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STRESS ANALYSIS OF ALUMINIUM LAP JOINTS BY USING DIFFERENT LAPING MATERIALS

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ABSTRACT

An adhesive is a substance which when applied to the surfaces of materials binds that surface together and resists separation. The strength of the adhesive joints under impact loads has become more important because of their huge use to the aircraft and automobile industries. In industries, adhesives are used to join the different or same material, But when those joined material comes under use, it may rupture or may not rupture. It depends on how much load has been applied on the joint, type of adhesive material used for joining and the contact area of the two materials. Joint failures contribute major cause of machinery breakdown resulting in costly down time. To prevent that, we should know the strength of the adhesive joint for that two particular material.

Key wards: Adhesive Joints. Strength, Loading.

INTRODUCTION

In engineering applications material joint often mechanical joining methods like Bolting, riveting, welding, soldering is chosen. However, engineers now often choose to use adhesive bonding. Joining of two materials by placing adhesive between them and allow it to solidify is nothing but an adhesive bonding and that joint is called as an adhesive joint. This joining technique is well provin and capable of replacing or supplementing mechanical fixing methods. The conventional methods like bolting, riveting, welding causes stress concentration on a surface of a joining material which results in damage of material parts. While uniform stress distribution which avoids concentration of stresses is the main advantage of adhesive joint method. In order to increase the strength of adhesive joints different types of adhesive joints like single lap adhesive joint, double lap adhesive joint, butt adhesive joint, stepped lap adhesive joint etc. are invented. Scarf adhesive joint is one of them in which scarf angle is a most critical parameter. Surface roughness, bond length, adhesive thickness, surface area (Function of scarf angle), properties of adhesive to be used are the other important parameters to be considered which affects the strength of scarf adhesive joint greatly. So, the study of these parameters is important to determine the strength of scarf adhesive joint.

In order to find maximum strength of scarf adhesive joint under tensile loading no. of experiments can be performed for different combinations of operating parameters and their optimum values can be found out. By applying design of experimentation (DOE) approach we can reduce the no. of experiments required without affecting the results.

Adhesive bonding is a process of joining two or more solid parts with an adhesive substance. The materials of the joined parts (adherents, substrates) may be different or similar.

The material of the adhesive layer is commonly a polymer (natural or synthetic). Thickness of the adhesive layer does not usually exceed 0.02” (0.5 mm).

LITERATURE REVIEW

Research has been conducted on very vast scale in adhesive joint analysis. The influence of loading with material properties and geometries and their response in the form of displacements and strength are also studied by the researchers.

L. Liao and T. Kobayashiet. al. [1] have worked on the stress wave propagations and interface stress distribution in the single-lap adhesive joint under impact tensile loading which is analyzed using the three-dimensional finite element method (3D-FEM) taking into account the strain rate sensitive of the adhesive using Cowper –Symonds constitutive model. It is found that the rupture of the joint initiates near the middle area of the edges of the interfaces along the width direction. The characteristics are compared with those of the joint under static loads, which show the different properties.

Experiments are also carried out for measuring the strain responses and the joint strength. The strength of the single-lap adhesive joint, which is described using impact energy, is obtained between 5.439 and 5.620J for the present joint.

He Danet. al. [2]in his study the stress distributions in scarf adhesive joints under static tensile loadings are analyzed using three-dimensional finite-element calculations. The effects of adhesive young's modulus, adhesive thickness and scarf angle in the adherend on the interface stress distribution are examined. The differences in the interface stress distributions between the 2-D and the 3-D FEM results are demonstrated. It is also observed from the 3-D FEM results that the maximum value of the maximum principle stress is the smallest when the scarf angle is around 60 degrees, while it is around 52 degree in the 2-D FEM when the singular stress at the edges vanishes. In addition, the joint strength is estimated using the interface stress distribution obtained from the FEM calculations. For verification of the FEM calculations, experiments were carried out to measure the strengths and the strains in the joints under static tensile loadings using strain gauges.

