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STRENGTH ANALYSIS OF 400 MM OVERLAPPED STEEL ADHESIVE DOUBLE LAP JOINTS REINFORCED BY RIVET

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ABSTRACT

This is the age of technological revolutions. For newer mechanisms, advancement in bonding procedures is desperately needed. The most famous bonding type is Adhesive bonding. Double lap joints are considered as a good category joint in many applications. This paper explains the investigation on double lap hybrid joint. This was done for the vertical loaded MS Steel specimens. Overlapping length was kept constant and equal to 400 mm and two other factors viz. Number of rivets and adhesive composition (Resin to Hardner ratio) were varied. Finite Element analysis is done by using Ansys to see the nature of changes in the joint. Further validation by Mechanical testing is done by using Universal Testing Machine for Max. Stresses induced. Load-Stress relation obtained by Ansys results is approximately closer to experimental results.

KEYWORDS: Double Lap Joint, Finite Element Analysis, Hybrid Joint, Number of rivets, Overlapping Length, Resin to Hardner ratio, UTM-60

1.INTRODUCTION

The existing demands in diverse branches of engineering require application of new multi component materials and structural systems. The correctly chosen joining technology can offer significant enhancement of structural system performance in terms of effectiveness, reliability, safety and other design criteria. Hybrid joints have a combination of adhesive bonding and mechanical fasteners. The advantage of using a combined bonded-riveted design is to enhance the joint strength. [1] It is generally accepted that an adhesively bonded joint is stronger than a mechanically fastened joint and a combination of these two named as hybrid joint is even stronger. [3]

A 'Hybrid Joint' combines multiple joining methodologies. A basic example is the bonded-and riveted joint. It has been found that it is possible to improve strength and fatigue characteristics of bonded joints through the inclusion of a single, or multiple, reinforcing rivets. [4]

This paper illustrates the effect of changing the adhesive composition i.e. resin to hardner ratio and Number of rivets on the stresses induced in Steel Double Lap joint specimen having overlapping length 400 mm. This analysis was carried out for only adhesive, only riveted and hybrid (adhesive and rivet) joints.

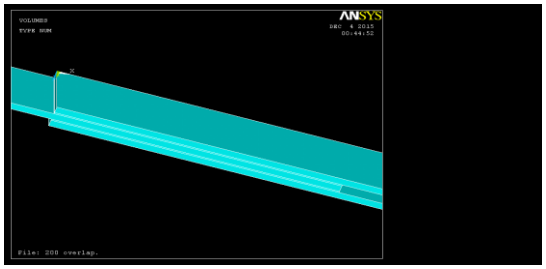
2.FINITE ELEMENT ANALYSIS

The finite element method is a numerical analysis technique for achieving fairly accurate results to a wide variety of engineering problems. Although originally developed to study stresses in complex airframe structures, it has since been extended and applied to the broad field of mechanics. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering disciplines and in industry. [3]

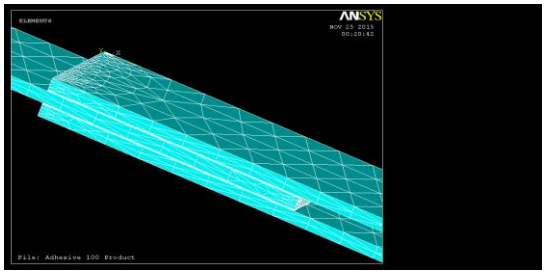
The ANSYS software has many finite element analysis capabilities ranging from simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. Any problem in ANSYS has to go through the three main steps build the model, apply loads, obtain solution and review the results. [2]

3.FEA METHODOLOGY

3.1 Adhesive Joint (400 mm Overlap) Resin to Hardener Ratio = 1:1

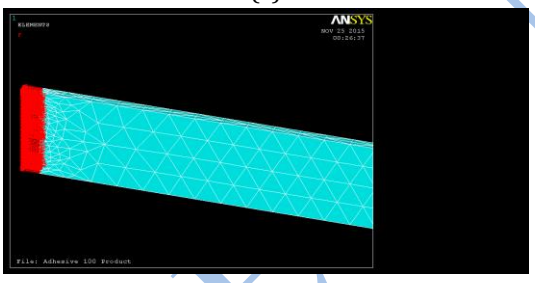


(a)



(b)

