

# Design and analysis of adhesive and riveted single lap joint for Al plates

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## Abstract

Adhesive bonded are already playing a significant role in the development and production of metal aircraft structures and indication are strong that such joints will be even greater importance in structures. The design is applied to analyze the parameters that influence the load transfer between the different components of the joints as well as the maximum stress in adhesive. Experimental analysis is used to investigate the shear strength behavior of aluminium alloy adhesive joint as well as rivet joints. It carried out in order to understand the effect of geometrical parameters and adhesive strength of adhesive bonding joints with the aim of optimizing shear strength. The adhered material used for the experimental tests was an aluminium alloy in the form of thin sheets, and the adhesive used was a high strength. Nine test to be studied. An experimental analysis was developed to give approximate value of load required to carry out test and shear strength of adhesive joint. Nine test specimens are testing on Universal Testing Machine. Then Compare results obtain from UTM machine. When comparing result of adhesive joint the shear stress is observed  $4.80 \text{ N/mm}^2$ ,  $5.10 \text{ N/mm}^2$  and  $3.44 \text{ N/mm}^2$  having lap length 12.5mm, 18mm & 25mm respectively. When comparing result of rivet joint the shear stress is observed at rivet position is  $96.66 \text{ N/mm}^2$   $99.78 \text{ N/mm}^2$  and  $94.32 \text{ N/mm}^2$  having lap length 12.5 mm, 18 mm & 25 mm respectively. When comparing result of adhesive + rivet joint the shear stress is observed  $4.19 \text{ N/mm}^2$ ,  $53.4 \text{ N/mm}^2$  and  $2.58 \text{ N/mm}^2$  having lap length 12.5 mm, 18 mm & 25 mm respectively.

**Key Terms:** Adhesive joint, Rivet Joints, Adhesive+Rivet joint, Shear Strength

## I. INTRODUCTION

Materials can be joined by utilizing an assortment of strategies. Up to around 60 years back, the important joining strategies were by mechanical attaching (screws, bolts, fasteners, and so on.) or by welding, binding or brazing [1]. These techniques had points of interest and detriments. Amid the Second World War, a progression of novel cements, created by Dr Norman de Bruyne at the organization which moved toward becoming to be known as Ciba, was utilized for fundamentally holding airplane, for example, the de Havilland Mosquito [1-5]. Since that time, huge advances have been made in glue holding innovation. With the advantage of science and experience, utilization of adhesives joints in stack bearing building circumstances which can withstand numerous times of utilization and in addition flying machine, adhesives are broadly utilized as a part of engine autos, and almost all lightweight structures[10]. They are being utilized to find course and outfits, and even to move stacks in gigantic structures, for example, are utilized as a part of structural building. Weights on expenses and vehicle weight (meeting Corporate Average Fuel Economy (CAFE) directions), while meeting wellbeing objectives, and further feature the test, driving the business towards new, less exorbitant materials and procedures. The pattern towards reusing the whole vehicle, as of now generally solid in Europe, has as of late influenced material and securing decisions in auto insides in Asia [6-9]. Accordingly, new materials and procedures are consistently being worked on. Some of the advantages of using adhesives include the following [11]:

- Invisible bonding.
- Even distribution of the bond stress.
- Ability to join dissimilar substrates and surfaces.
- Ability to fill gaps
- Elimination of vibration failure.
- Corrosion protection;
- Reduced manufacturing/assembly costs.
- Bond strength;
- Potential for dual functionality; and

- Ability to fit into tight spaces.

### I. OBJECTIVE PROPOSED WORK

1. The major objective of the proposed research work is to enhance the shear strength of a lap joint.
2. To propose a joint preparation technique, to develop a robust joint which can sustain maximum possible shear strength.
3. Analyze Effect of varies adhesive joint, rivet joint and rivet –adhesive joint on strength and failure of joint.