AlirezaChadegani, Romesh C. Batra [3] have used the first-order shear deformation plate theory (FSDT) to analyze stresses in two layers bonded together with an adhesive as recommended by the ASTM D3165 standard, except that we also include a void within the adhesive. Depending upon the number of notches and voids, the specimen is divided into several regions. The inverse transform of the solution of the algebraic equations provides stresses and displacements in the adhesive and the substrates, which are found to agree well with those obtained by the finite element method (FEM). It is also found that the order of the stress singularity at the corner of the free surface of the adhesive and the substrate, and the strain energy release rate computed from the solution of the problem with the FSDT agree well with those determined from the solution of the problem by the FEM. We note that the computational effort required to analyze the problem with the FSDT is considerably less than that needed to solve the problem by the FEM.

Quantian Luo and Liyong Tong [4] presented analytical nonlinear solutions for composite single-lap adhesive joints. The ply layups of each composite adherend can be arbitrary, but in the overlap region the ply layups of the upper and lower adherends are assumed to be symmetrical about the adhesive layer. In the present formulation, equilibrium equations of the overlap are derived on the basis of geometrical nonlinear analysis. To verify the present analytical solutions for nonlinear analysis of composite single-lap joints, the geometrically nonlinear 2D finite element analysis is conducted using commercial package MSC/NASTRAN. The numerical results of the edge moment factor, deflections and adhesive stresses predicted by the present solutions correlate well with those of the geometrically nonlinear finite element analysis. This indicates that the present analytical solutions capture key features of geometrical nonlinearity of composite single-lap adhesive joints.

D. Castagnetti and E. Dragoni [5] his paper, documents, ongoing research in the field of stress analysis of adhesive bonded joints and aims at developing efficient and accurate finite element techniques for the simplified calculation of adhesive stresses. Goal of the research is to avoid the major limitations of existing methods, in particular their dependency on special elements or procedures not supported by general purpose analysis packages. Two simplified computational methods, relying on standard modeling tools and regular finite elements are explored and compared with the outcome of theoretical solutions retrieved from the literature and with the results of full, computationally intensive, finite element analyses. Both methods reproduce the adherends by means of structural elements (beams or plates) and the adhesive by a single layer of solid elements (plane-stress or bricks). The difference between the two methods resides in the thickness and in the elastic properties given to the adhesive layer. One of the two simplified methods investigated provides accurate results with minimal computational effort for both 2D and 3D configurations.

Solyman Sharifi and Naghdali Choupani [6] presented that adhesively bonded joints are preferred over the conventional methods of joining such as riveting, welding, bolting and soldering. Some of the main advantages of adhesive joints compared to conventional joints are the ability to join dissimilar materials and damage-sensitive materials, better stress distribution, weight reduction, fabrication of complicated shapes, excellent thermal and insulation properties, vibration response and enhanced damping control, smoother aerodynamic surfaces and an improvement in corrosion and fatigue resistance. This paper presents the behavior of adhesively bonded joints subjected to combined thermal loadings, using the numerical methods. The joint configuration considers aluminum as central adherend with six different outer adherends including aluminum, steel, titanium, boron epoxy, unidirectional graphite-epoxy and cross-ply graphite-epoxy and epoxy-based adhesives. Free expansion of the joint in x direction was permitted and stresses in adhesive layer and interfaces calculated for different adherends.

Young Tae Kim, Min Jung Lee,et. al. [7] he represents that adhesive joints have been widely used in various fields because they are lighter than mechanical joints and show a more uniform stress distribution if compared with traditional joining techniques. Also, they are appropriate to be used with composite materials. Therefore, several studies were performed for the simulation of the bonded joints mechanical behavior. In this paper, the super imposed finite element method is introduced to overcome this problem. The superimposed finite element method is one of the local mesh refinement methods. In this method, a fine mesh is generated by overlaying the patch of the local mesh on the existing mesh called the global mesh. Thus, re-meshing is not required. Elements in the substrate are generated. Then, the local refinement using the superimposed finite element method is performed near the interface between the substrate and the adhesive layer considering the shape of the element, the element size of the adhesive layer and the quality of the generated elements. After performing the local refinement, cohesive elements are generated automatically using the interface nodes. The total mesh generation time is reduced and the element quality is improved. The proposed method is applied to several examples.

Structure of adhesive joint

a. Adhesion
b. Wetting
c. Failure of adhesive bonding

Adhesive joint generally consists of two substrate surfaces with the adhesive material filled the gap between them. However, the adhesive layer is not uniform. Besides the part of the adhesive layer, properties of which are not affected by the substrate, there are two boundary layers, which have been changed by impurities and products of reactions at the substrate surfaces. Boundary layer is a part of the adhesive layer adjacent to the substrate surface.