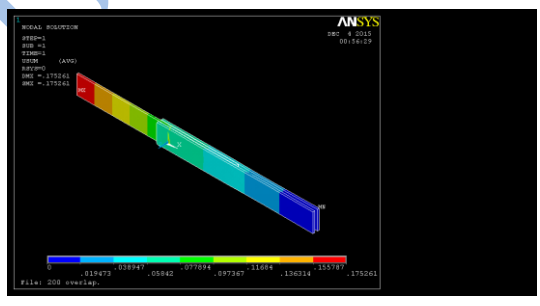
(c)



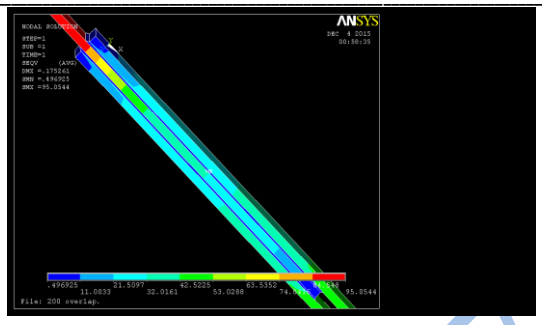
(d)

Figure 1: Initial Process in FEA (a)Adhesive Joint in ANSYS APDL (b) Meshing Using Tet. 10 Node (c) Constrained at end face (All Dof=0) (d) Load Application

3.1.1 Results: Deformation and Stress for above conditions as shown below



(a)



(b)

Figure 2: (a) Deformation = 0.45 mm (b) Max. Von Misses Stress (At 39.27 kN) = 158.96 Mpa

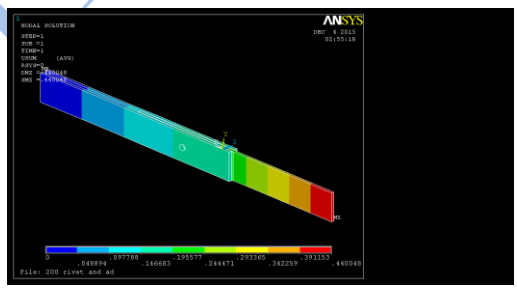
3.1.2 Similarly results are obtained for adhesive with Resin to Hardener Ratio = 1.5:1 and 2:1 as follows

Table 1: Results of Adhesive Joint for 400 mm overlap

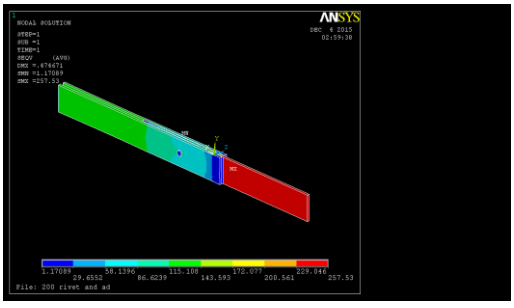
Sr. No.	Resin to Hardener Ratio	Force (kN)	Deformation (mm)	Stress (Mpa)
1	1:1	39.27	0.45	158.96
2	1.5:1	42.23	0.49	171.05
3	2:1	44.12	0.51	178.71

3.2 Rivet Joint (400 mm Overlap)

3.2.1 Results: Deformation & Stress are shown below



(a)



(b)

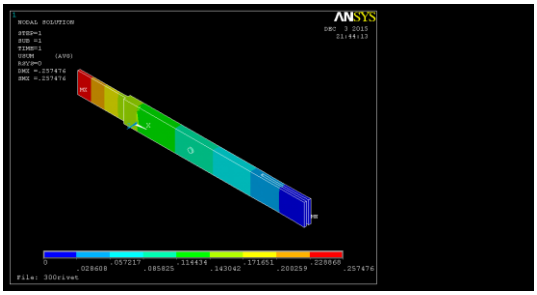
Figure 3: (a) Deformation = 0.38 mm (b) Max. Von Misses Stress = 285.84 Mpa (at 54.30 kN) for one rivet

Table 2: Results of Rivet Joint for 400 mm overlap

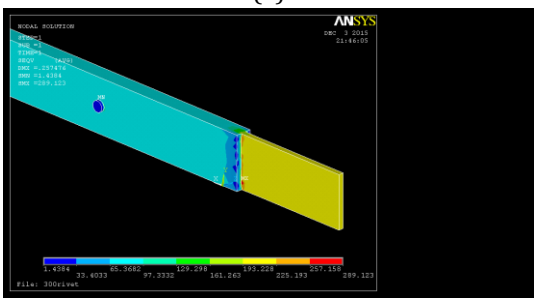
Number of rivet	Load Applied (kN)	Deformation Obtained (mm)	Stress Obtained (N/mm^2)
One Rivet	54.30	0.38	285.84
Two Rivets	54.30	0.61	307.94

