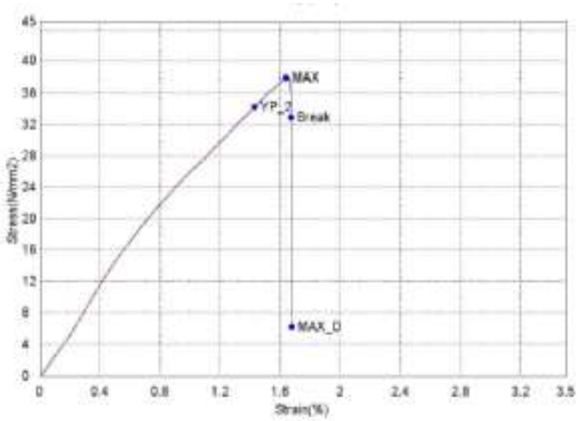


Fig 20. Sio$_2$-Glass and Kevlar

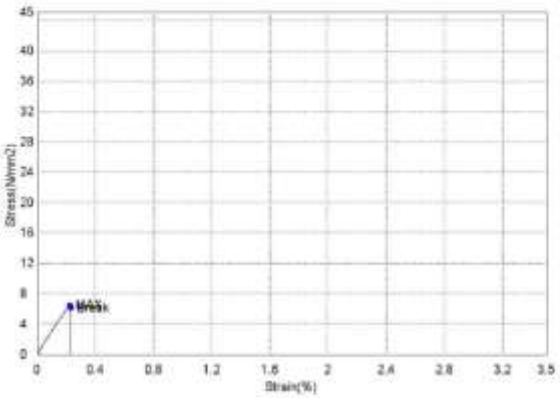


Fig 21. Sio$_2$-Aluminium and Kevlar

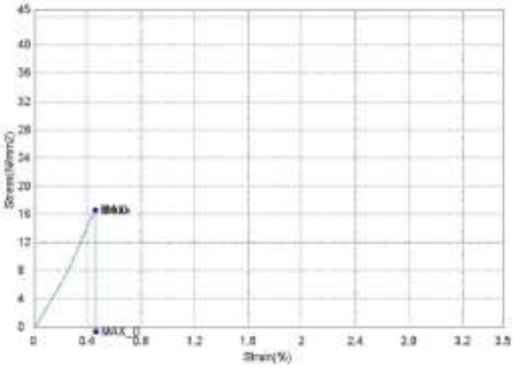


Fig 22. Sio$_2$-Aluminium and Glass

Calcium Carbonate

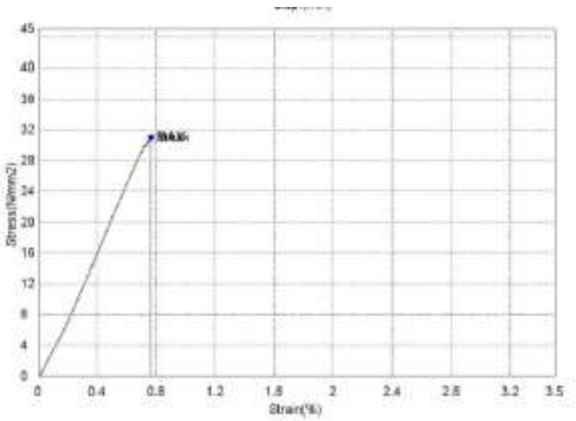


Fig 23. $CaCO_3$-Kevlar and Aluminium

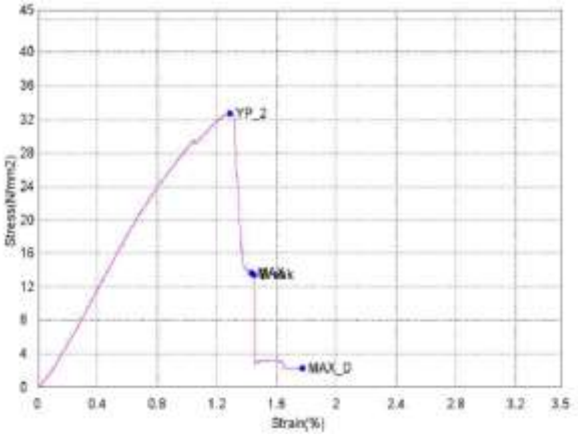


Fig 24. $CaCO_3$-Kevlar and Glass

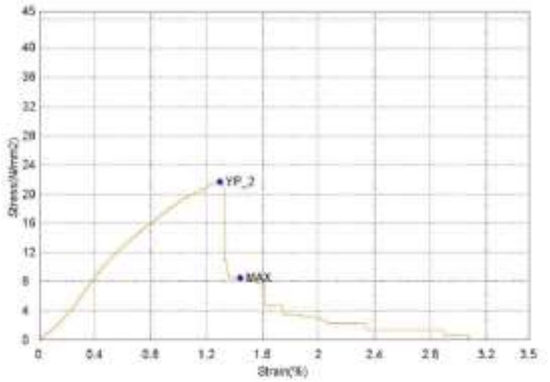


Fig 25. $CaCO_3$-Kevlar and Kevlar

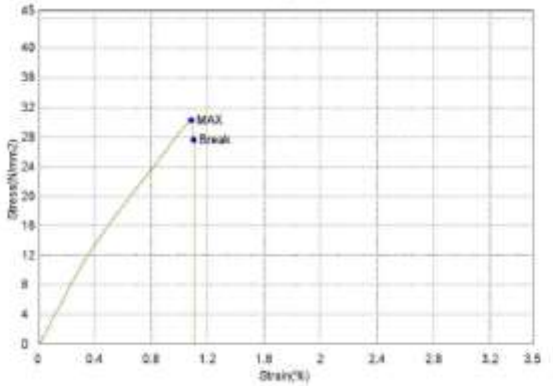


Fig 26. $CaCO_3$-Glass and Aluminium

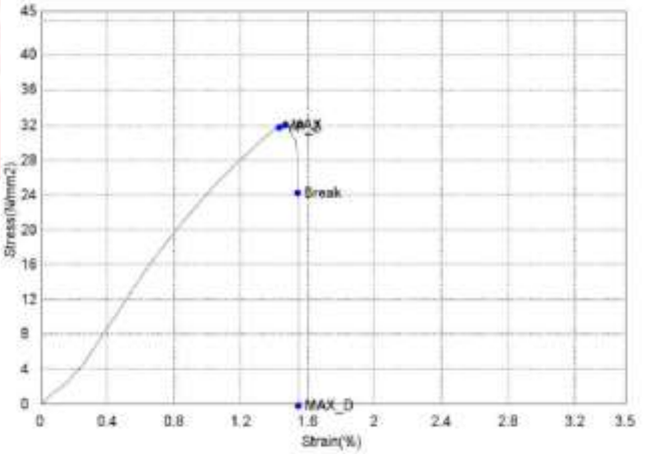


Fig 27. $CaCO_3$-Glass and Glass

5. Result

The ultimate loads of bonded lap joints with adhesive thicknesses of 0.2 mm were founded. That similar metal lap joint are Able to withstand than the dissimilar metal lap joint.

5.1. Conclusion

In the present paper, the response of single lap joints with composite adherend subjected to tensile load was investigated for three different adhesive fillers.Experimental data showed that the maximum stress occurred at the corner sections of the joint, whereas minimum displacement occurred at 0.2 mm .The suitable strength prediction of the adhesively-bonded joints is essential to decrease the amount of expensive testing at the design stage.

It provides more structural integrity applications during assembly of parts.

Adhesive strength of selected material can reduce the cost of failure and maintenance.

It is a practical method for joining composite materials, though it has low shear and tensile strength and joint efficiency, including automobiles, robotic arms and even architecture.

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