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Strength Analysis of Adhesively Bonded AA6082-T6 Al Alloy Lap Joint

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ABSTRACT

AA6082-T6 is widely used in modern automotive and aviation industries. The usage of adhesive bonding offers the reduced weight and cost as compared with mechanical bonding. The single lap joint with metallic flat plates is the most common due to its simplicity in many applications. The safety and reliability of these bonds depend on appropriate design. In this paper experimental investigations were carried out in order to evaluate shear strength of adhesively bonded AA6082-T6 Aluminium alloy under lap joint. Three adhesives were procured from different manufacturers. Effects of adhesive type, adherence thickness, surface texture pattern depth and type of adhesive on shear strength were experimentally evaluated using Taguchi technique. Experiments were carried out on universal testing machine. Analyses of variance were carried out and percentage contribution of each factor was evaluated in order to determine a joint strength. This study will help to design appropriate joint which may lead to manufacture highly durable products.

Keywords: Shear Strength, Surface Texture Pattern, ANOVA, Universal Testing Machine

I. INTRODUCTION

The aircraft industry was one of the first industries that adopted adhesive bonding in aircraft manufacturing for aluminium alloys. Currently, aluminium alloys are the centre of attention of auto manufacturers because of their mass savings potential and good mechanical properties making them an appropriate alternative to steel. The significant growth in aluminium alloy consumption in the past decade and a parallel growth in the use of adhesives makes aluminium alloys an ideal substrate for adhesive bonding research [1]. The three and four point loading were investigated is various angles, overlap length and adhesive thickness. The loading is at different point is placed on tensile testing machine. As bondline thickness increases, there is an increase in the bending stress since the bending moment has increases [2]. 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 [3]. The surface preparation of the used methyl ethyl ketone cleaning the surfaces of each substrate and then after applying the different adhesives and check the strength. The roughness surface area is more shear strength also increase. [4].

In automobile industries adhesively bonded joints are used because good strength, increased component life, temperature resist, vibration is less as compared to welding, nut and bolts. The single lap is very common in practice and simple design rules are available for design purposes. The adhesively bonded joints improves joint strength reduced the time and cost compared to fusion joining. Experiments were carried out by various researchers to find out an effect of material, adherence thickness, overlap length, adhesive thickness and surface treatment using orthogonal arrays and optimum result on contribution of each parameter in order to improve the quality of joints [5,6,7]. Adhesively bonded joints can provide an efficient method of joining that would be more extensively used, if reliable methods of testing and analysis were available. The focus is placed on methods of testing and analysis and the effect of variations in the lap length, type of material to be joined. curing time and thickness of the adhesive bondline [9].

The objective of this paper is to analyse the strength of adhesively bonded AA6082-T6 Al alloy lap joint using different types of adhesives, adherence thickness, surface pattern depth and adhesive thickness.

II. METHODS AND MATERIAL

A. Materials

The material used for the substrate AA6082-T6 aluminum. This choice was made because of its low weight and good mechanical properties and hence can be used aerospace and automotive industries which are among those that use adhesive techniques.

TABLE 1
MECHANICAL PROPERTIES OF ALUMINUM

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

B. Adhesive Description

Adhesive is the important factor in adhesive joint and the strength of joint is depends on the properties of adhesive. The mechanical properties of adhesive shown in table 2.

TABLE 2
MECHANICAL PROPERTIES OF ADHESIVE

Properties	Loctite 4090	Araldite 2015	Loctite E-30HV
Shear modulus (Mpa)	565	564	638
Shear strength (Mpa)	7.6	17.9	12.6
Poisson's ratio	0.39	0.38	0.39
Temperature (^{0}c)	300	356	250
Shore hardness	65	43.9	85
Mixing ratio	1:1	1:1	2:1

C. Specimen Geometry

Specimen was prepared by using 100 mm length and 25mm width plate of thickness 2, 3 and 4mm with surface texture pattern of 0.5, 0.75 and 1mm depth over 25mm length. Joint two specimens with 25mm overlap thickness is 1, 2 and 3mm adhesive thickness in between two plates as shown in fig. 1.

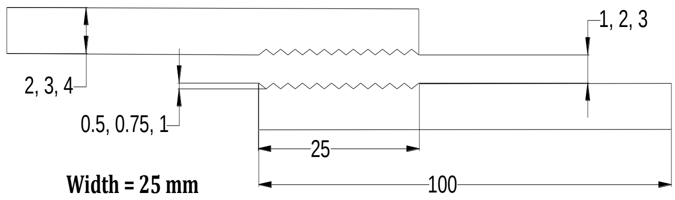

Figure 1. Joint geometry (All dimensions are in mm)

D. Surface Patterning

Surface pattern was prepared on horizontal milling machine with different depths of surface texture 0.5, 0.75, 1mm and constant 60^0 angle.

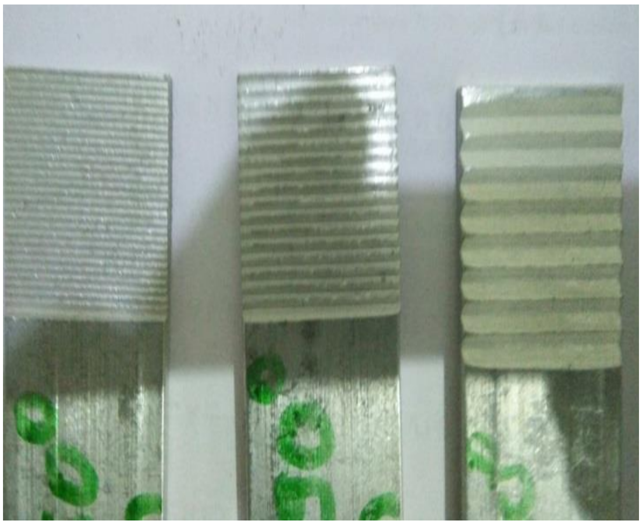

Figure 2. Surface prepared with variable pattern

III. EXPERIMENTAL METHOD

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 recirculating 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. Each experiment were carried out with two replicates, results in total eighteen experiments, as per standard L_9 orthogonal array.