### II. METHODOLOGY

1. Analytical calculation of different joint that is adhesive joint, riveted joint and adhesive plus riveted joint.
2. For performing shear strength analysis Universal Testing Machine is used. In which one jaw is fixed and other jaw is used for the applying load.
3. Results were recorded by means of Load Vs. Displacement graph

### III. THEROTICAL CALCULATIONS

#### A) Type of Joint – (Aluminum & Aluminum Adhesive Joint)

Geometry of Specimen-

- Adhesive Lap Length – 12.5mm, 18mm, 25mm
- Adhered plate dimensions :- 100mm X 25mm
- Thickness of plate – 3 mm
- Adhesive use- 495 (General Purpose)
- Material – Aluminium.

Sample No. 1. Calculations for lap length = 12.5 mm

$$\begin{aligned}\text{Shear Stress} &= F/ L \times a \\ &= 1362/12.5 \times 25 \\ &= 4.35 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2.2/130 \\ &= 0.0169\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/ L \times 100 \\ &= 2.2/130 \times 100 \\ &= 1.692\%\end{aligned}$$

Sample No. 2. Calculations for lap length = 18 mm

$$\begin{aligned}\text{Shear Stress} &= F/ L \times a \\ &= 2234/18 \times 25 \\ &= 4.96 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2.2/130 \\ &= 0.0169\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/ L \times 100 \\ &= 2.2/130 \times 100 \\ &= 1.692\%\end{aligned}$$

Sample No. 3. Calculations for lap length = 25 mm

$$\begin{aligned}\text{Shear Stress} &= F/ L \times a \\ &= 2107/25 \times 25 \\ &= 3.37 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2/130 \\ &= 0.0153\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/ L \times 100 \\ &= 2/130 \times 100 \\ &= 1.53\%\end{aligned}$$

**B) Type of Joint – (Aluminium & Aluminium Rivet Joint)**

## Geometry of Specimen-

- Adhesive Lap Length – 12.5mm, 18mm, 25mm
- Adhered plate dimensions :- 100mm X 25mm
- Thickness of plate – 3 mm
- Adhesive use- No only jointed by Rivet 4mm Diameter.
- Material – Aluminium.

For rivet joint resistance offered by the plate against tearing is known as tearing resistance.

Sample No. 4. Calculations for lap length = 12.5 mm

i. Tearing area is given by equation

$$A_t = d \times t$$

Where, d= diameter of rivet

t = thickness of Plate

$$A = d \times t = 4 \times 3 = 12 \text{ mm}^2$$

ii. Tearing Resistance  $P_t = A_t \times \sigma_t$

Where  $\sigma_t$  = Permissible tensile stress of aluminium plate

$$P_t = A_t \times \sigma_t = 12 \times 290 = 3480 \text{ N}$$

Shearing off a rivet in a lap joint .

iii. We know Shearing area =  $A_s = \pi/4 \times d^2$

d = diameter of the rivet hole

$$= 0.785 \times 16$$

$$= 12.56 \text{ mm}^2$$

$$\text{Shear stress} = F/A$$

$$= \text{Force} / \text{Shearing area}$$

$$= 1215/12.56$$

$$= 96.735 \text{ N/mm}^2$$

$$\text{Strain} = dl/L$$

$$= 2.2/130$$

$$= 0.0169$$

$$\% \text{ of Elongation} = dl/L \times 100$$

$$= 2.2/130 \times 100$$

$$= 1.69\%$$

Sample No. 5. Calculations for lap length = 18 mm

$$\text{Shear stress} = F/A$$

$$= \text{Force} / \text{Shearing area}$$

$$= 1254/12.56$$

$$= 99.840 \text{ N/mm}^2$$

$$\text{Strain} = dl/L$$

$$= 2.8/130$$

$$= 0.0215$$

$$\% \text{ of Elongation} = dl/L \times 100$$

$$= 2.8/130 \times 100$$

$$= 2.15\%$$

Sample No. 6. Calculations for lap length = 25 mm

$$\text{Shear stress} = F/A$$

$$= \text{Force} / \text{Shearing area}$$

$$= 1186/12.56$$

$$= 94.426 \text{ N/mm}^2$$

$$\text{Strain} = dl/L$$

$$= 2.8/130$$

$$= 0.0215$$

$$\% \text{ of Elongation} = dl/L \times 100$$

$$= 2.8/130 \times 100$$

$$= 2.15\%$$

**C) Type of Joint – (Aluminium & Aluminium Rivet + Adhesive Joint)**

## Geometry of Specimen-

- Adhesive Lap Length – 12.5mm, 18mm, 25mm
- Adhered plate dimensions :- 100mm X 25mm
- Thickness of plate – 3 mm
- Adhesive use- jointed by Rivet 4mm Diameter with adhesive
- Material – Aluminium.

