Stress-strain effects of adhesive layer thickness on Single lap joint by using Ansys Rohan P. Chumble¹ Dr. S. N. Shelke²

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Abstract—Adhesive bonding is widely used for sheet metal joining. Single lap joints are considered as a good category joint for sheet metals. Here, investigation on single lap adhesive joint is to be done. Adherend used is aluminium 99.5% with the specimen size of 130*30*1.95 mm. Overlap length is kept constant which is equal to 40mm. Adhesive layer thickness has varied as 0.05mm, 0.1 mm, 0.15mm, 0.2 mm, 0,3mm and 0.6mm. Tensile load of 400N, 1600N, 3200N etc are applied and stress-strain nature is obtained. It is observed that deformation at small adhesive layer thickness is lesser than that of high adhesive layer thickness at same load. More accurate results can be found out by using higher versions of analysis software.

Keywords—Adhesive bonding,single lap,loctite E-30CL, aluminium, Ansys, FEA

I. INTRODUCTION

Manufacturing large and complex structures is usually possible only when they are composed of assemblies of smaller parts joined together by variety of joining techniques since most products are impossible to be produced as a single piece. [3] A lot of influencing factors affect the load carrying capacity of an adhesive joint. The geometrical configuration of bonded parts is essential to obtain enough structural strength. Even joints having same adhesively bonded area, they might have different joint strength according to the bonded configuration. The adhering conditions are also important to attain the joint strength (e.g. the surface roughness of adhering surface, the thickness of the adhesive layer, the pressure applied to adhesive resin and its holding time, and curing conditions of adhesive resin are substantial factors affecting the joint strength). Adhesive strength is affected by the many physical and chemical factors. Here in this paper, geometrical configuration of the joint is kept constant. One adhering parameter has been varied which is adhesive layer thickness while other parameters are also kept constant. Mechanical testing is done on the specimen to find out the strength of the joint.

II. PROBLEM DEFINATION

Adhesive joints of aluminium as adherend sheet material have been considered in this work. Basic single lap adhesive joint is represented in figure 1.



Fig. 1:Single lap adhesive joint

Thin plates from aluminium with dimensions: *a* x *b* $x = 30 \times 130 \times 1.95$ mm are to be bonded with two component epoxy adhesive Loctite E-30CL (allowed to cure for 72 hours at 25 °C to reach maximum strength). Here "l" is overlap length which is optimized at 40mm for maximum joint capacity. Generally, increasing of the overlap length leads to the increasing of the joint strength due to increased area of bonding. However, it was shown that after some amount of the overlap length increasing an optimum overlap length can be defined, what means that after that point load capacity of the joint decreases. It should be pointed also that an optimal design of the bonded joint depends not only on the overlap length, than also on the applied adherend and adhesive material [5]. Adhesive layer thickness is to be varied by using appropriate clamping method. It is to be varied in between 0.05mm to 0.6 mm [9].



Fig. 2: Cad drawing of SLA joint

A. Overview of Ansys

The ANSYS computer program is a large scale multipurpose finite element program, which may be used for solving several classes of engineering analyses. As ANSYS has been developed, other special capabilities, such as sub structuring, sub modelling, random vibration, free convection fluid analysis, acoustics, magnetic, piezoelectric, couple field analysis and design optimization have been added to the program[1-3].

Analysis of any problem in ANSYS has to go through three main steps. They are,

- Pre-processor
- Solution
- Postprocessor

The input of the ANSYS is prepared using Preprocessor. The general Preprocessor contains powerful solid modelling and mesh generation capabilities, and is also used to define all the other analysis data such as geometric properties like real constants, material properties, constraints, loads, stiffness damping etc.,

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 and obtain solution
- Review the results

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B. Building the model

Before creating the finite element model, job name and job title has to be specified first. After that element type, real constants, material properties and geometry of the model are defined by using PREP7 command in the ANSYS input window or by using preprocessor from the ANSYS main menu.

- 1. Defining the job name
- Utility menu=>file=>save as
- 2. Defining the title
- Utility menu=>file=>change title 3. Defining element type MainMenu=>preprocessor=>Element
 - type=>Add/Edit/Delete
- 4. Defining real constants
 - MainMenu=>preprocessor=>Real Constants

When creating the elements, the appropriate real constant set reference number for the portion for the element is specified by the following path.