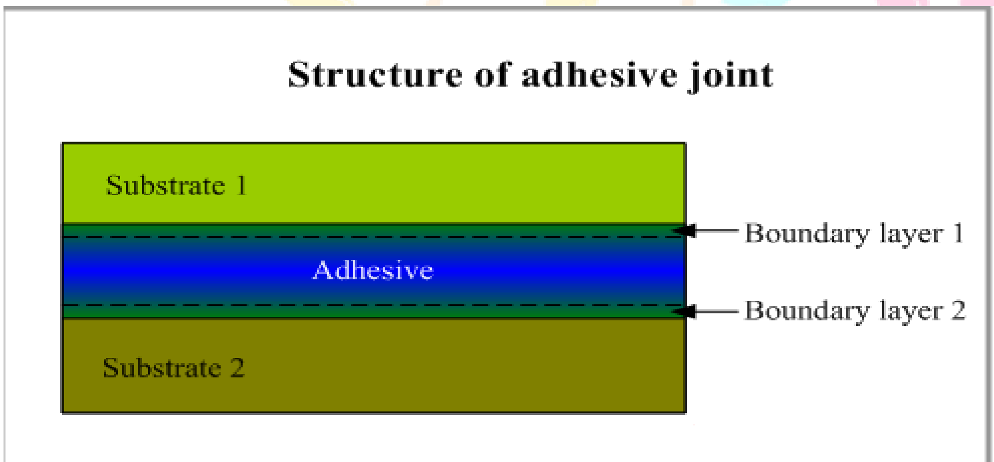

Fig. 1 Structure of adhesive joint

FINITE ELEMENT ANALYSIS

In the present study, stress distribution in double lap adhesive joint is obtained as,
Load (F) = 100N (from both way in opposite direction).
Material Properties:
Modulus of elasticity (E) = 206 GPa
Poisson's ratio (μ) = 0.3
Density (ρ) = 7.843 × 103 kg/m3
Parameters selected for analysis:
Length of adherends is 90 mm, 100 mm and 110 mm.
Width of adherends is 10 mm, 15 mm and 20 mm.
Length of adhesive layer is 25mm, 27mm and 30mm.
To obtain the stresses developed in the double lap adhesive joint under loading condition, analysis is carried out taking 100 N load on both sides in opposite direction.

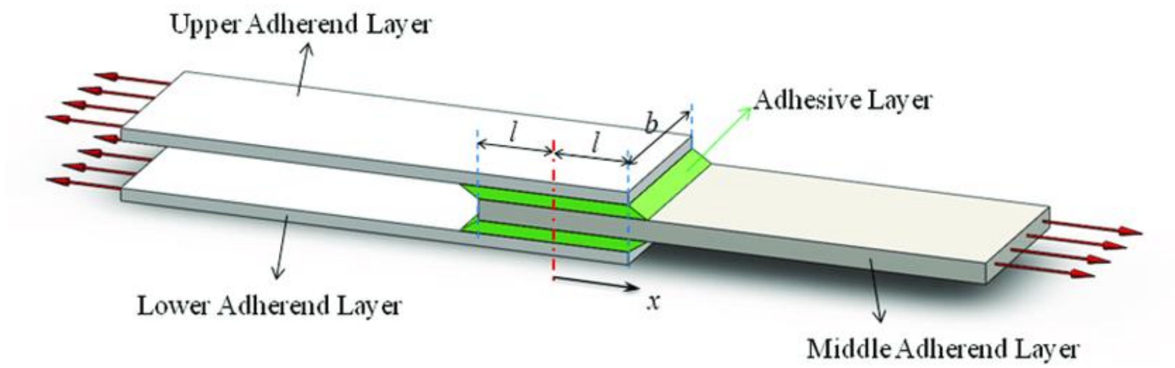

Fig. 2 Parameters used in ANSYS Analysis.

Cases of stress obtained:

Following Figure 3 shows that deformation accurse in lap joint due to applied load by using ANSYS 14.5 workbench. On double lap join in this join maximum deformation accurse is 0.00134mm.

