Research Paper

EXPERIMENTAL & PHOTOELASTIC ANALYSIS OF ARC WELDED LAP-JOINT

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ABSTRACT

This research work deals with the stresses in the weldment of an arc welded lap-joint under static load condition. For the analysis, Finite Element method along with experimental techniques is used. A single arc welded lap joint subjected to transverse static load is considered for the analysis. The stresses in the weldment are evaluated by varying the gap between the parent plates which may occur during manufacturing. The Finite Element results are compared with Photoelastic analysis. The breaking strength of the weldment is also determined analytically and experimentally to verify F.E. results. It is observed that the magnitude of stress in the weldment varies with respect to gap between the parent plates.

KEYWORDS Lap-Joint, Weldment, Photoelasticity, FEM.

1. INTRODUCTION

Stress analysis is complete and comprehensive study of stress distribution. As welding involves number of applications in industry, so it is necessary to know the main root cause of failure of weldment. The manufacturer of weld components requires the accuracy of weld size. For the FE & Theoretical analysis on the weldment of Arc Welded Lap-joint, three plates are used. Two plates of uniform dimensions of 100mm X 50mm X 8mm thick are welded with one plate with weld size of 5 mm providing the gap between them to take into account the positional error which may occur during welding or manufacturing. The analysis is carried out using analytical, experimental & Finite Element method considering transverse loading on weldement. The gap between parent plates is varied from 0.1 mm to 1.0 mm in the step of 0.1 mm to take into account the positional error. In this work static stress analysis of weldment is carried out by FEM & to verify the FE result experimental techniques like Photoelasticity is used. Experimentation is also carried using UTM to determine the breaking strength of weldment to validate the FE model & results.

2. EXPERIMENTAL DETERMINATION OF BREAKING STRENGTH OF ARC WELDED LAP JOINT & ITS COMPARISON WITH FE & ANALYTICAL RESULTS.

An Arc welded Lap-joint with dimension considered for determination of breaking strength is shown in fig. 1.

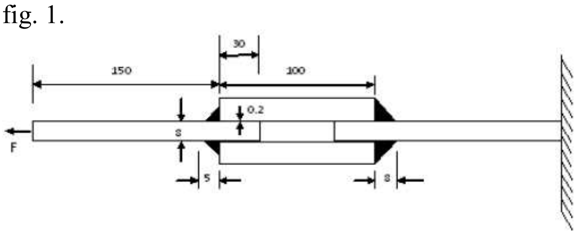

Fig. 1. Dimensions for Test Specimens

Fig. 2. Test Plate

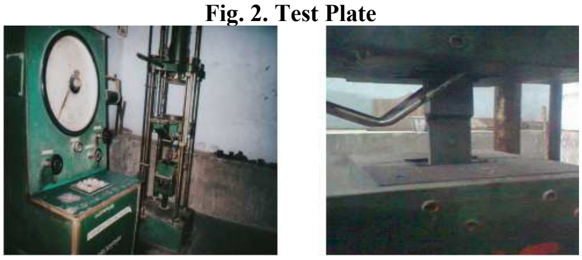

Fig.3. Mounting and loading of Test Specimen on UTM

Fig. 4. Failure of Test Specimen

It is seen that the weldment having weld size of 5.0 mm has failed under the load of 144.403 KN, which revealed the breaking strength for the weldment**.** The experimental breaking stress found out to be 1045.766 MPa.

2.1. FINITE ELEMENT APPROACH

To verify the experimental result for breaking stress, FE model is prepared with same geometric dimensions of model used during experimentation. The material properties specified are as follows.

- Modulus of elasticity of parent plate material (E) = 2.3 x 10^5MPa
- Poisson's ratio of parent plate material (μ) = 0.3
- Modulus of elasticity of weld material (E) = 1 x 10^5 MPa
- Poisson's ratio of weld material (μ) = 0.4

For this analysis, "SHELL63" element is used which is a 2-D structural higher order element, which allows a coarser mesh with good solution accuracy. The mesh is generated using triangular meshing. Loads and constraints required are added to perform a static finite element analysis. The stress contours for maximum shear stress in weldment are shown in fig.5.

