EXPERIMENTAL AND NUMERICAL STUDY OF WELDED CURVED PLATES

MR. JAIDEEP BUDGUDE

MR. GANESH WAGH

MR. RAHUL YADAV
Assistant Professor, Department of Mechanical Engineering, MMCOE, Karvenagar, Pune, M.S.

ABSTRACT
Welding is widely used in all the fabrication process for the development of structural component. An accurate and physically suitable curved fillet model is to be given as input for analysis of welding process. Flux core arc welding (FCAW) is an arc welding process that that uses continuous flux cored filler wire . The flux is used as a welding protection from the atmosphere environment. Materials like CS and MS with varying thickness of 5,6,7 mm and overlapping angles starting with 30° and success ding with minimum difference of 5° in consecutive angle up to 100° and tested using UTM machine . Metallurgical welded joints that are in service may be subjected to high stresses and different types of loads such as fatigue loads, tension loads compression loads and thus temperature and residual stress modeling is one of the complex processes which utilize the weld parameters and properties at higher temperature. Finite element analysis (FEA) has become a practical method of predicting stresses and deflection for loaded structures. In this study, finite element analysis software, ANSYS, is used for a parametric study for effect of curved fillet welded joint on compression strength and tensile strength as it is an important tool for designing and analysis of engineering structures which do not facilitate model evaluation and result interpretation easily. The article deals with the physical test of steel supporting elements, whose main purpose is obtaining the material, geometry and strength characteristics of fillet welds. The main aim was comparison of samples testing using UTM (universal testing machine) and for analysis, done on commercial software like ANSYS.

KEYWORDS- Fillet weld, Lap joint, MS AND CS material, Strength and Deformation Testing, Tensile stress, FEA analysis

1. INTRODUCTION

Welding is the process of permanent joining of two materials (usually metals) through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon combination of temperature and pressure from high temperature with no pressure to high pressure with low temperature, a wide range of welding processes has been developed. Welding enables direct transfer of stress between members eliminating gussets and plates necessary for bolted structures. Welding is used as a fabrication process in every industry, large or small. It is a principal means of fabrication and repairing metal products. The process is efficient, economical and depending as means of joining metals. The process finds its application in air, underwater and space. Like steel bridges, shipbuilding, offshore structures, pressure vessels and pipelines.

Fillet welds are widely used because of their economy, ease of fabrication and adoptability. The weld of concave shape has free surface which provides a smoother transition between the connected parts and causes less stress concentration than convex surface. But it is more vulnerable to shrinkage and cracking than the convex surface and has a much reduced throat area to transfer stresses. [1]. Fillet welds are broadly classified into side fillet and end fillets. When a connection with end fillet is loaded in tension, the weld develops high strength and the stress developed is equal to the value of weld metal, but the ductility is minimal. On the other hand, when a specimen with side weld is loaded, the load axis is parallel to weld axis. The weld is subjected to shear and the weld shear strength is limited to just about half the weld metal tensile strength. But ductility is considerably improved. Most common FEA packages are suitable for this analysis.

ANSYS is used for the present study with its parametric command files, design variations are easily evaluated [2]

Typically, metallurgical joint made by fusion welding process is used to fabricate steel structure. The types of welded joint can be divided into five basic classes butt, fillet, corner, lap and edge.[3]. The residual stresses are present in many fabricated structures due to local plastic deformation from thermal and mechanical operations due to manufacturing. The presence of residual stresses in engineering components and structures can significantly affect the fatigue behavior during external cyclic loading. The effect of residual stresses may either be beneficial or detrimental, depending on magnitude, sign and distribution of stresses wrt load induced stresses.[4-7]. In the welding world, Flux-cored arc welding (FCAW) process is commonly used in different industries to join the metals and alloys. It has a few numbers of benefits such as high deposition rates, more tolerant to rust and mill scale than (GMAW) simpler and adoptable, less operator skill required, high productivity and good surface appearance.[8]. For the repair industry they are performed by using the manual metal arc welding (MMAW) However flux cored arc welding (FCAW) process has more benefits and have been appreciated by the industry for many years.[9]

But Fillet welding is the process of joining two pieces of metal together whether perpendicular or in angle between 80-100 degrees (AWS 2010). This weld are commonly referred as Tee joints which is perpendicular to each other or lap joints which are overlapped one another and welded at the edges. The present study uses (FCAW) welding for the experimentation of this project. The lap joint is perhaps the easiest joint of all parts to assemble. It comprises of two overlapping plates joined by the fillet weld and welding them either in the joint where they meet, asys done in FCAW, thus variations in component sizes are easily accommodated. This joints can be used to weld pieces of dissimilar thicknesses and materials. They also reduce number of critical parameters in weld. Thus this study will help to characterize the behavior of fillet welded joints.

2. METHODOLOGY

The specimens of different materials are used in testing methods and processes carried on for physical investigation, while analysis is done to determine deformation of curved plate fillet welded structure in specimen. In this study main purpose is to show structural and mechanical behavior of the joints. In physical test maximum load is used to disturb the object and compare with simulation result. The design process is the over view of the project research that is carried out to complete the finite element analysis and physical investigation. All specimens are made from materials like CS and MS for present study.