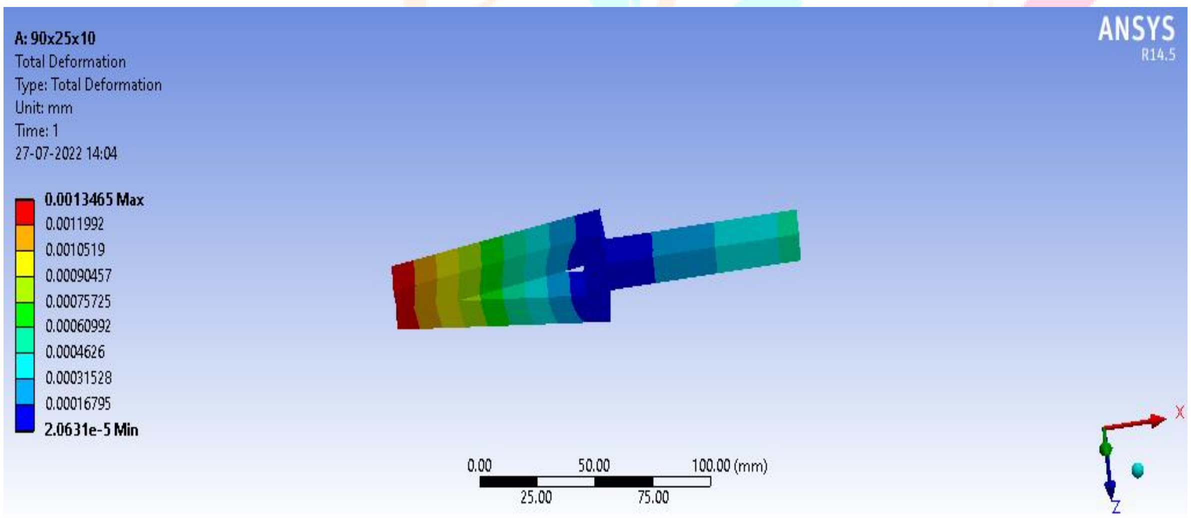

Fig.3 Case 1.90×25×10

Following Figure 4 shows that stress induced in lap joint due to applied load by using ANSYS 14.5 workbench. In this join maximum stress induced is 1.979MPa

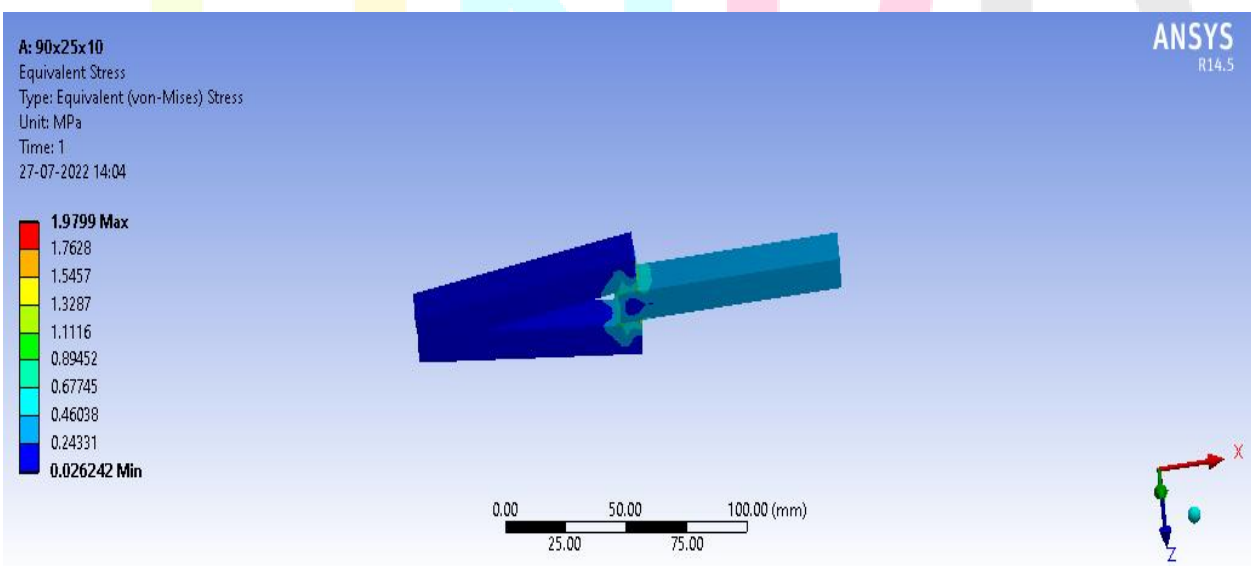

Fig. 4 Case 2. 90×25×10

Following Figure 5 shows that total deformation induced in lap joint due to stress occurred .
In this case the maximum total deformation is 0.00104mm.