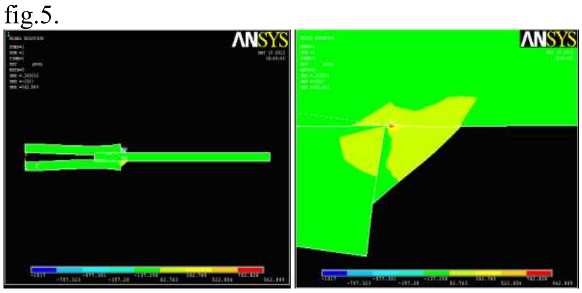

Fig. 5. Maximum Shear stress contour in Arc Weldment Lap-joint

The FE analysis revealed the maximum stress in the weldment as 962.849 MPa, which is in close agreement with experimental breaking stress value of 1045.766 MPa, which also validated the FE model of weldment. The variation of maximum shear stress as per weld geometry is shown in fig.6 are also studied along the weld length and throat thickness. These stress variations are given in fig. 7 to fig.10.

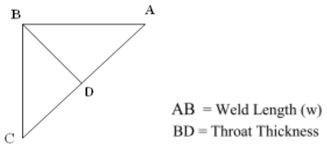

Fig. 6. Weld Geometry

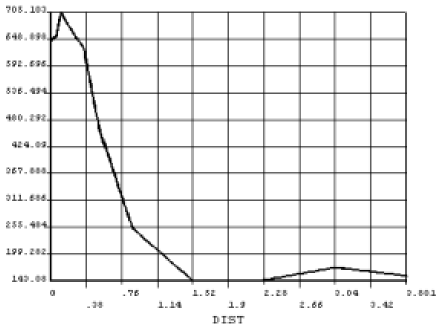

Fig. 7 Shear stress Distribution on weld BD

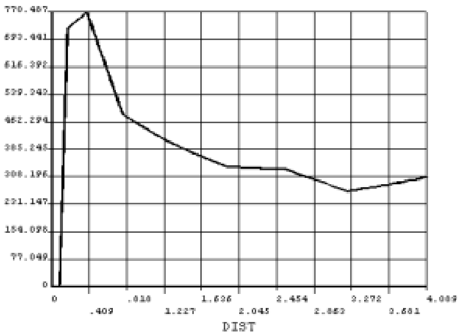

Fig. 8. Distribution of Maximum Principal Stress along throat thickness BD

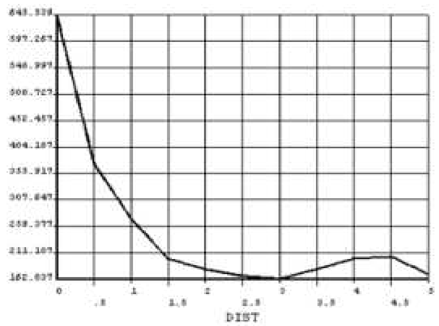

Fig. .9 Shear Stress Distribution on weld leg AB

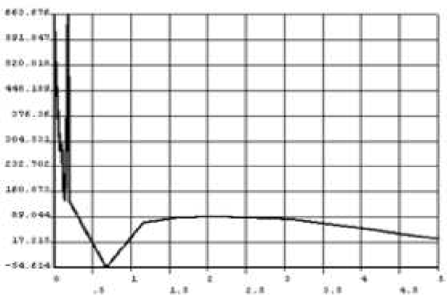

Fig. 10. Shear Stress Distribution on weld leg BC

3. PHOTOELASTIC ANALYSIS OF LAP JOINT AND ITS COMPARISON WITH FE RESULTS

In the field of present engineering development, stress analysis using photo-elastic method plays an important role. This method provides means for visualization of stresses spread across the cross section of loaded specimen and determination of stresses in whole field.

The experimental photoelastic test is done on photoelastic model made of araldite. The similar analysis is also carried out by FEM and results are compared.

The photoelastic model considered for the analysis is shown in fig. 12 & their dimensions are shown in fig. 11.

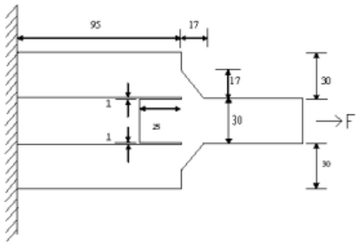

Fig. 11. Dimensions for Test Specimen (All dimensions are in mm)

Fig. 12. Photoelastic model of Arc Welded Lap joint

Material fringe value Fσ (Determined using Circular disk) is found out to be 10.242 N/mm.

