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Experimental and Fe Analysis of Eccentric Loaded Welded Joint Structure

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Abstract
Arc welded structures are widely used in automobiles, constructions & power plants. As the main cause of weldment failure is design defect & overload, hence it is necessary to analyze the maximum stresses in the weldment. In this project experimentation is carried out on symmetrical and unsymmetrical eccentric loaded welded joint to determine the breaking stress in the weldment. The FE analysis & analytical estimation of breaking stress is also carried out to verify the experimental results. The stress distribution along weld size & throat thickness is evaluated and also compared with reported findings under same loading condition. Further eccentric loaded welded joint is analyzed under eccentric load by varying the gap between parent plates.
Keywords: Eccentric, weldment

I. Introduction

The strongest and most common method of permanently joining steel components together is by welding. Arc welded structure are widely use in construction, automobiles & heavy industry, nuclear power plants. Fillet welded joints are widely used in engineering construction due to their relatively high strength and the ease of surface preparation required for such welds. In many joint configurations used in practice in-plane or out-of-plane eccentricity are unavoidable, creating more complex stress conditions in the joint than concentrically loaded joints where the welds are generally subjected to shear in only one direction. In welded joints that are subjected to in-plane eccentricity, the weld is free to deform over its entire length.This study solely focuses on the design of welded joints subjected to an eccentric load in the plane of welds, consists of calculation of primary and secondary shear stresses. A model of each element of transverse fillet weld joint is developed in PROE**5.0** and analyzed in **ANSYSWORKBENCH 12.0**. FE analysis is carried out for symmetrical and unsymmetrical weld patterns and maximum von mises stress and maximum shear stress are determined.Validation is supported by stress analysis using experimental results of eccentrically loaded welded joints.Finally, the results obtained from FEM software, experimental and analytical results are compared.

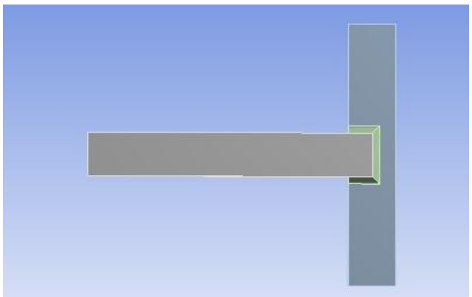

Fig. 1.1 Symmetrical eccentric loaded welded joint

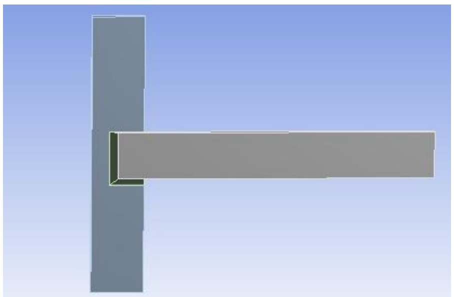

Fig. 1.2 Unsymmetrical eccentric loaded welded joint

1.1 Objectives and Methodology

For the FE analysis on the weldment eccentric loaded joint as shown in fig. 1 is considered. Two parent plates of uniform dimensions are welded by arc welding. Horizontal plate having length 300 mm, thickness 8 mm & width 50 mm, while vertical plate of dimensions are with the length of 300 mm, thickness 8 mm & width 50 mm. These parent plates are welded with weld size of 8 mm with a small gap between them.

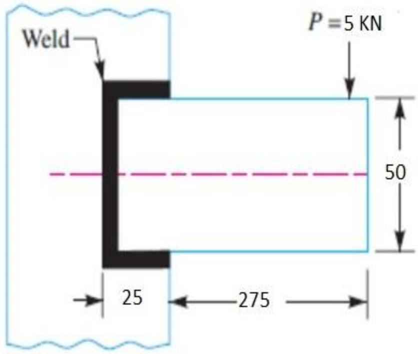

Fig 1.3 Symmetrical eccentric loaded welded joint

It is also intended to vary the gap between parents plates to take into account the positional error which occurs during welding or manufacturing. The analysis is proposed to be carried out using Finite Element method with FE software ANSYS WORKBENCH. The following type of load is considered, which are acting on the horizontal plate.