## Sample No. 7. Calculations for lap length = 12.5 mm

$$\begin{aligned}\text{Shear Stress} &= F/L \times a \\ &= 1333/12.5 \times 25 \\ &= 4.265 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2/130 \\ &= 0.0154\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/L \times 100 \\ &= 2/130 \times 100 \\ &= 1.54\%\end{aligned}$$

## Sample No. 8. Calculations for lap length = 18 mm

$$\begin{aligned}\text{Shear Stress} &= F/L \times a \\ &= 1372/18 \times 25 \\ &= 3.048 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2.9/130 \\ &= 0.022\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/L \times 100 \\ &= 2.2/130 \times 100 \\ &= 2.2\%\end{aligned}$$

## Sample No. 9. Calculations for lap length = 25 mm

$$\begin{aligned}\text{Shear Stress} &= F/L \times a \\ &= 1548/25 \times 25 \\ &= 2.47 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Strain} &= dl/L \\ &= 2.1/130 \\ &= 0.0161\end{aligned}$$

$$\begin{aligned}\% \text{ of Elongation} &= dl/L \times 100 \\ &= 2.1/130 \times 100 \\ &= 1.61\%\end{aligned}$$

**IV. EXPERIMENTAL WORK DATA**

For performing shear strength analysis, Universal Testing Machine is used in which one jaw is fixed and other jaw is used for the applying shear load.

**D) Type of Joint – (Aluminium & Aluminium Adhesive Joint)**

## Geometry of Specimen-

- Adhesive Lap Length – 12.5mm, 18mm, 25mm
- Adhered plate dimensions - 100mm X 25mm
- Adhesive use- 495 (General Purpose)
- Material – Aluminium.



Fig.1 Universal Testing Machine with specimen.



Fig. 2 Actual Specimen of adhesive joint having lap length 12.5mm, 18mm & 25mm



Fig.3 Load vs. Displacement graph of adhesive joint having 12.5 mm Lap length.

For performing shear strength analysis, Universal Testing Machine is used. In which one jaw is fixed and other jaw is used for the applying shear load. It is observed that when 1362.2 N force is applied on specimen which having lap length 12.5mm the specimen get break and shear force 4.801 N/mm<sup>2</sup> is observed as shown in fig 3.

From the adjacent fig.4, it is observed that when 2234 N force is applied on specimen which having lap length 18 mm the specimen get break and shear force 5.107 N/mm<sup>2</sup> is observed.

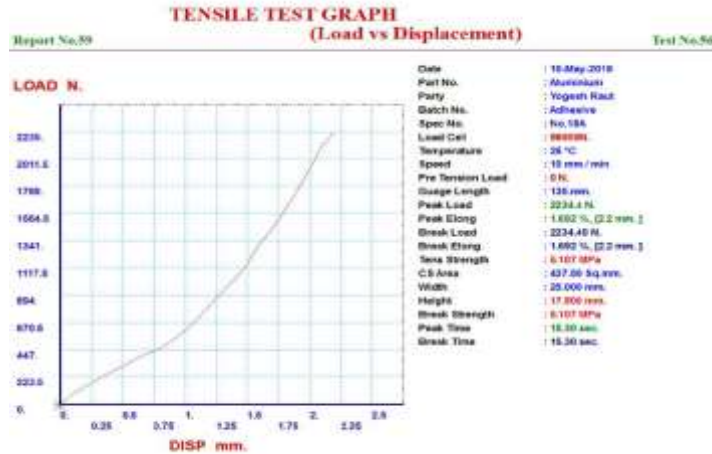


Fig.4 Load vs. Displacement graph of adhesive joint having 18 mm Lap length.