Observations

Photoelastic stress analysis is carried out by using polariscope to determine the Maximum Shear stress at the critical point and observation are shown in table no.1

Table 1 Observation Table

Sr. No	Weight in Pan (kg)	Lever Ratio	Weight (N)	Fringe order (N) Higher order (N1)	Fringe order (N) Lower order (N2)	N = N1+N2 / 2	τ_{max} = NFσ/ 2h (MPa)
1	13	3.3	420.84	3.5 + 9.7 = 4.47	4.5 – 0.21 = 4.29	4.38	3.737
2	14	3.3	453.22	4.5 + 0.98 = 5.48	5.5 – 0.16 = 5.34	5.41	4.612
3	15	3.3	485.59	4.5 + 0.95 = 5.45	5.5 – 0.17 = 5.32	5.42	4.62

To validate these result FE techniques is used and described in next section.

Fig. 13 Polariscope

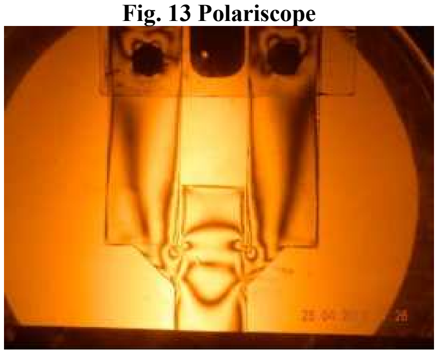

Fig. 14 Isochromatic fring pattern of Lap joint

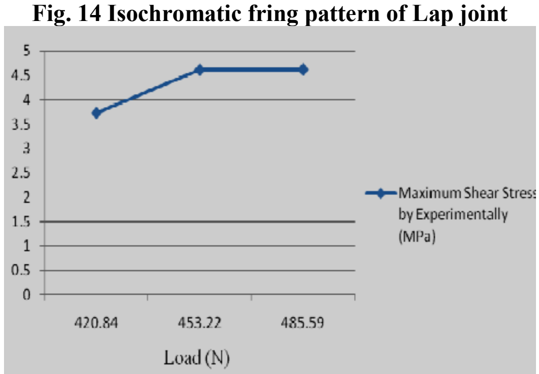

Fig.15 Variation of Maximum Shear Stress in Photoelastic model of Arc Welded Lap joint

3.1 FINITE ELEMENT ANALYSIS OF LAP JOINT

The FE model of plate with weldment is shown in fig.16. Material properties are Young's modulus of 200 GPa and poisons ratio of 0.3. An eight-node solid element, i.e, Plane 82 is used for analysis. To investigate maximum shear stress in an elastic range, the plates are modeled as a linear elastic material. The plate is fixed at one edge and the various loads are applied at the other edge and results are shown in Fig.17.

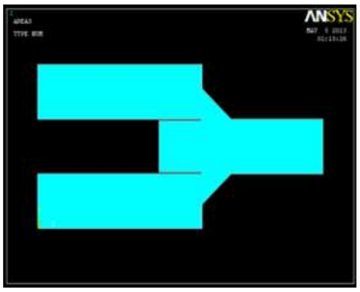

Fig.16 FE Model of Arc Welded Lap-Joint

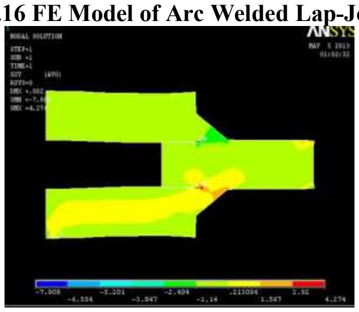

Fig. 17 FEA result of Lap joint

The maximum shear stress in the weldment for various magnitudes of loads is given in table 2.

Table 2 Maximum Shear stress in the weldment of Arc Welded Lap joint

Load (N)	Maximum Shear Stress by FEM MPa
420.84	4.274
453.22	4.602
485.59	4.931

The comparison between FE & photoelastic results is given in table 3 & fig.18. It is observed that the Photoelastic & FE result are in good agreement.

Table 3 Comparison of Maximum Shear stress by Photoelastic & FE analysis

Load (N)	Maximum Shear Stress		% of Error
	Photoelastic Analysis (MPa)	Finite Element Analysis (MPa)	
420.84	3.737	4.274	12.56
453.22	4.616	4.602	0.30
485.59	4.62	4.931	6.307

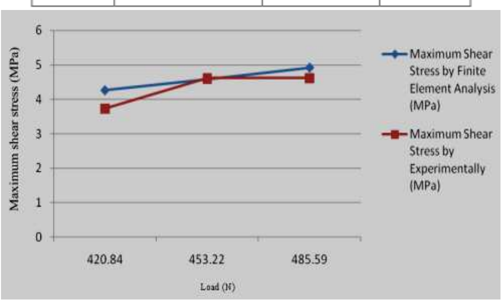

Fig. 18 Comparision of Maximum Shear stresses by Photoelastic & Finite Element Analysis

