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Shear Strength Enhancement of Single Lap Adhesive Joint using Surface Pattern

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Abstract— Structural adhesive bonding technology is widely utilized in various applications in modern automotive and aviation industries. The use of adhesive bonding rather than mechanical fasteners offers the potential for reduced weight and cost. Adhesive bonding technology offers great design as it can be easily integrated into almost all available industrial sequences of single-piece work or mass production. The single lap joint with metallic or compo-site flat plates is the most common due to its simplicity and efficiency. In this paper, experimental investigations were carried out in order to evaluate shear strength of adhesively bonded AA6082-T6 Aluminum alloy under lap joint. Three adhesives were used from different manufacturers. The aluminum alloy metal on surface generates the micro-texture pattern is tested the shear strength. Effects of different adhesive type, adherence thickness, surface texture pattern depth and adhesive thickness on shear strength were experimentally evaluated using Taguchi technique. Experiments were carried out on the universal testing machine (STS-248). Results indicate that surface with micro-texture is able to achieve noticeable improvement in adhesion shear strength.

Key words: Shear Strength, Adhesive, Micro-Surface Texture Pattern, Finite Element Analysis

I. INTRODUCTION

The aircraft industry was one of the first industries that adopted adhesive bonding in aircraft manufacturing for aluminum alloys. Currently, aluminum alloys are the center of attention of auto manufacturers because of their mass savings potential and good mechanical properties making them an appropriate alternative to steel. Reducing vehicle mass lowers the fuel consumption and related CO_2 emissions it is an important factor. The significant growth in aluminum alloy consumption in the past decade and a parallel growth in the use of adhesives makes aluminum alloys an ideal substrate for adhesive bonding research [1]. The adhesively bonded joints are the main importance of the bondline thickness is 0.05-0.5mm, but in many practical applications are very difficult to achieve [2]. The surface preparation of the used in methyl ethyl ketone was used and cleaning the surfaces of each substrate and then after applying the different adhesives and check the strength [3].

The new invention of the different patterns on the surface at different pitch and depth and apply on adhesive Locality 4090 and Araldite 2015 then fatigue test were done [4]. The automobile industries adhesively bonded joints are used because strength is good, life of the component is increased, temperature resists, vibration is less and replacing welding, nut, and bolts. The objective of this paper studied that, used aluminum alloy AA6082-T6 because reduced weight and cost, different adhesives manufacturers (Henkel Corp.), adherence thickness, surface pattern depth, adhesive thickness.

II. EXPERIMENTATION DETAILS

A. *Specimen Geometry*

For the test, a specimen with sample geometry is chosen. The single lap joint aluminum alloy AA6082-T6 material on surface texture pattern. An overlap area is 25mm, length of 100mm and width is 25mm. The adherence thickness is 2, 3mm, adhesive thickness 1, 2 mm and surface texture pattern depth is 0.75, 1mm.

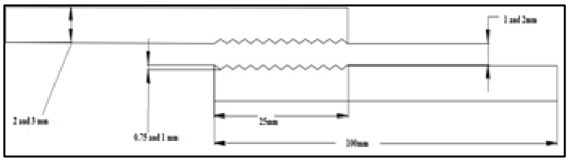


Fig. 1: Joint Geometry (All Dimensions Are In Mm)

B. *Selection of Material*

The material used for the substrates AA6082-T6 aluminum. This choice was made because aluminum due to its low weight and good mechanical properties is an increasingly used material in aerospace and automotive industries which are among those that use adhesive techniques. Aluminum also helps to keep costs down in the fabrication of the specimens.

Tensile Strength (Mpa)	305.6
Yield Stress (Mpa)	245.1
Elongation at failure (%)	16.5
Young's Modulus (Gpa)	69.5
Shear modulus (Gpa)	25.34
Poisson's ration	0.346

Table 1 Mechanical Properties of Aluminum

C. *Adhesive Description*

Sr. No.	Properties Name	Loctite AA3342	Loctite 4090
1	Tensile strength (N/mm^2)	12	7.1
2	Elongation (%)	2.8	3.6
3	Shore hardness(D)	71	69
4	Shear strength (N/mm^2)	21	7.6
5	Tensile Modulus (N/mm^2)	478	565
6	Mixing ratio	No mix	1:1
7	Temperature resistance	356	300