Main Menu=>preprocessor=>Create=>Elements=>Element Attributes.

1) Defining material properties

MainMenu=>preprocessor=>Material Properties

After defining the material properties, material properties sets are assigned to the particular element using the following path.

Main Menu=>preprocessor=>create=>Elements =>Element Attributes

- 2) Creating the finite element model
 - The finite element model is created by any of the three methods
 - Solid modelling
 - Surface modelling
 - Wire frame modelling

The following paths are used in creating the finite element model.

Main Menu=>preprocessor=>Create

Main Menu=>preprocessor=>Operate

Main Menu=>preprocessor=>Delete

Main Menu=>preprocessor=>Move/Modify

The mesh operation is performed by using the following path.

- Main Menu=>preprocessor=>Mesh
- C. Apply loads and obtain the solution
- 1) Applying loads:

Different loads acting on the model and boundary conditions are applied either in the preprocessor or by using the solution Menu. The loads in the ANSYS program are

- DOF Constraints
- Forces
- Surface loads
- Body loads
- Inertia loads
- Coupled-field loads

2) Defining the type of analysis and analysis options Static Analysis:

Used to determine displacements, stresses etc. under static loading conditions, both linear and nonlinear static analysis. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. Our present analysis is "static Analysis". 3) Specifying load step options:

The following path is used to specify load step options.

Main Menu=>Solution=>Load step options

4) Initiating the solution:

The solution to the given problem is initiated by using the following path. Main

Menu=>Solution=>Solve-Current LS (Load step)

D. Present Work

The present work deals with the analysis of adhesively bonded single lap joint. This is quite commonly used technique for finding the strength of different applications like pressure vessels, aerospace, marine and mostly for leak proof joints like oil tanks, boilers etc. In this, an aluminium plate material having 30 x 130 x 1.95 mm dimension is overlapped with length 40 mm. The adhesive layer thickness is varied as 0.05mm, 0.1mm, 0.15mm, 0.2mm, 0.3mm, 0.6mm.

One end of the joint is fixed while pulling load is applied on the other end. Load applied are 400N, 800N, 1600N, 3200N for all joints and 5400N, 4800N, 400N, 3600N for some cases. Results are obtained for each load and adhesive layer thickness. These results are compared to get some significant information.



Fig 3: SLA joint in Ansys 11.0

Models are prepared by using SolidWorks CAD software. These models are assembled and saved in '*.iges' format. Then these files are imported in Ansys 11.0 for further processes. Line bodies and surface bodies are suppressed. New project simulation is carried out for each model. Contact regions are defined.

Following are the material properties which are used in Ansys.



Fig. 4: Discretized adherend (aluminium) true stress-strain curve used for finite element calculations.^[5]



Fig. 5: Discretized adhesive (epoxy) true stress-strain curve (marked points used for finite element modeling).^[5]

Properties	Adhesive (Al99.5)	Adherend (E-30Cl)
Young's Modulus, E_0	1400Mpa	70000Mpa
Poisson's ratio, υ	0.35	0.3
Yield strength, R _{p0.2}	27Mpa	100Mpa
Utimate tensile strength, R _m	38Mpa	115Mpa

Table 1: Material Properties

E. Boundary Conditions

Six Samples with minimum four different loading conditions. One end is fixed while another end is given a tensile load. These loads are defined below.

Model with	1st end	2nd End		
ALT				
0.05mm	Fixed	400N,800N,1600N,3200N,		
100		4800N, 5400N		
0.1mm	Fixed	400N,800N,1600N,3200N,		
		4800N		
0.15mm	Fixed	400N,800N,1600N,3200N,		
100		4000N		
0.2mm	Fixed	400N,800N,1600N,3200N,		
		3600N		
0.3mm	Fixed	400N,800N,1600N,3200N		
0.6mm	Fixed	400N,800N,1600N,3200N		
Table.2: Boundary conditions.				