4. STRESS ANALYSIS OF WELDMENT BY FE APPROACH CONSIDERING POSITIONAL ERROR

The stresses in the weldment are evaluated by varying the gap between the parent plates which may occur during manufacturing. To study the FE stresses of weldment, the gap between parent plates is varied from 0.1 mm to 1.0 mm in the steps of 0.1 mm. To study the FE stresses of weldment, the overlap between parent plates is also varied from 10 mm to 100 mm in the steps of 10 mm. It is observed that as the overlap between parent plates increases from 10 mm to 100 mm, the maximum shear stresses is found to be 917.42 to 979.18 MPa, which indicates, negligible effect of overlap on shear stress. Meshing, boundary conditions & loading under tensile load is shown in fig.19 and Maximum Shear stress contain for gap of 0.1mm, 0.5 mm & 1.0 mm are shown in fig. 20 as representative cases.

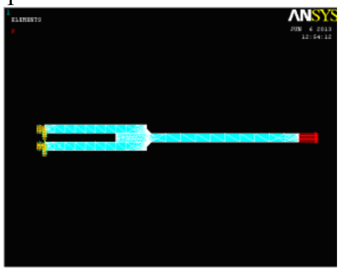

Fig. 19 Meshing, Loading & Boundary Conditions for Lap-Joint

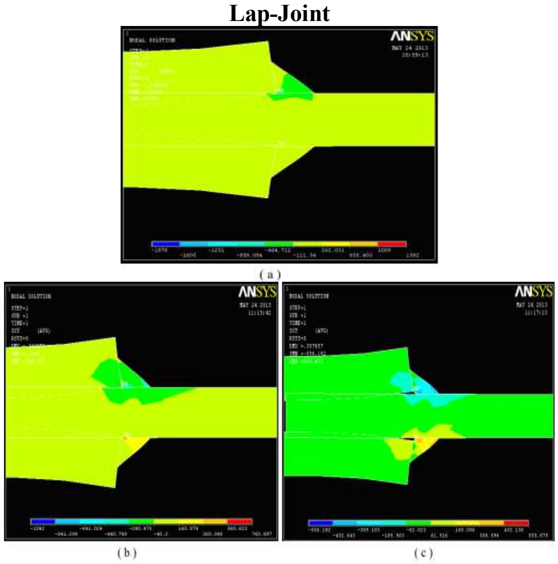

Fig. 20 Maximum shear stress Counter for (a) 0.1 mm gap, (b) 0.5 mm gap & (c) 1.0 mm gap

Table No. 4 Maximum Shear stress with variation in gap between parent plates

Sr. No.	Gap between parents plates (mm)	Maximum Shear Stress (MPa)
1	0.1	1382
2	0.2	962.849
3	0.3	760.897
4	0.4	872.625
5	0.5	758.659
6	0.6	676.565
7	0.7	664.913
8	0.8	581.885
9	0.9	594.743
10	1.0	555.675

Fig. 21 Maximum Shear Stress w.r.t. Gap between parent plates

5. DISCUSSION AND CONCLUSION

The discussion and conclusion on the results is as follows:

The experimental determination of breaking strength of Arc welded Lap joint revealed the breaking stress 1045.766 MPa. The FE analysis of Arc welded lap joint for the same geometry revealed the maximum shear stress of 962.849 MPa. This investigation confirmed that the breaking stress in the weldment determined by experimentation and FE analysis are in close agreement, which eventually validated the FE model of the Arc welded lap joint considered for further analysis.

To verify further the FE model of Arc Welded Lap joint, photoelastic analysis is carried out. The photoelastic model revealed the Maximum shear stress of 3.737, 4.612 & 4.62 MPa which are in close agreement with FE results of 4.274, 4.602 & 4.931 MPa for three different load magnitudes. This again validated the FE model of weldment considered for analysis.

The static stress analysis on weldment is performed to take into account the positional error which may occur during manufacturing. For this purpose the gap between the parent plates is varied from 0.1mm to 1mm in the step of 0.1 mm and it is observed that the maximum shear stress in the weldment varies w.r.t. gap between the parent plates. It is seen that the maximum shear stress reduces as the gap between the plate increases. This may be due to shifting of shearing zone of the weldment which resulted into increase in the throat length. Further investigations are required to verify this fact under fatigue loading and also under other loading condition like bending load etc.

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