- Eccentric Load (Static Load)

It is intended to vary the gap between parent plates from 0.01 mm to 0.1mm in the step of 0.01 mm. Following types of analysis are carried out for present work.

- Experimental determination of breaking stress of weldment.
- Static analysis of weldment under eccentric load.

II. Determination of Breaking Stress in Symmetrical weldment by experimentation & its verification by FEM

The horizontal and vertical plates are welded with fillet weld by overlapping on each other which is cross section of 50 X25 X 8 mm. The size of fillet weld is taken as 8mm. To carry out the experimentation by using Hydraulic jack set up, the vertical plate is welded from the top & bottom side to the structure for fixing the test specimen.

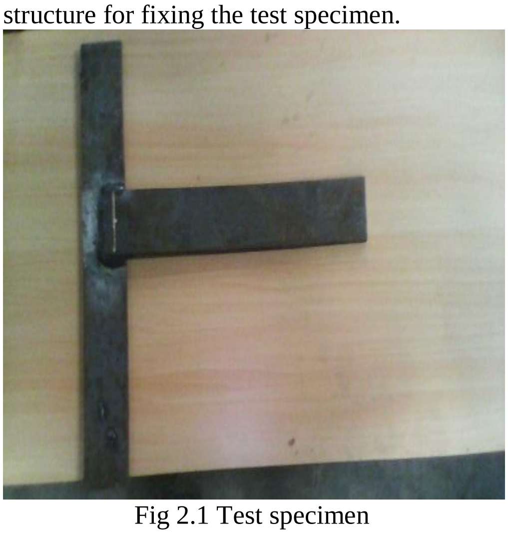

Fig 2.1 Test specimen

Fig 2.2 Mounting & Loading of Test specimen

Fig 2.3 Failure of Test specimen

The weldment of size 8.0 mm has fail in breaking at a load of 509.684 kg(5000 N) which is the breaking strength for the weldment**.**

2.1 Analytical Calculation

P is the load on Horizontal Plate = 5000 NEccentricity e = 220mmWidth of plate b=50mmLength of weld *l*=25mmSize of weldment s=8mmThroat thickness of weldment
t=0.707x s=0.707x8=5.656 mm
Distance of C.G. from left hand edge of the weld system be 'x'

$$x=\frac{l^2}{(2l+b)}$$

Polar moment of inertia of the throat area of the weld system about C.G.

$$J = t\left[\frac{(b+2l)^2}{12} - l^2 \times \frac{(b+l)^2}{(b+2l)}\right]$$

Maximum radius of weld,

$$r_2=\sqrt{r1^2 + (r1 - x)^2}$$

Angle between Primary & Secondary Shear Stress

$$\cos\theta=\frac{r1}{r2}$$

Throat area of weld system

$$A = 2 \times 0.707sl + 0.707sb$$

Direct or primary shear stress,

$$f_{s1}=\frac{P}{A}$$

Shear stress due to the turning moment or secondary shear stress,

$$f_{s2}= (P\times e\times r_2)/J$$

Now the resultant shear stress,

$$fs= \sqrt{fs1^2 + fs^2 + 2fs1 \times fs2 \times cos\theta}$$

Breaking stress in shear by mathematical calculation has been found to be 140.04 MPa for symmetrical weld pattern.

2.2 Determination of Breaking Stress by FE Analysis

Analysis of weldment is carried out by considering data as per experimentation & analytical calculation.The analysis is carried out by developing a model of eccentric loaded-joint on modeling software PRO ENGINEER 5.0 and this model is imported in ANSYS WORKBENCH 12.0.