Figure 3. Universal testing machine with test piece

TABLE 3
FACTOR AND LEVEL

Sr No.	Factor	Level		
A	pattern depth	0.5	0.75	1
B	Adherence thickness	2	3	4
C	Adhesive thickness	1	2	3
D	Type of adhesive	Loctite 4090 (Type A)	Araldite 2015 (Type B)	Loctite E-30HV (Type C)

A. Data Analysis Results and Discussion

Experiments were conducted with the aim of relating the influence of surface pattern depth, adherence thickness, adhesive thickness and type of adhesive with shear strength. Table 4 represents the results with two replicates.

B. Analysis of Variance and S/N Ratio

The relative magnitude of the effect of different factors can be obtained by the decomposition of variance, called analysis of variance (ANOVA). Larger is better (S/N) ratio is used when there is no predetermined value for the target and larger the value characteristic the better the product [9].

$$S/N = -10 \log (MSD) \quad (1)$$

Where MSD = Mean Square Deviation

For larger is better

$$MSD = (1/y_1^2 + 1/y_2^2 + 1/y_3^2 + \text{-----} \; y^2 n)/n \quad (2)$$

Where n is the number of observations and y is the observed data.

IV. RESULTS AND DISCUSSION

Using MINITAB, Taguchi Design Software, S/N ratios for load, ranking of parameters and ANOVA are calculated and are shown in table 5 and table 6 respectively. The mean effects plot for the S/N ratio is plotted for the various parameters namely surface pattern depth, adherence thickness, adhesive thickness are shown in fig. 4.

TABLE 4
EXPERIMENTAL RESULTS WITH S/N RATIOS

A	B	C	D	Shear Strength (Kg/mm^2)		S/N Ratios
				1st	2nd	
0.5	2	1	Type A	349.6	324.3	50.5
0.5	3	2	Type B	341.6	341.7	50.6
0.5	4	3	Type C	338.7	338.0	50.5
0.75	2	2	Type C	412.8	359.87	51.6
0.75	3	3	Type A	534.3	501.84	54.2
0.75	4	1	Type B	551.6	546.62	54.7
1	2	3	Type B	457.5	485.70	53.4
1	3	1	Type C	575.3	572.72	55.1
1	4	2	Type A	585.1	582.34	55.3

A. Pooling

Initially it was observed that the contribution of type of adhesive is very little hence, it was decided to used pooled ANOVA to perform further analysis. This process of discarding the contribution of a selected factor (type of adhesive) and subsequently adjusting the contribution of the other factor is known as pooling. Pooling is usually accomplished the smallest factor and smallest rank which has been reduced and which has not effect on parameter.

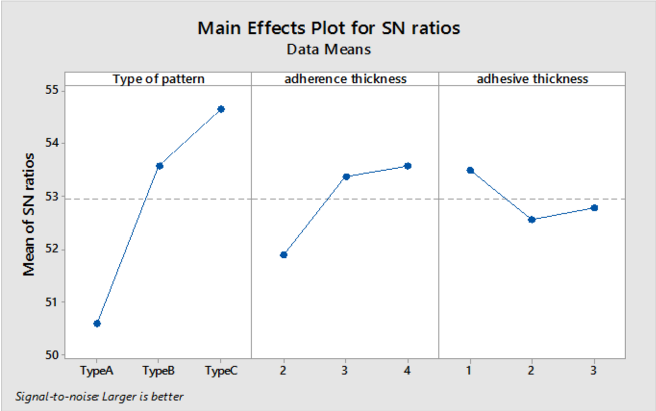

Figure 4. Main effects plot for S/N ratios

TABLE 5
RANKING OF THE PARAMETERS

Levels	Type of Pattern	Adherence Thickness	Adhesive Thickness	Type of Adhesive
1	339.0	398.3	486.7	479.6
2	484.5	478.0	437.3	454.2
3	543.1	490.4	442.7	432.9
Delta	204.1	92.1	49.4	46.7
Rank	1	2	3	4

TABLE 6
ANOVA TABLE

Factor	Df	SS	V	*f*	% Contribution
type of pattern	2	66242	33121	20.2	74.49
Adherence thickness	2	14974	7487	4.5	16.83
Adhesive thickness	2	4410	2205	1.3	4.95
Type of adhesive	Pooled				
Residual error	2	3279	1639		3.68
Total	8	88926			100

V. CONCLUSION

The effect of surface pattern depth, adherence thickness, adhesive thickness, type of adhesives on the lap shear strength of adhesively bonded aluminum alloy AA6082–T6 was investigated using the Taguchi analysis technique. The ranking of parameters were done. Type of pattern is most effective followed by adherence thickness, adhesive thickness and type of adhesives. The effect of type of adhesive is found to be negligible on shear strength hence that parameter is pooled used. Further analysis showed that, the lap shear strength increases with surface pattern depth. Increasing in adherence thickness increases lap shear strength and decreases in adhesive thickness.

The surface pattern depth found to be more effective to increase in strength because of large contact area. The work may be extended with few more surface patterns in order to investigate strength in other materials also.

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