Table 2: Adhesive Properties Data from Henkel Adhesive Corp

D. Surface Patterning

The preparation of the surface of the substrate is of extreme importance in the implementation of a bonded joint, as the joint strength depends heavily on the quality of this operation. Different surface pattern angle 60^0 and 90^{00}were tested in the shear strength test for three adhesives and the best pattern angle will be selected

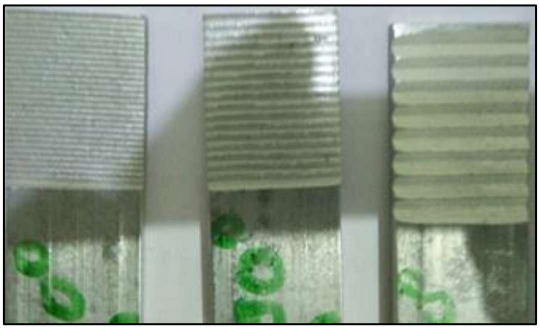


Fig. 2: Geometry of Pattern

The manufacturing of the patterned specimens was done on a universal tool milling machine (FP3), which was previous-ly fitted with a milling cutter tool with a 60^0, 90^0 angle in the tool holder and manufacturing on aluminum surface at dif-ferent depths as shown fig.2.

E. Experiment Setup

Shear strength analysis of various specimens as per test combinations mentioned in table 3 was carried out on a universal testing machine (STS-248) having linear recirculat-ing ball screw and inbuilt load cell. The plates of different depth are having different adherence thickness and width 25 mm were used for the given analysis.

Specification	Requirement
Capacity	98000N
Test speed	3 to 500 mm/min
Accuracy	± 1%
Room Temperature	25^0c

Table 3: Specification

As per experimentation we can observe that the 60^0 angle patteren angle is having the highest breakinn load value.

Surface pattern depth (mm)	Adherence thickness (mm)	Adhesive thickness (mm)	Type of adhesive	Load (N)
0.75	2	1	Araldite 2015	2912.17
	2	2	Loctite4090	4172.02
	3	1	Loctite4090	5106.89
	3	2	Araldite 2015	5027.14
1	2	1	Loctite4090	3110.12
	2	2	Araldite 2015	3486.27
	3	1	Araldite 2015	5813.12
	3	2	Loctite4090	3917.25

Table 4: Load combination with 60^0 Angle Pattern

III. FINITE ELEMENT ANALYSIS

A numerical method has animportant contribution to solving complex computational mechanics problems, quickly and correctly. There are many methods generally used to solve avariety of problems. Each method has their own advantages and limitations. Finite element method is one which used differential equations to solve most of the problems related to automobile, civil, aerospace industries.

All single lap joint pairs for different adhesive thickness, surface pattern depths, and angles are drawn in CATIA V5-R20. The final assembly model in IGES format of single lap joint is imported in Ansys workbench 14.5. Because of simple geometry model is default mesh with tetrahedral mesh element. A bonded contact is defined between aluminum plate and Loctite E-30UT adhesive. For given analysis one end of single lap joint is fixed and a load of 4500N is applied on another load. Finally, the analysis results are generated for given loading and boundary conditions for all single lap joint pairs. Results of 1mm thick adhesive lap joint with 60^0 surface pattern angle and 0.75mm depth are shown in fig. 7, 8, 9.

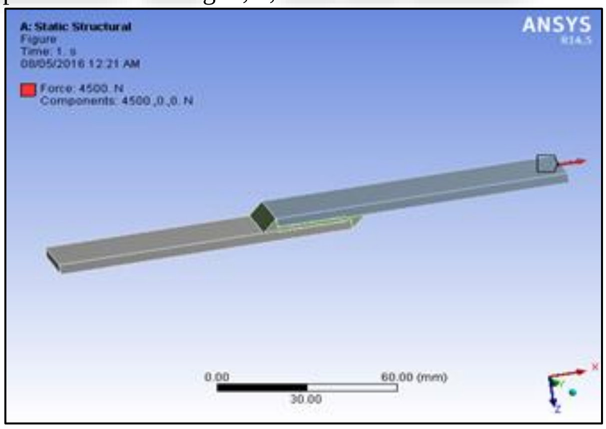


Fig.4 CAD Model of 1mm Thick Adhesive Lap Joint with 60^0 Surface Pattern Angle & 0.75mm Depth

