Effect of Surface Roughness on Single Lap Adhesive Joint Strength

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Abstract : - The requirements for lightweight in automotive, aerospace and construction industries have led to a trend of replacing commonly used steel by aluminum alloy, fiber reinforced plastic and other types of alloy in auto- mobile parts, such as roofs, doors and engine covers. However, some traditional joining methods, such as riveting, bolting and threading and welding are not suitable to be applied in joining dissimilar materials and may bring problems in inevitable stress concentration. Epoxy-based adhesive has a wide range of applications in bonding similar & dissimilar materials for better lightweight effect. In this project, experimental comparison and investigations were carried out to study the performance and make a comparison between one, two, three, and four different adhesive joint layer thickness and roughness value on joint strength and mechanical properties

***Index Terms* – adhesive bonding, aluminum alloy, roughness, shear strength, single lap joint.**

I. INTRODUCTION

Adhesives have been widely used in the automotive, aerospace and construction industries to replace the conventional joining techniques. The lack of accurate strength prediction of adhesively bonded joints exposed to long-term hot-humid environment inhibits a more wide-spread application of adhesive bonding. Reliable strength prediction model is essential to reduce the amount of expensive and time Consuming durability testing at the design stage with the increasing use and importance of adhesive bonds in structural engineering a high demand for the optimization of adhesive joint designs has developed. Understanding of the mechanical behaviour is required. In particular, this includes the knowledge about the load transfer and the resulting stresses in adhesive joints. The different parameters that will effect on the joint strength and durability like as

- surface preparation methods
- Joint Bond thickness
- Types of adhesive use
- Types of adherend surface

Surface preparation is one of the important parameters which is directly related to the quality of the bonded joint.

II. LITERATURE REVIEW

The work of different researchers in the area of strength analysis of single lap adhesive joint is presented below Xiacong He (2010) reviewed the recent work relating to finite element analysis of adhesively bonded joints, in terms of static loading analysis, environmental behaviors, fatigue loading analysis and dynamic characteristics of the adhesively bonded joints. It is observed that the finite element analysis of adhesive bonded joints will help future applications of adhesive bonding by allowing system parameters to be selected to give as large a process window as possible for successful joint manufacturing. This will allow many different designs to be simulated in order to perform a selection of different designs before testing, which would currently take too long to perform or be prohibitively expensive in practice. [1] Yasmine Bouter (2015) investigated the performance of recessed single-lap joints with similar and dissimilar adherends through the finite element method. The influence of material and geometric nonlinearity of the adhesive as well as the impact of the recess length was examined in terms of maximum principal stresses. The strength of the joint is obtained as the load to initiate the crack propagation. Results suggested that either adding a spew fillet or considering the adhesive plasticity led to reduced peak stresses at the edge of the adhesive layer. Large stresses occurred at the interfaces rather than the middle plane of the adhesive layer, which implied a limitation of analytical solutions. [2]

III.EXPERIMENTAL SET UP

3.1 Materials

Aluminum AA6063 is used as adherends in this study. Aluminum alloy cut by hand shearing machine at required dimension of “200 mm x 25 mm x 2 mm”. A bicomponent structural epoxy adhesive Araldite® 2015 supplied by Huntsman International (India)Private Limited) was selected for this study. Mechanical properties of Araldite® 2015 and aluminum AA 6061 are summarized in table number 1 and 2.

Table 1 Epoxy Adhesive Araldite® 2015

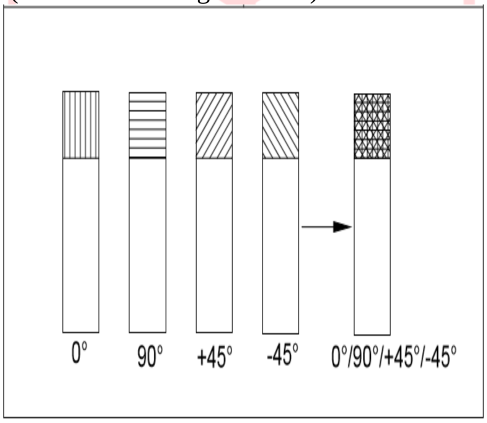
Sr No	Property	value
1	Young's modulus, E (GPa)	1.85±0.21
2	Shear Yield strength (MPa)	14.6±1.3
3	Shear Modulus G GPa)	0.56 ± 0.21
4	Poisson ratio	0.33

Table 2 Epoxy Aluminum 6061

Sr No	Property	value
1	Tensile strength (MPa)	110-152
2	Yield strength (MPa)	65-110
3	Elongation of Failure %	14 to 16
4	Shear Modulus G GPa)	20-25
5	Young's modulus, E (GPa)	70-80
6	Poisson ratio	0.33

3.2 Surface Preparation of Sample

Two kinds of adhered surface were used, abraded surface are prepared by using a different grade of emery paper. Three different grades of emery paper, P50, P80 and P120 are used for the making the different surface roughness values and the flat plate without abraded surface were measured with the help of digital surface roughness tester. The surface roughness pattern applied to the adherend was 0°, 90° and ±45° orientations (relative to loading direction).