2.2.1 Material Data

Table no.2.1 Structural Steel (For plates)

Density	7850 kg/m^3
Tensile yield strength	250 MPa
Compressive yield strength	250MPa
Tensile ultimate strength	460 MPa
Young's modulus	2.3E+05 MPa
Poisson's ratio	0.3

Table no.2.2 Weld Material (E6013)

Density	7872 kg/m^3
Tensile yield strength	420 MPa
Compressive yield strength	420MPa
Tensile ultimate strength	490 MPa
Young's modulus	1E+05 MPa
Poisson's ratio	0.4

2.2.2 Static Structural Analysis

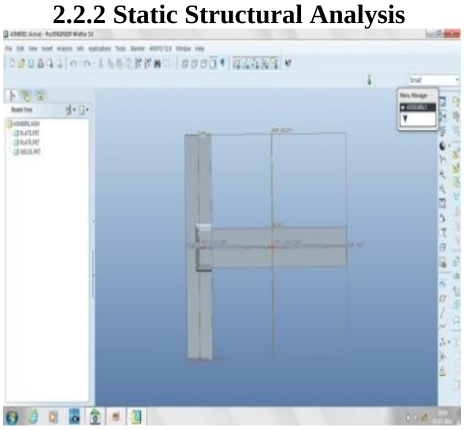

Fig 2.4 Geometrical model of Test specimen

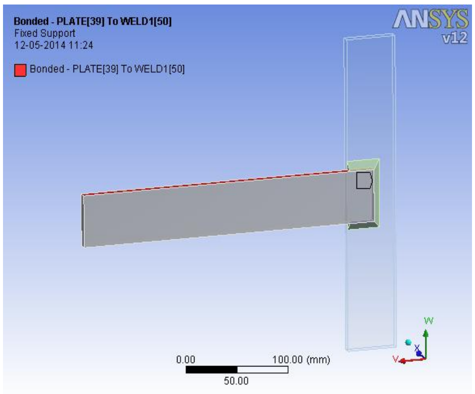

Fig 2.5 Contact Region (Bonded Type)

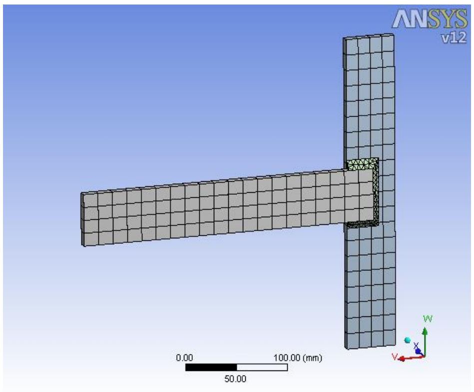

Fig 2.6 Meshing (Fine Mesh)

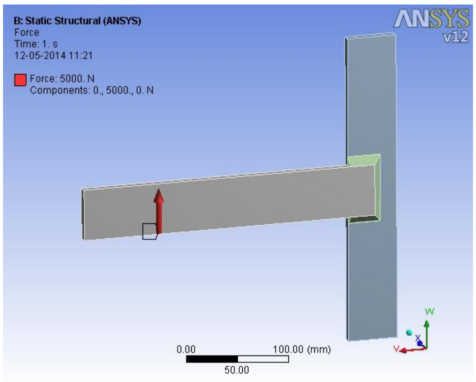

Fig 2.7 Loading Condition

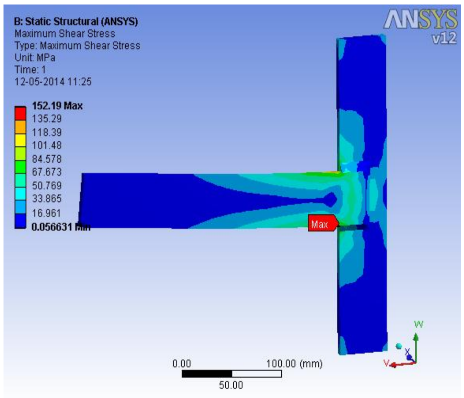

Fig 2.8 Solution

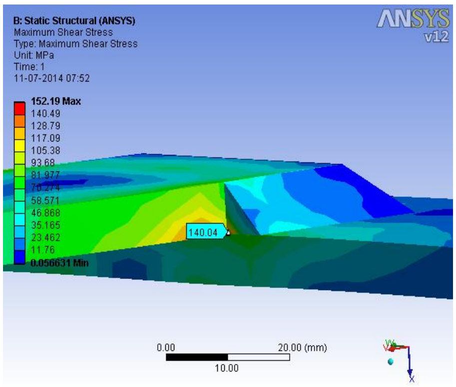

Fig 2.9 Maximum Shear Stress In weldment

In analytical problem, the value of maximum permissible shear stress is 140.04 MPa and during FEM analysis, value obtained is in the range of 135.29 MPa to 152.19 MPa which is validated. Thus the FE model of weldment is validated for induced stresses.