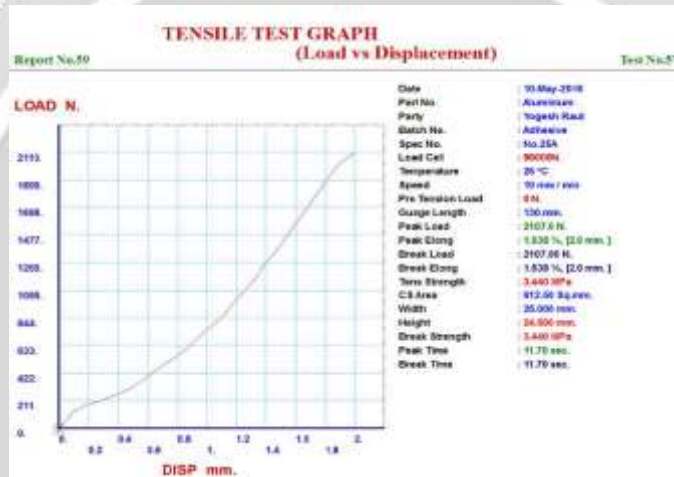


Fig. 5 Load vs. Displacement graph of adhesive joint having 25 mm Lap length.

From above fig.5 It is observed that when 2107 N force is applied on specimen which having lap length 25 mm the specimen get break and shear force 3.44 N/mm<sup>2</sup> is observed.

The three graphs show that as load increases, the displacement also increases. But at certain point, the adhesive joints get brittle failure.

*E )Type of Joint – (Aluminium & Aluminium Rivet Joint)*

Geometry of Specimen-

- Adhesive Lap Length – 12.5mm, 18mm, 25mm
- Adhered plate dimensions :- 100mm x 25mm
- Adhesive use- No only jointed by Rivet 4mm Diameter.
- Material – Aluminium.



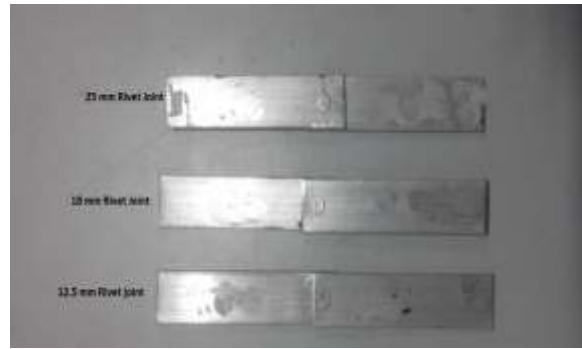


Fig. 6 Actual Specimen of Rivet joint having lap length 12.5 mm, 18 mm & 25 mm



Fig. 7 Load vs. Displacement graph of Rivet joint having 12.5 mm Lap length



Fig. 8 Load vs. Displacement graph of Rivet joint having 18 mm Lap length.

From fig. 7, it is observed that when 1215.2 N force is applied on specimen which having lap length 12.5 mm the specimen get break and shear force 96.664 N/mm<sup>2</sup> at rivet section and breaking strength 26.505 N/mm<sup>2</sup> is observed.

From fig.8, it is observed that when 1254.4 N force is applied on specimen which having lap length 18 mm the specimen get break and shear force 99.782 N/mm<sup>2</sup> at rivet section and breaking strength 26.505 N/mm<sup>2</sup> is observed.

From fig. 9 it is observed that when 1185.8 N force is applied on specimen which having lap length 25 mm the specimen get break and shear force 94.325 N/mm<sup>2</sup> at rivet section and breaking strength 24.954 N/mm<sup>2</sup> is observed.

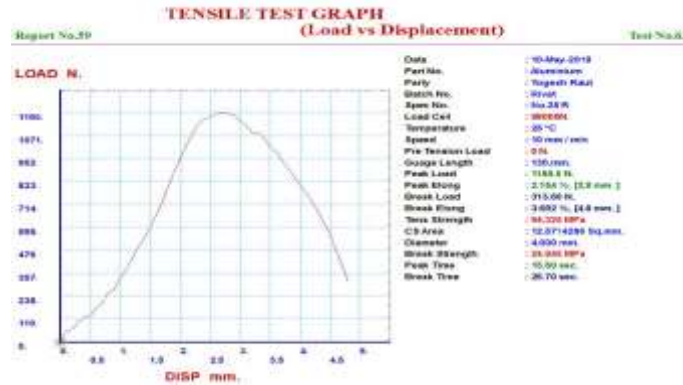


Fig. 9 Load vs. Displacement graph of Rivet joint having 25 mm Lap length.