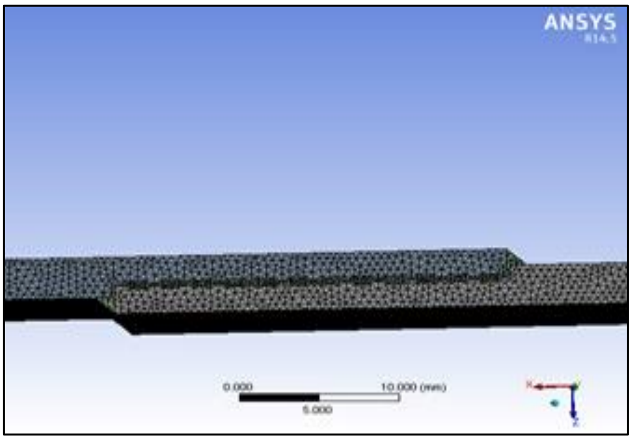


Fig. 5: Meshing

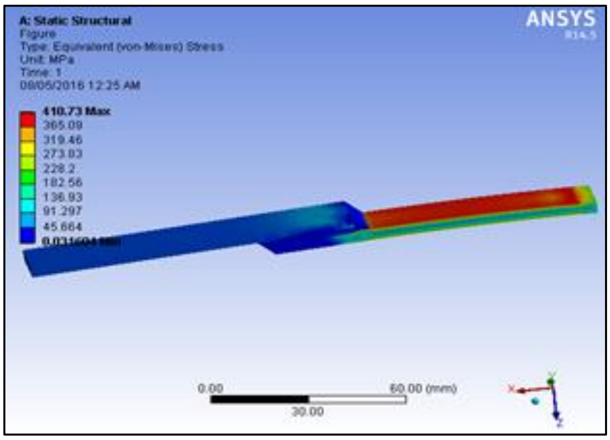


Fig. 7: Equivalent Von-Mises Stress

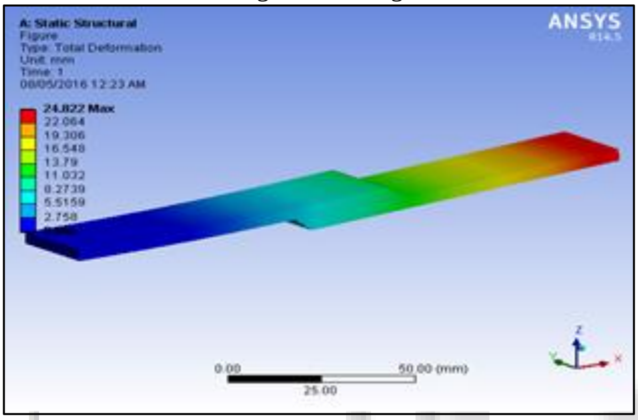


Fig. 6: Total Deformation

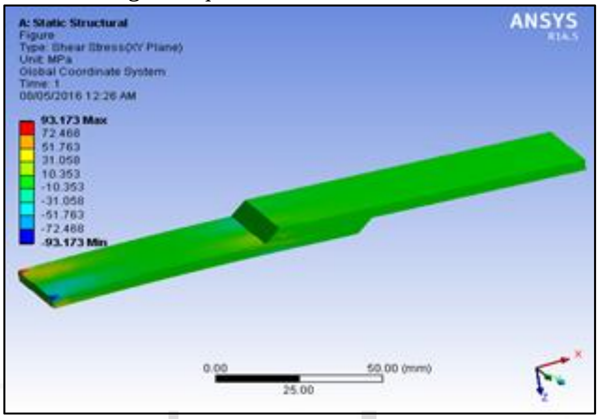


Fig. 8: Shear Stress

Surface pattern depth (mm)	Adherence thickness (mm)	Adhesive thickness (mm)	Type of adhesive	Load (N)
0.75	2	1	Araldite2015	3017.35
	2	2	Loctite4090	4026.13
	3	1	Loctite4090	5210.6
	3	2	Araldite2015	4789.65
1	2	1	Loctite4090	3217.89
	2	2	Araldite2015	3165.02
	3	1	Araldite2015	5727.2
	3	2	Loctite4090	4170.16