III. Determination of Breaking Stress in Unsymmetrical weldment by experimentation & its verification by FEM

An unsymmetrical welded eccentric loaded joint is considered for determination of breaking strength. A prototype of weld joint is prepared & it is tested by using setup of hydraulic jack.

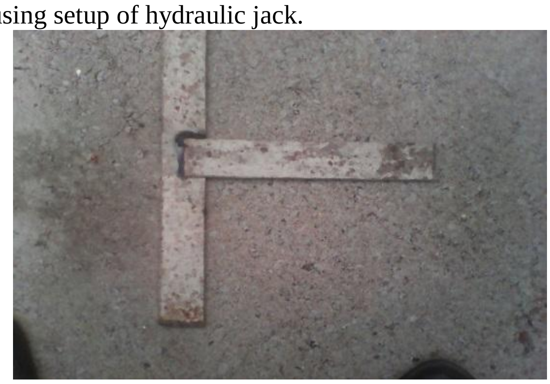
Fig 3.1 Test Specimen of Unsymmetrical Weldment


Fig 3.2 Test Setup


Fig 3.3 Failure of Test specimen

The same experimental procedure has been applied for unsymmetrical weld pattern which is previously discussed in section 4.2.After experimentation, the weldment of size 8.0 mm has fail in breaking at a load of 305.810 kg (3000 N) which is the breaking strength for the weldment**.**

3.1 Analytical Calculation

The breaking stress determined from the breaking strength determined experimentally is calculated as follows:

Breaking Load, P=3000 N
Eccentricity, e = 220mm
Width of plate, b=50mm
Length of weld, *l*=25mm
Size of weldment, s=8mm
Throat thickness of weldment,
t=0.707x s=0.707x8=5.656 mm

Breaking stress in shear by mathematical calculation has been found to be 143.34 MPa for unsymmetrical weld pattern.

3.2 Determination of Breaking Stress by FE Analysis for Unsymmetrical weldment

Analysis of weldment is carried out by considering data as per experimentation & analytical calculation. The same FE analysis commands have been utilized for unsymmetrical weld pattern which are previously discussed in section 2.2.2 Material properties have been remaining same which are taken in symmetrical weld pattern in section 2.2.1.

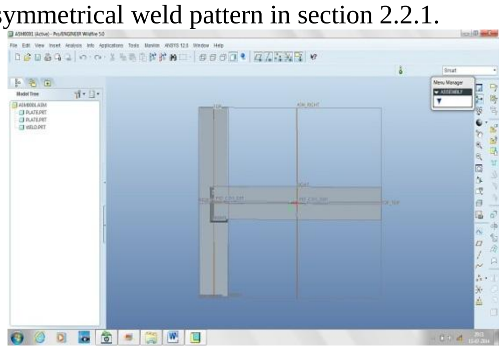
Fig 3.4 Geometrical model of Test specimen

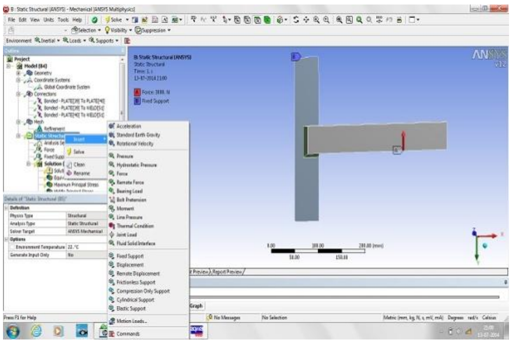

Fig 3.5 Loading Condition

Load value is taken from experimentation result i.e.3000N.