The above three graphs show that as load increases, the displacement also increases. But when load reaches to a certain threshold value, the displacement starts decreasing gradually.

*F )Type of Joint – (Aluminium & Aluminium Rivet + Adhesive Joint)*

Geometry of Specimen-

- Adhesive Lap Length – 12.5 mm, 18 mm, 25 mm
- Adhered plate dimensions :- 100 mm X 25 mm
- Adhesive use- jointed by Rivet 4 mm Diameter with adhesive
- Material – Aluminium.

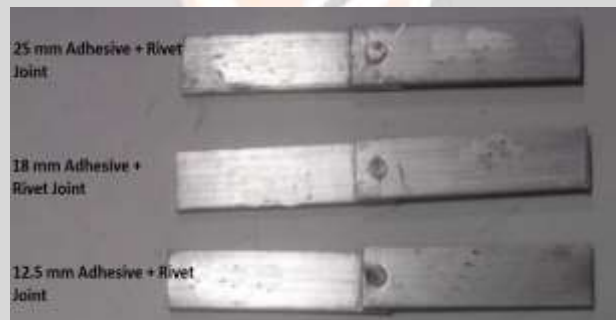


Fig. 10 Actual Specimen of Rivet + Adhesive joint having lap length 12.5mm, 18 mm & 25 mm



Fig. 11 Load vs. Displacement graph of Adhesive+ Rivet joint having 12.5 mm Lap length.

From fig. 11, it is observed that when 1332.8N force is applied on specimen which having lap length 12.5mm the specimen get break and shear force 4.198 N/mm<sup>2</sup> is observed.



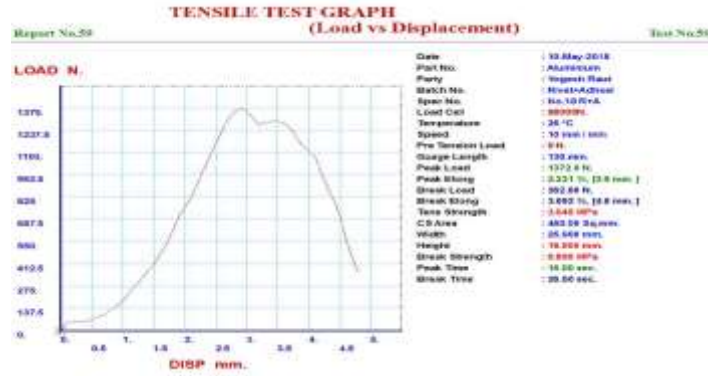


Fig. 12 Load vs. Displacement graph of Adhesive+ Rivet joint having 18 mm Lap length.

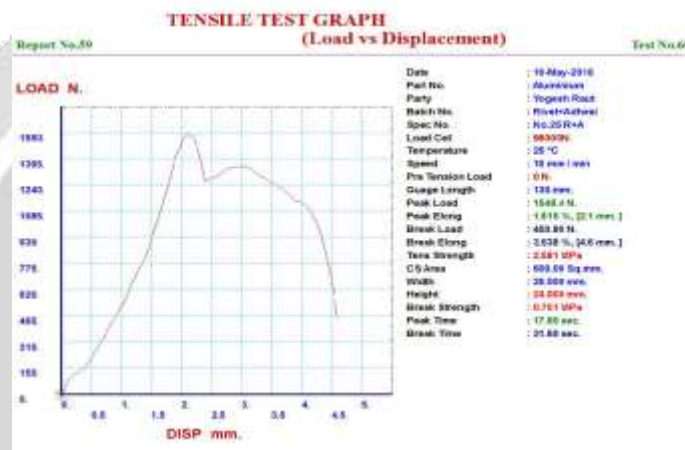


Fig. 13 Load vs. Displacement graph of Adhesive+ Rivet joint having 25 mm Lap length.