Table 5: Analysis of Results for 60 Degree Pattern

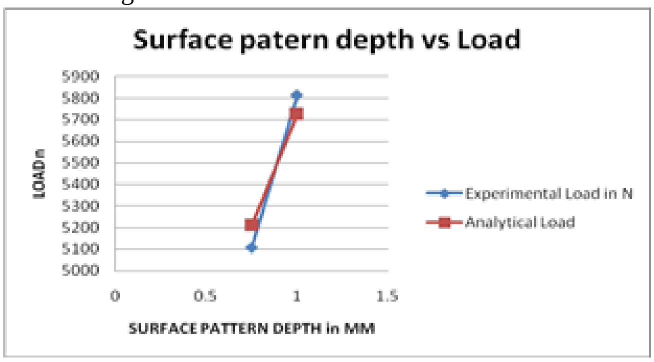
IV. RESULTS & DISCUSSION

For modifying the stress distribution in the adhesive joint certain guideline to be followed such as,

- Increase the adhesive thickness
- Increase joint strength
- Modify adherend geometry

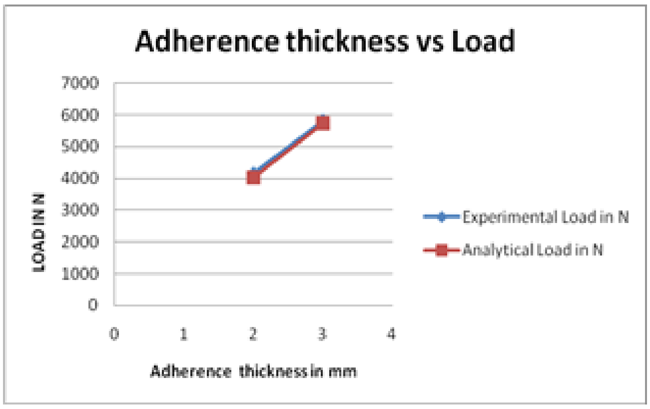
In this test analysis this guidelines are verified from the results it is found that they are true. It shows two responses are taken for further analysis to find out the optimum combination, which can yield into higher shear strength of the adhesively bonded single lap joint. It also helps to propose certain recommendation and design changes in the joint geometry, so that joint integrity can be maintained under severe operating conditions.

Comparison of Experimental and Finite Element Analysis of Results



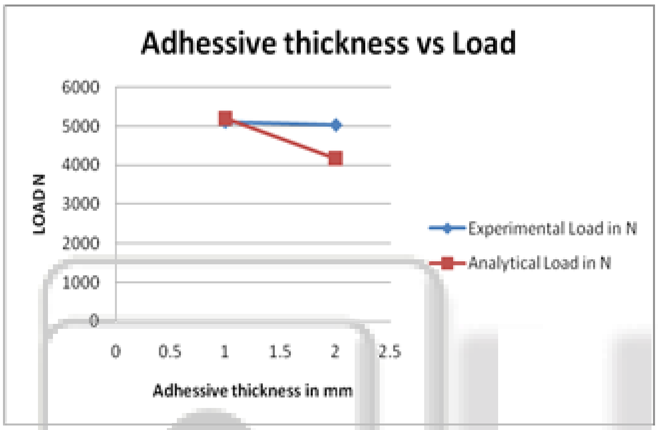
Graph 1: Type of Pattern vs. Load

Graph 1 shows type of pattern vs. load in experimental and analytical results are comparison and the results are very minor changes then there is experimental results is better than analytical results.



Graph 2: Adherence thickness Vs. Load

A graph 2 show adherence thickness vs. load isexperimental results is most effetive and adherence thickness increases also load increases.



Graph 3: Adhessive Thickness Vs Load

A graph 3 shows graphical representation of the adhesive thickness vs. load when adhesive thickness increases load is decreases also experimental and analytical results is same way.

V. Conclusion

The effects of surface pattern depth, adherence thickness, adhesive thickness, type of adhesives on the lap shear strength were investigated using the experimental and analytical method. The following can be drawn

1) The lap shear strength increases with surface pattern depth
2) The lap shear strength increases the adherend thickness increases
3) The lap shear strength increases adhesive thickness decreases
4) The experimental and finite element analysis results are nearly same only the type of adhe-sive is large difference because, of most of adhe-sives manufactures properties are different then strength also changed.
5) The finite element analysis 1mm pattern depth, adherence thickness 3mm, adhesive thickness 1mm and adhesive Loctite 4090 is superior.

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