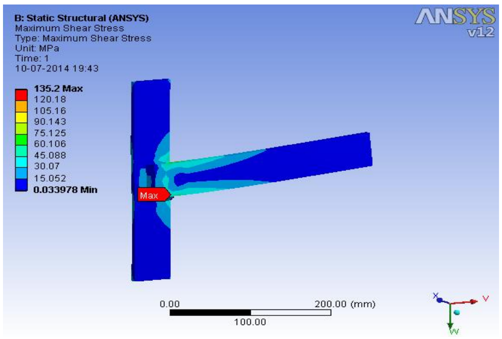

Fig 3.6 Solution

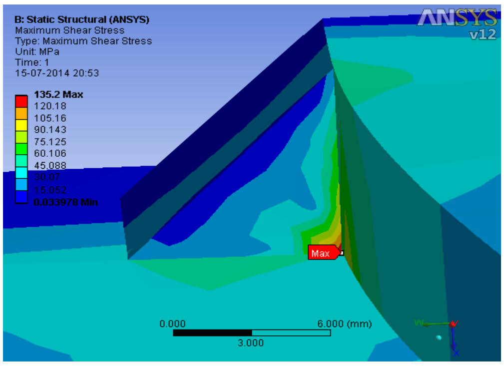

Fig 3.7 Maximum Shear Stress in weldment

In analytical calculation, the value of maximum permissible shear stress is 143.34 MPa and during FEM analysis, value obtained is 135.2 MPa which is validated. Thus the FE model for unsymmetrical weldment is validated for induced stresses.

IV. Comparison of Symmetrical and Unsymmetrical weldment under same loading condition

FE analysis is carried out for eccentric load of 5000N on unsymmetrical weldment pattern. The load is applied on horizontal plate of cross section of 300x50x8 mm and vertical plate remains fixed from its upper and lower side. Procedure for FE analysis is same as previously discussed in section 2.2.2. Eccentricity is taken as 220 mm and result gets compared with results of symmetrical weld pattern.

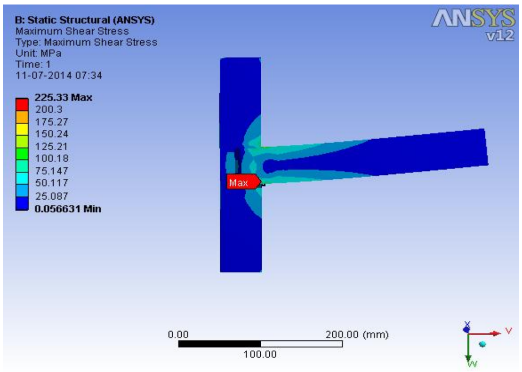

Fig 4.1 Maximum shear stress

Table no.4.1

Type of stress (MPa)	Symmetric weldment	Unsymmetric weldment
Maximum shear stress	152.19	225.33
Maximum principal stress	434.7	481.81
Minimum principal stress	130.31	62.04
Maximum von mises stress	280.14	422.22

V. FE analysis of Symmetrical weldment with Variation in the Gap between Parent Plates

FE analysis is carried out for the eccentric load of 60000N which is applied on horizontal plate and the bottom and top surface of vertical plate is constrains in all directions. To study the FE stresses of weldment, the gap between parent plates is varied from 0.01 mm to 0.1 mm in the steps of 0.01 mm. All the models are developed with ANSYS WORKBENCH 12.0 using the procedure already described in section2.2.2. For stress analysis of the eccentric loaded joint weldment, the Maximum Shear stress is considered.