From fig. 12, it is observed that when 1372 N force is applied on specimen which having lap length 18 mm the specimen get break and shear force 3.049 N/mm<sup>2</sup> is observed.

From fig.13, it is observed that when 1548.4 N force is applied on specimen which having lap length 25 mm the specimen get break and shear force 2.581 N/mm<sup>2</sup> is observed.

The above three graphs show the relationship like the stress-strain curve.

### RESULT AND DISCUSSION

After performing final experiments, analysis of experimental data is done by using universal testing machine. The effect of various input parameters on output responses will be analyzed using universal testing machine.

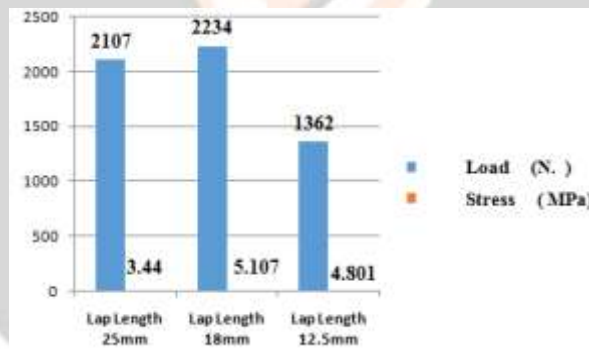
From fig 14 and table I it is observed that when the adhesive joining specimen has lap length 12.5 mm, then specimen is break at 1362 N and strain is 0.0169, displacement is 2.2 mm, shear stress 4.801 N/mm<sup>2</sup>. When lap length 18mm, then specimen breaks at 2234 N and strain is 0.0169, displacement is 2.2mm, shear stress 5.107 N/mm<sup>2</sup>. When lap length 25mm, then specimen break at 2107 N and strain is 0.0154, displacement is 2 mm, shear stress 3.44 N/mm<sup>2</sup>.

**TABLE I**  
**ANALYTICAL RESULT OF ADHESIVE JOINT, RIVETED JOINT & ADHESIVE + RIVETED JOINT**

Sr. No.	Material	Type of Joint	Lap Length mm	Load N	Stress Mpa
1	Al + Al	Adhesive	12.5	1362	4.35
2	Al + Al	Adhesive	18	2234	4.96
3	Al + Al	Adhesive	25	2107	3.37
4	Al + Al	Riveted	12.5	1215	96.735
5	Al + Al	Riveted	18	1254	99.840
6	Al + Al	Riveted	25	1186	94.426
7	Al + Al	Adhesive + Riveted	12.5	1333	4.265
8	Al + Al	Adhesive + Riveted	18	1372	3.048
9	Al + Al	Adhesive + Riveted	25	1548	2.476

**TABLE II**  
**SPECIMEN UTM RESULT OF ADHESIVE JOINT**

Sr. No.	Material	Type of Joint	Lap Length	Time (sec.)	Disp. (mm.)	Load (N.)	Stress (MPa)	Strain	% Elong. (% mm.)
1	Al + Al	Adhesive	12.5mm	13.5	2.2	1362	4.801	0.0169	1.692
2	Al + Al	Adhesive	18mm	15.3	2.2	2234	5.107	0.0169	1.692
3	Al + Al	Adhesive	25mm	11.7	2	2107	3.44	0.0154	1.538



**Fig. 14 Comparison value of adhesive joint**

**TABLE III**  
**SPECIMEN UTM RESULT OF RIVET JOINTS**

Sr. No.	Material	Type of Joint	Lap Length	Time (sec.)	Disp. (mm.)	Load (N.)	Stress (MPa)	Strain	% Elong. (% mm.)
1	Al + Al	Riveted	12.5mm	12.7	2.2	1215	96.664	0.0169	1.692
2	Al + Al	Riveted	18mm	20	2.8	1254	99.782	0.0215	2.154
3	Al + Al	Riveted	25mm	15.6	2.8	1186	94.325	0.0215	2.154