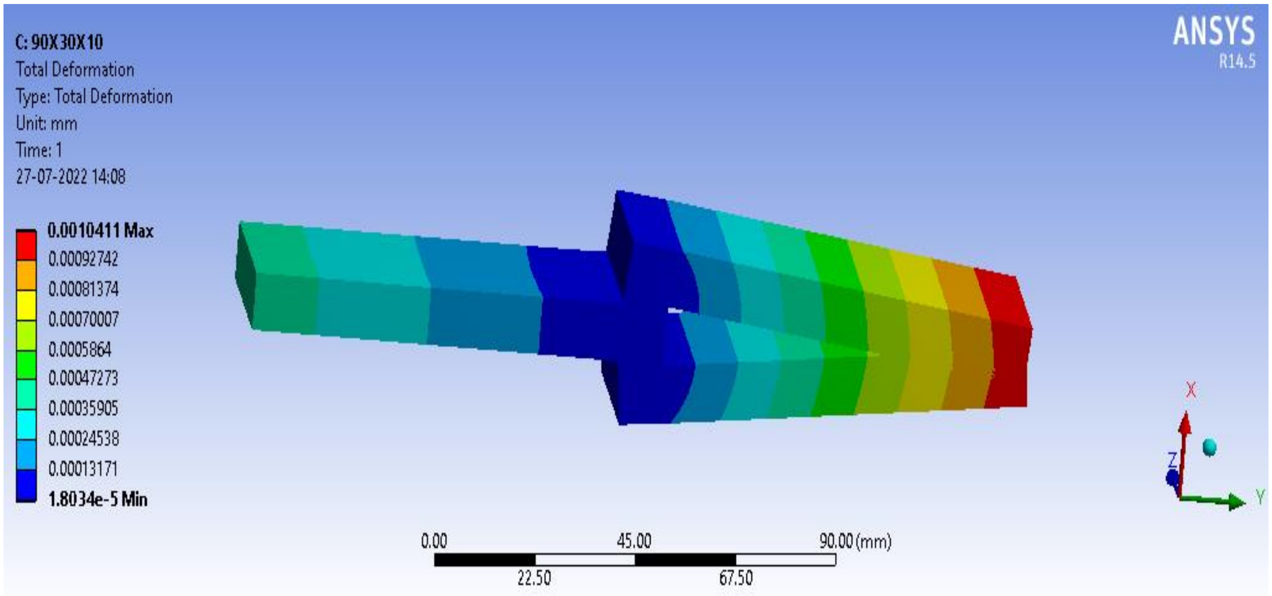

Fig.5 Case 3. 90×30×10

Following Figure 6 shows that stress induced in lap joint due to applied load by using ANSYS 14.5 workbench. In this join maximum stress induced is 1.608MPa.