3.2 Geometry of Surface Roughness Pattern (0°/90°/+45°/-45°).

Shows the surface roughness pattern used for all aluminum adherend. Two roughness parameters the average surface roughness value (Ra) and the maximum surface roughness value maximum height of profile, (Rz) were used to evaluate the surface quality of the specimens. Surface roughness values, Ra and Rz were measured using a digital surface roughness tester made by (Mitutoyo-3100, Japan) for both abraded and non-abraded four samples. The surface roughness measurements were performed in different areas, along two different directions. The measured surface roughness values, Ra and Rz of aluminum adherend are given in table 3

3.2.1 Surface preparation

Table 3 Surface roughness value

Sample no	Ra µm	Rz µm
1	0.06	0.18
2	0.41	0.65
3	2.46	7.70
4	3.61	8.60

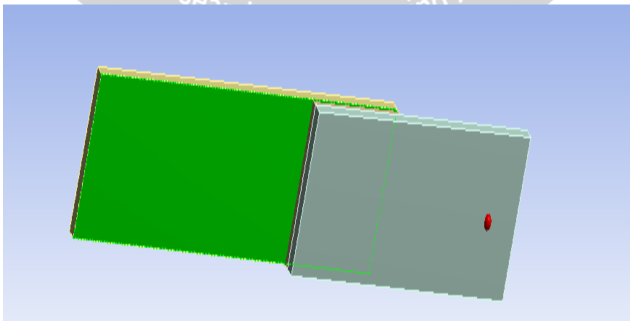
3.3 Testing on UTM

I was prepared the four different sample of given material with the size “200 mm x 25 mm x 2” mm with the different layer thickness value like a 0.5, 0.7, 1.0, 1.5 mm. The overlap (gauge) length of every joint has 40 mm. The specimens were tested in a Universal Testing Machine (Made by Blue Star, Model UTE 20) at a crosshead rate of 5 mm/min. The UTM was connected with a computer for automatic data acquisition and storage. Single strap shear tests were carried out in tensile testing mode. Four specimens were tested for each condition. The gripping length was kept at 30 mm at both ends, while the gripping width was over the whole width of the specimen. The tensile test set-up is as shown in Figure. The load and displacement values were recorded during the tests.

3.3 Experimental set up of SLJ

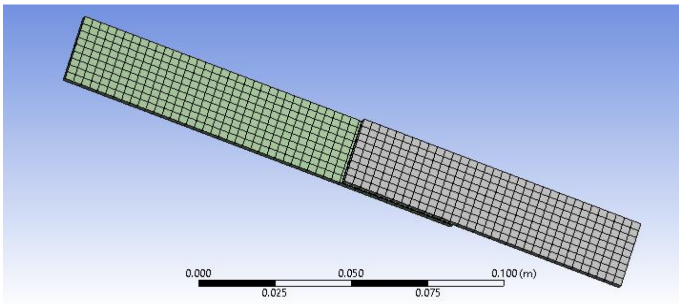
3.4 Finite Element Analysis of Single Lap Joint

In numerical analysis the commercial FEA ANSYS 14.5 software has been used. The same geometry and different roughness of single lap bonded specimens was tested experimentally and numerically modelled by using two-dimensional 8-node isoperimetric finite element. Simulations of axial stretching of the bonded joints have been carried out under the same boundary conditions as in experimental work.



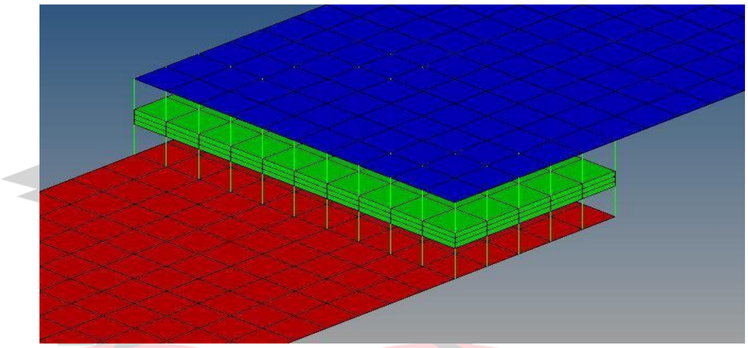
3.4 3 D model of SLJ

First make a 3D model in catia V5 in given dimension as bellow. Width of joint is 25 mm, length of first and second plate are 100 mm, 140 mm, thickness of plate is 2 mm. To mesh the plates, after clean up the geometry, mesh both plates one by one. Enter the following values. Element Size: 2 Mesh Type: quads Click on mesh button. A uniform mesh will be generated. The meshed component will be as shown in figure.