Fig. 6: Total Deformation at 3200N load in 0.05 mm ALT

20.000 (mm



Fig. 7: Shear Elastic strain at 3200N load in 0.05mm ALT



Fig. 8: Shear stress at 3200N load in 0.05 mm ALT



Fig. 9: Equivalent Strain at 3200N load in 0.05mm ALT



Fig. 10: Equivalent stress at 3200N load in 0.05 mm ALT

A. For Specimen with Adhesive layer thickness 0.6 mm. Graph shows the straight line nature, i.e. for given values stress goes on increasing with strain. Straight line indicates a linear nature joint



Fig. 11: Stress Strain graph for 0.6 mm ALT









Fig. 8: Stress Strain graph for 0.2 mm ALT Here joint shows partial straight line nature but at higher load values slop of the graph is reduced.

D. For Specimen with Adhesive layer thickness 0.15 mm. Almost a straight line nature. This diviates at around 70 Mpa stress value.



Fig. 9: Stress Strain graph for 0.15 mm ALT

	Total Deformation (mm) For			
Layer Thickness(mm)	400N	800N	1600N	3200N
0.05	4.6416	9.2833	18.567	37.133
0.1	1.6559	9.4772	18.954	37.909
0.15	4.8591	9.7183	19.437	38.873
0.2	5.0027	10.005	20.011	40.022
0.3	5.2403	10.481	20.961	41.922
0.6	5.9265	11.853	23.706	47.412

E. For Specimen with Adhesive layer thickness 0.1 mm.



Fig. 10: Stress Strain graph for 0.1 mm ALT





Fig. 11: Stress Strain graph for 0.05 mm ALT Table 3: Total Deformation

-	Strain For				
Layer Thickness (mm)	400N	800N	1600N	3200N	
0.05	0.0085772	0.017154	0.034309	0.068617	
0.1	0.00014486	0.013953	0.027907	0.055814	
0.15	0.0061604	0.012321	0.024642	0.043824	
0.2	0.0051499	0.011578	0.023157	0.041199	
0.3	0.0051622	0.010324	0.020649	0.036742	
0.6	0.0042593	0.0085186	0.017037	0.034074	
Table 4. Equivalent strain in ALT					

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	Stress (Mpa) At			
Layer Thickness(mm)	400N	800N	1600N	3200N
0.05	12.008	24.016	48.032	96.064
0.1	28.971	19.535	39.69	78.139
0.15	8.6246	17.249	34.498	68.997
0.2	8.1048	16.21	32.419	64.997
0.3	7.2271	14.454	28.908	57.817
0.6	5.963	11.926	23.852	47.704

Table 5: Equivalent stress in ALT

G. Results of all specimens are graphically represented as follows:

Graphical representation of the result mentioned above is as show in fig 3.81. It can be observed that the deformation is increasing with the increase in adhesive layer thickness at the constant load. Almost every layer shows the same nature. Only in the specimen with ALT 0.1 mm shows decrease in deformation at 400N load compared with 0.05 mm ALT specimen. It can be understood that joint with 0.6 mm ALT will fail at lower load than that of 0.2 mm and values less than that.



Fig. 12: Total Deformation Vs Adhesive layer Thickness



Fig. 13: Equivalent Strain Vs. Adhesive Layer Thickness

Above graph shows the nature of strain behavior with respect to adhesive layer thickness. Strain value goes on decreasing with increase in ALT. For 3200N strain value decreases rapidly up to 0.15 mm ALT, then value decreases slower rate. Strain at 1600N, 800N and 400N load decreases with moderate rate. Strain value suddenly drops at 0.1 mm ALT.



Fig. 14: Equivalent Stress Vs. Adhesive layer Thickness



IV. CONCLUSION

This method can be effectively utilized to find out the effects of adhesive layer thickness on overall joint strength. To understand how adhesives work, it is necessary to understand their mechanical properties and the chemistry used to create those properties. Accuracy of adhesive properties data depend on reliable materials models that can be used to predict the strength of adhesively bonded structures. Deformation increases with increase in adhesive layer thickness at the same load. Strain value reduces with increase in adhesive layer thickness. Shear stress value is maximum for 0.05mm ALT while it is minimum for 0.6 mm ALT. More accurate results can be found out by using higher versions of analysis software and by performing more effective meshing of the model.

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