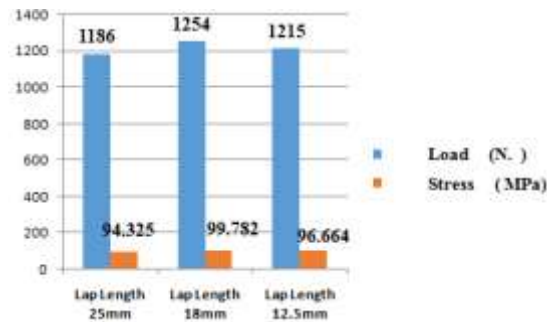


Fig. 15 Comparison value of rivet joint

From fig 15 and table II it is observed that when the riveted joint specimen has lap length 12.5mm, then specimen is break at 1215 N and strain is 0.0169, displacement is 2.2 mm, shear stress 96.664 N/mm<sup>2</sup>. When lap length 18 mm, then specimen breaks at 1254 N and strain is 0.0215, displacement is 2.8 mm, shear stress 99.782 N/mm<sup>2</sup>. When lap length 25mm, then specimen breaks at 1186 N and strain is 0.0215, displacement is 2.8 mm, shear stress 94.325 N/mm<sup>2</sup>.

TABLE IV  
SPECIMEN UTM RESULT OF RIVET + ADHESIVE JOINTS

Sr. No.	Material	Type of Joint	Lap Length	Time (sec.)	Disp. (mm.)	Load (N. )	Stress ( MPa)	Strain	% Elong. (% mm. )
1	Al + Al	Rivet + Adhesive	12.5mm	11.6	2	1333	4.198	0.0154	1.538
2	Al + Al	Rivet + Adhesive	18mm	16	2.9	1372	3.049	0.0223	2.231
3	Al + Al	Rivet + Adhesive	25mm	17.8	2.1	1548	2.581	0.0162	1.615

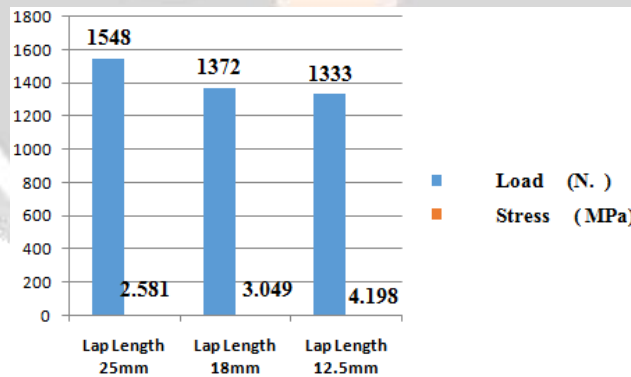


Fig. 16 Comparison value of rivet + adhesive joint

From fig 16 and table III it is observed that when the riveted + adhesive joint specimen has lap length 12.5mm, then specimen is break at 1333N and strain is 0.0154, displacement is 2 mm, shear stress 4.198 N/mm<sup>2</sup>. When lap length 18mm, then specimen breaks at 1372 N and strain is 0.0223, displacement is 2.9mm, shear stress 3.049 N/mm<sup>2</sup>. When lap length 25mm, then specimen breaks at 1548 N and strain is 0.0162, displacement is 2.1mm, shear stress 2.581 N/mm<sup>2</sup>.

VI. CONCLUSION

1. The experimental results are found out from universal testing machine. There are nine samples test are carried out and from this testing load, shear stress, percentage elongation etc. are found out.

2. When we compare the load value of rivet joint having different lap length, it is observed that load required for this test is less as compare to adhesive joint and rivet + adhesive joint.
3. In adhesive joint for lap length 12.5mm load required to break the specimen is increased by around 12% as compare to rivet + adhesive joint.
4. In adhesive joint for lap length 18mm load required to break the specimen is increased by around 63-78% as compare to rivet + adhesive joint.
5. In adhesive joint for lap length 25mm load required to break the specimen is increased by around 36-78% as compare to rivet + adhesive joint.
6. Hence It is observed that the adhesive joint having much better strength as compared to rivet joint and adhesive + Rivet joint in all parameters giving maximum possible shear strength and also increases maximum load carrying capacity.

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