3.3 Hybrid Joint (400 mm Overlap) for Resin to Hardener Ratio = 1:1

3.3.1 Results: Deformation & Stress for above conditions are shown below



(a)



(b)

Figure 4: (a) Deformation = 1.07 mm (b) Max. Von Misses Stress = 370.38 Mpa (at 81.37 kN) for one rivet

3.3.2 Similarly results are obtained for Hybrid Joint with Resin to Hardener Ratio = 1.5:1 and 2:1 with one and two rivets as follows

Table 3: Results of Hybrid Joint for 400 mm overlap

Joint Combination	Load Applied (kN)	Deformation Obtained (mm)	Stress Obtained (N/mm2)
1:1 + One Rivet	81.37	1.07	370.38
1:1 + Two Rivets	81.37	1.08	375.28
1.5:1 + One Rivet	86.67	1.08	375.25
1.5:1 + Two Rivets	86.67	1.11	385.42
2:1 + One Rivet	91.30	1.10	381.33
2:1 + Two Rivets	91.30	1.14	395.56

4. EXPERIMENTAL WORK

4.1 Preparation of Specimen

Mild Steel Plate having Carbon specification as C-15 is selected for preparation of Experimental Specimens. For all the specimens Dimensions are:

Table 4: Dimensions of Specimen Used

Control factors/Varieties	1	2	3
Number of Rivets	1	2	--
Type of Joint	Only Adhesive	Only Rivet	Hybrid (Adhesive + Rivet)
Resin to Hardner Mixture ratio (by volume)	1:1	1.5:1	2:1
Overlapping Length (mm)	400		

(a)

(b)

Figure 5: Sample Specimen (a) Before Test (b) After Test

4.2 Experimental Set Up

UTM-60 is used for testing the prepared specimens.

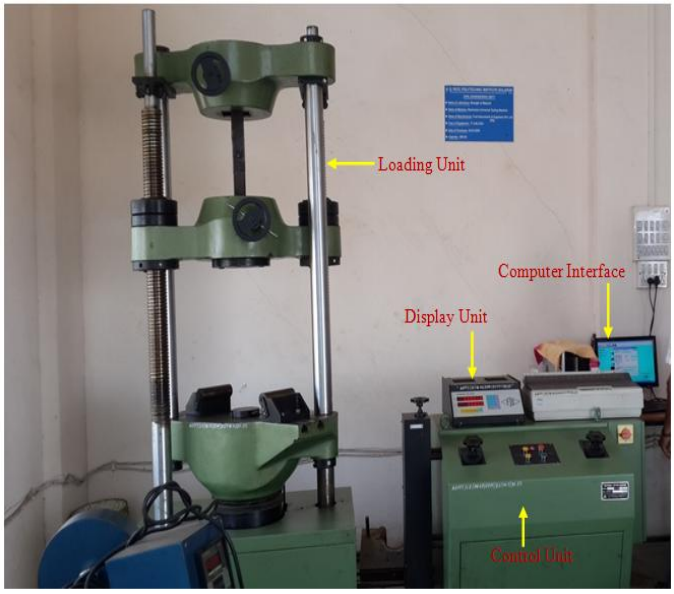


Figure 6: Experimental Set up

4.3 Experimental Results

Below table displays the results obtained in Joint Specimen test on Universal Testing Machine.

Table 5: Experimental Results

Type of Joint	Resin To Hardner Ratio	Load Applied (kN)	Deformation Obtained (mm)	Max. Stress Obtained (Mpa)
Only Adhesive	1:1	39.27	0.49	165.45
	1.5:1	42.23	0.53	179.11
	2:1	44.12	0.55	186.12
Only Rivet	With One Rivet	54.30	0.43	292.48
	With two Rivets	54.30	0.65	320.55
Hybrid (Adhesive + Rivet)	1:1 + One Rivet	81.37	1.20	381.62
	1:1 + Two Rivets	81.37	1.22	386.72
	1.5:1 + One Rivet	86.67	1.23	385.99
	1.5:1 + Two Rivets	86.67	1.25	395.53
	2:1 + One Rivet	91.30	1.22	390.42
	2:1 + Two Rivets	91.30	1.19	399.56

4.4 Validation of Results

The numerical values of deformation and stress obtained in experimentation can be compared with FEA.