3.4. (a) Meshing of SLJ

For creating adhesive connection between two plate first of all hide one meshed plate then select some of the elements on bottom plate. Then click on elements and select by adjacent to select required row of elements to join. For components click on components and select Al Plate 01 and Al Plate 02



3.4. (b) Adhesive Connector

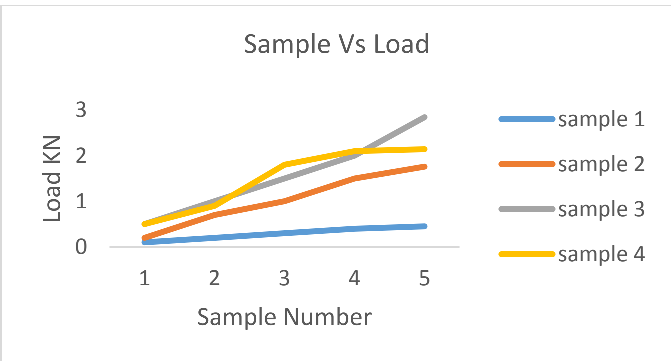
After the addition of adhesive connecter apply the boundary condition which is found by experimentally and find the different result like as Shear Stresses, Von Mesh Stresses, Principle stresses etc.

IV. RESULT AND DISCUSSION

I was found that different parameters of single lap joint with the help of experimental as well as FEA procedure is repeated for different loads at adhesive thickness of 0.5,0.7,1.0 and 1.5 mm and determine the respective stresses. The values obtained by analysis and experimentation are entered into tabular form table 4 The graph showing relation between load applied and stresses.

Table 4 load and samples

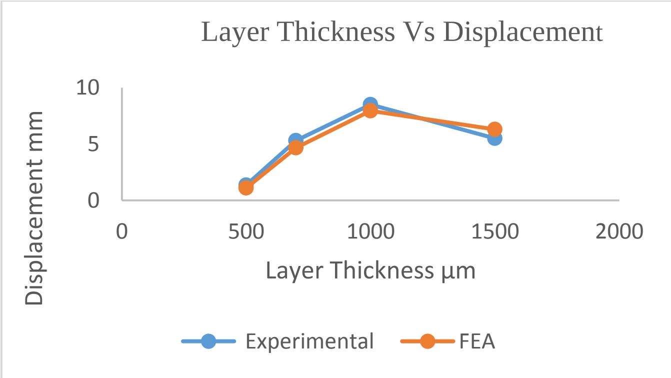
	sample 1	**sample 2**	**sample 3**	**sample 4**
Load KN	0.1	0.2	0.5	0.5
	0.2	0.7	1	0.9
	0.3	1	1.5	1.8
	0.4	1.5	2	2.1
	0.45	1.76	2.84	2.14



In my experimentation I have been used four different layer sample of a layer thickness is given in bellow table at the time of loading observed the displacement with the help of strain gauge.

Table 5 Thickness and Displacement

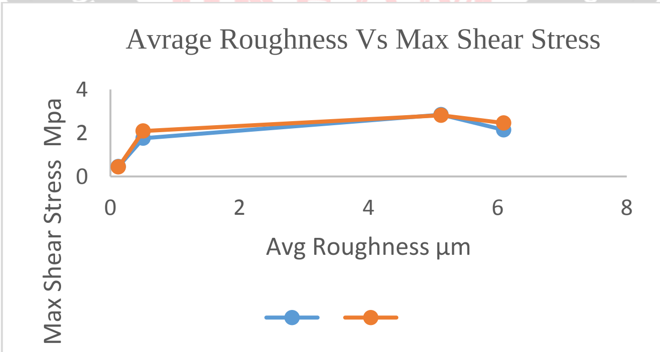
Layer Thickness µm	Displacement mm	
	Experimental	FEA
500	1.35	1.1
700	5.3	4.67
1000	8.5	7.95
1500	5.5	6.3



Roughness is one of the important parameter that effect the adhesive layer strength. Roughness of every specimen measured by digital surface roughness tester and takes an average roughness value (Ra+Rz) the result is observed as tabulated form in table 6 bellow.

Table 6 Average roughness and Max Shear stress

Avg Roughness(µm)	Max Shear Stress Mpa	
	Experimental	FEA
0.125	0.45	0.44
0.51	1.76	2.09
5.125	2.84	2.81
6.095	2.14	2.46



CONCLUSION

In this project work study, the effect of aluminium surface adherend surface roughness on Epoxy adhesive bond strength was investigated. Single lap joints with different adherent's roughness and layer thickness (i.e.0.5,0.7,1.0,1.5mm) were tested. Contact angle is also play important role in surface roughness strength of joint. The following are conclusions:

1) The strength variations with respect to the surface roughness follow the same trend (initially increases and then decreases with roughness.
2) The surface roughness parameter must be considered during the design stage of adhesively bonded joints, as the bond strength varied significantly by 30–35 %, between the different surface roughness values.
3) The equal amount of stress distribution of single lap adhesive joint is only possible with the help of adhesive joint.

4) There is an optimum surface roughness for maximum strength in aluminium adhered joints is found by experimentally and analytically.
5) Adhesive joint is satisfying the characteristics like corrosion resistance, leak proofness and sound deadening.

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