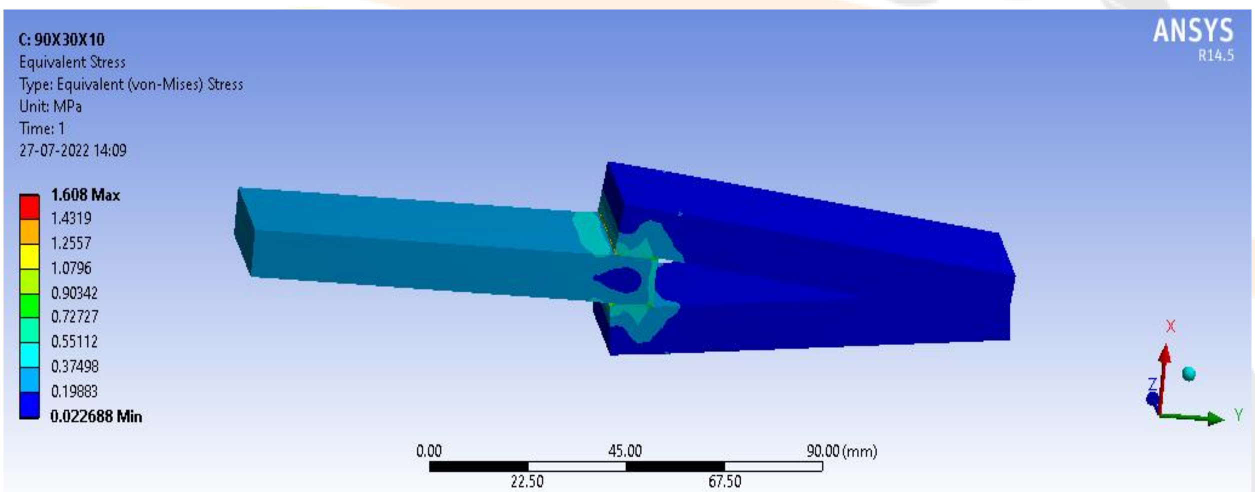

Fig.6 Case 4. 90×30×10

PRACTICAL TESTING

Fig.7 (a) 3D model of Experimental Setup (b) Testing setup with joint

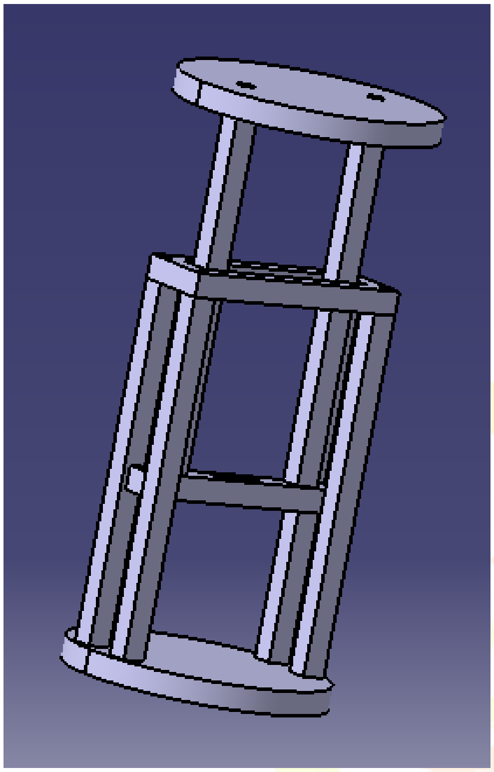

Fig.7 (a) 3D model of experimental setup

Fig.7 (b) Testing setup with joint

RESULTS & DISCUSSION

Case	Specification of joint (Length ×Width × Height) (mm)	Total deformation (mm)	Stress (MPa)
1	90×25×10	0.0013	1.97
2	90×27×10	0.0011	1.80
3	90×30×10	0.0010	1.82
4	100×25×10	0.0013	1.75
5	100×27×10	0.0012	1.62
6	100×30×10	0.0011	1.43
7	110×25×10	0.0011	0.92
8	110×27×10	0.0012	0.859
9	110×30×10	0.0011	0.77
10	90×25×15	0.000566	1.341
11	90×27×15	0.00052	1.23
12	90×30×15	0.00104	0.580
13	100×25×15	0.000615	1.36
14	100×27×15	0.000572	1.03
15	100×30×15	0.000513	0.936
16	110×25×15	0.000665	0.57
17	110×27×15	0.000615	0.505
18	110×30×15	0.00055	0.456
19	90×25×20	0.000433	1.10
20	90×27×20	0.000401	1.02

21	90×30×20	0.00036	0.92
22	100×25×20	0.00049	0.991
23	100×27×20	0.000453	0.916
24	100×30×20	0.000408	0.817
25	110×25×20	0.00054	1.146
26	110×27×20	0.00050	1.05
27	110×30×20	0.00045	0.939

Table 1. ANSYS results in the form of stress and deformation for all samples

Sr. No.	Specification of joint	Break Impact				
		1	2	3	4	5
1	90×25×10	N	N	Y		
2	90×30×20	N	N	N	N	N
3	100×30×10	N	N	N	N	

Table 2. Practical hammering effect on samples

CONCLUSIONS

- The ANSYS program was successfully carried out which can be used to determine the total deformation and stresses developed in double lap adhesive joint.
- The double lap adhesive joint of 90×30×20 is most suitable.
- This joint gives the minimum deformation of joint 0.00053 mm and minimum stress developed 0.497 MPa.
- The change in the joint structure results in the change of deformation and stresses.

Also, by practical testing we can find out 90×30×20 is not break after 5 times of hammering on it.

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