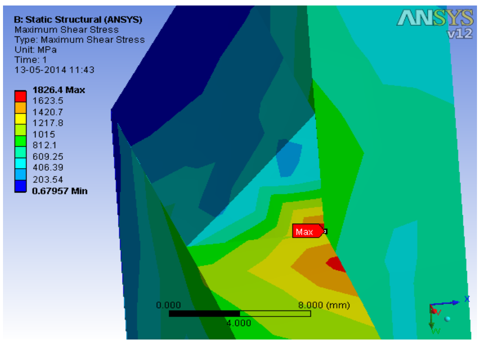

Fig 5.1 For a gap of 0.01 mm

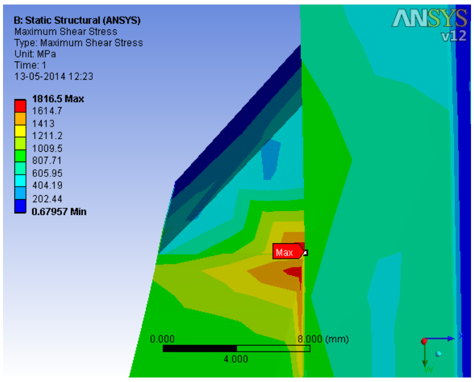

Fig 5.2 For a gap of 0.05 mm

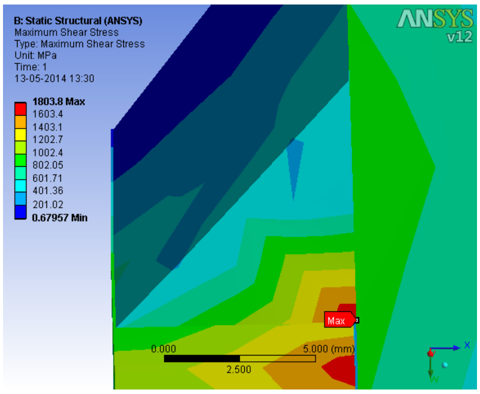

Fig 5.3 For a gap of 0.1 mm

Table No. 5.1Maximum Shear Stress

Sr. No.	Gap between parents plates (mm)	Maximum Shear Stress (MPa)
1	0.01	1826.4
2	0.02	1823.9
3	0.03	1821.5
4	0.04	1819
5	0.05	1816.5
6	0.06	1814
7	0.07	1811.4
8	0.08	1808.9
9	0.09	1806.3
10	0.1	1803.8

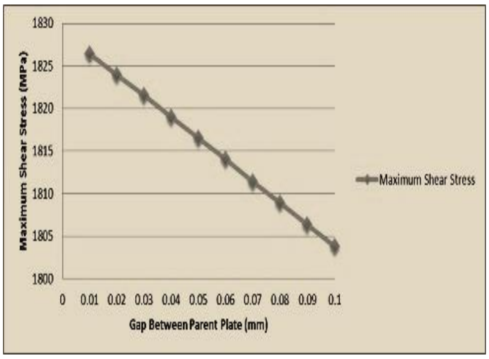

Fig 5.4 Variations of Max. Shear Stress w.r.to Gap between Parent Plates

VI. Discussion and Conclusion

Though the detail result are presented in previous sections. The discussion and conclusion on this result is presented in this section. The experimental determination of breaking strength of symmetrical eccentric loaded welded joint revealed the breaking stress is 140.04 MPa. The FE analysis of symmetrical eccentric loaded welded joint for the same geometry revealed the maximum shear stress is in the range of 135.29 MPa to 152.19 MPa as shown in fig.2.9. This investigation revealed that the stress in the weldment calculated by experimentation & FE analysis are in close agreement, which validated the FE model of the eccentric loaded welded joint considered for the analysis.

The experimental determination of breaking strength of unsymmetrical eccentric loaded welded joint revealed the breaking stress is 143.34 MPa. The FE analysis of unsymmetrical eccentric loaded welded joint for the same geometry revealed the maximum shear stress is in the range of 135.2 as shown in fig.3.7. This investigation also revealed that the stress in the weldment calculated by experimentation & FE analysis are in close agreement, which validated the FE model of the eccentric loaded welded joint considered for the analysis.

From comparison of results obtained in FE analysis of symmetrical eccentric loaded welded joint and unsymmetrical eccentric loaded welded joint under same loading condition as shown in table no.4.1,it reveals that effect of induced stresses goes on decreasing in symmetrical weld pattern as compared to unsymmetrical weld pattern. This is due to increasing the weld area in symmetrical weld pattern. This revealed that eccentric loaded welded joint get more strength in symmetric weld pattern than unsymmetrical weld pattern.

Static stress analysis perform on the weldment under eccentric load revealed the maximum shear stress w. r. to gap between parent plates, which is given table no. 5.1 and its variations is shown in fig. 5.4. It is observed from fig. 5.2 that as the gap between parent plates increases from 0.01 mm to 0.1 mm, the maximum shear stresses decreases from 1826.4 MPa to 1803.8 MPa. From this analysis, it is evident that the effect of stress concentration goes on reduces as the gap between parents plates is increases. Thus the slide gap between parent plates may be desirable for eccentric load.

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