Table 6 Comparative results of FEA & Expt. Analysis: Load Vs. Deformation

Type of Joint	Resin to Hardner Ratio	Load (kN)		Deformation (mm)	
		FEA	Experimentation	FEA	Experimentation
Only Adhesive	1:1	39.27	39.27	0.45	0.49
	1.5:1	42.23	42.23	0.49	0.53
	2:1	44.12	44.12	0.51	0.55
Only Rivet	With One Rivet	54.30	54.30	0.38	0.43
	With Two Rivets	54.30	54.30	0.61	0.65
Hybrid (Adhesive + Rivet)	1:1 + One Rivet	81.37	81.37	1.07	1.20
	1:1 + Two Rivets	81.37	81.37	1.08	1.22
	1.5:1 + One Rivet	86.67	86.67	1.08	1.23
	1.5:1 + Two Rivets	86.67	86.67	1.11	1.25
	2:1 + One Rivet	91.30	91.30	1.10	1.22
	2:1 + Two Rivets	91.30	91.30	1.14	1.19

Following sample graphs drawn for Load Vs. Deformation and Load Vs. Stress for 400 mm overlapping length

From fig. 7, the deformation starts at load value of 39.27 kN and it increases gradually. At the load 81.37 kN, deformation suddenly increases and final failure occurs at 91.3 kN.

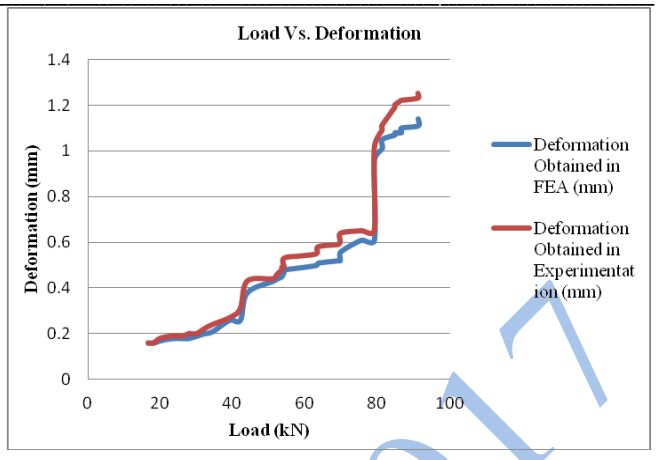


Figure 7: Graph of Load Vs. Deformation values in FEA & Experimental

As deformation starts, the stresses get develop in the specimen, fig. 8 the variation in stress between FEA and Experimental values. There is gradual increment in stress value from 165.45 Mpa till specimen failure at stress value 399.56 Mpa.

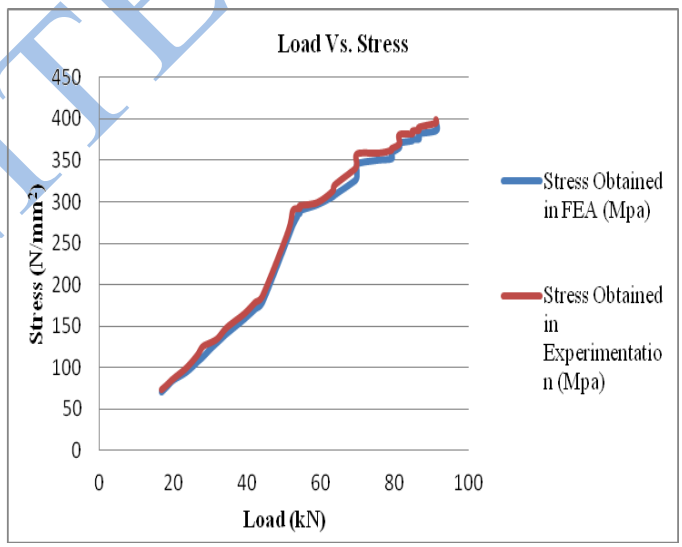


Figure 8: Graph of Load Vs. Stress values in FEA & Experimental

5. CONCLUSIONS

Following are some important outcomes of this analysis.

- ✓ The effect of overlapping length has significant impact on the joint strength. The Load carried in case of Hybrid joint having 400 mm overlap was 91.30 kN having stress value equal to 399.56 N/mm².
- ✓ The joint analysis was carried out by using two rivets for 400 mm overlap and the strength obtained is in this case was comparatively higher than single rivet specimens. So it is clear that the increment in number of rivets for reinforcement should be done only when there is scope for maximum overlap.

- ✓ The effect of overlapping length was negligible on strength of Rivet joint.

Finally this analysis will help to enhance the peculiarity of hybrid joints in engineering applications in coming time.

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