3.1 EXPERIMENTATION

3.1 Material and processing

Table no 1: Material constituents and their range

Material	Constituents	Range
Cs	Carbon	0.12-2.0%
Cs	Manganese	1.65%
Cs	Copper	0.60%
Cs	Silicon	0.60%
Ms	Carbon	0.16-0.18%
Ms	Manganese	0.70-0.90%
Ms	Sulphur	0.040%
Ms	Silicon	0.40%
Ms	Phosperous	0.040%

Table 2 : Material Properties of carbon steel (SA516 Gr.60) & Mild steel (IS2062)

Sr. No.	Material	Ultimate tensile strength (MPa)	Yield tensile strength (MPa)	Poisson's ratio	Density (kg/m3)
1.	Carbon Steel (SA516 Gr.60)	415-550	220	0.25	7850
2.	Mild steel (IS2062)	350-450	240	0.27-0.30	7850

Initially For making specimen, we used materials with MS and CS, thus combination of both with varying certain thickness with 1 mm and imparted various machining operations. Firstly punching operation was carried out to give a semicircular shape for specimen. Then with varying lapping angles of the curved plates they were welded using FCAW welding process, thus weld used was fillet weld on both sides of specimen. Then grinding and finishing operations were carried out to remove impurities and burr remaining on the specimen. This is how the specimens were made ready for further testing.

The dimension of Welded Curved Plate with None curved length of plate is 50 mm, Innermost Radius is 62.5 mm and Overlap angle is varying between 30 to 100 degree, Thickness of plate is 5 mm and width of plate is 50 mm. Thus (FCAW) flux cored arc welding process is used to weld the curved plates refer figure 1.

Figure1: Physical Model

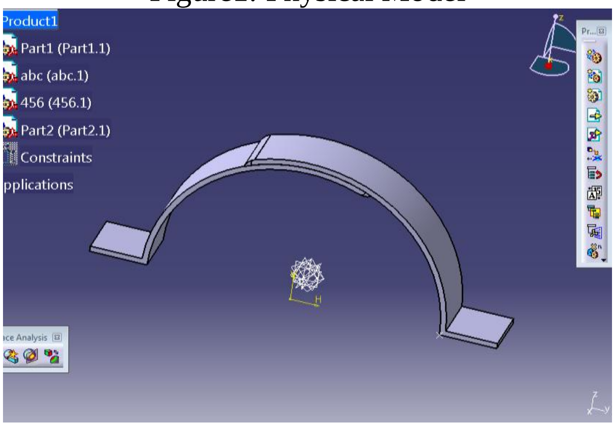


Figure 2: physical Catia model

Failure test is the fundamental test in the material science where we can find ultimate load and displacement. The test has been carried out to find failure load of the welded joint where mostly heat passes through during welding. The load will be applied on two axis, one is on the base metal which is continuous plate, this will allow us to find stress on the heat affected zone Another loading axis will be normal to the welded metal this will help us to find welding strength or bonding strength. Thus the experimental testing is done on Universal Testing Machine (UTM) with standard shape and size of test specimen with fillet joint shown in refer figure 2.

Figure 3: Universal testing machine

Table 3. UTM Specification

Sr no	Technical specifications	Requirements
1	Capacity	Upto 100 KN
2	Minimum test speed	0.01mm/min
3	Maximum test speed	500 mm/min
4	Width	1000-1200 mm
5	Depth	500-600 mm
6	Height	1600-2000 mm
7	Total crosshead travel	1200-1400 mm
8	Frame stiffness	Medium (higher is preferable)
9	Data acquisition	As per ASTME 1856

Ultimate tensile strength (UTS), often shorten to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is the opposite of compressive strength and the values can be quite different. Some materials will break sharply, without deforming, in what is called a brittle material failure. Others, which are more ductile, including most materials, will stretch some – and for rods or bars shrink or neck at the point of maximum stress as that area is stretched out. The UTS is usually found by performing a tensile test and recording stress vs strain; the highest point of stress –strain curve is UTS[10]

3.2 Numerical Analysis

1Model development is the crucial part of the analysis, if the model parameter is not matched with the experiment then desire results will not match with the simulation results. The dimension of the first curved plate is taken as 50mm width and 5mm thickness. Similarly the dimension of the second curved plate is taken 50mm width and 5mm thickness. The model is than separated in four main parts which is first (Left) curved plate, second (Right) curved plate and left weld and right weld. Reason to do that its can apply different type of material property. Figure drawn in CATIA V 5 and for analysis CATIA model will be exported to ANSYS for the simulation shown in figure 1&2.The section presents finite element model development, creating fillet weld, methodology of mesh element size development and grid independent study. Meshing element size defined with various numbers of elements and graphical representation. In traditional finite element analysis we know that, the number of element increases the accuracy of solution will be improved also it is not necessary to put element size very small figure 4 shows the FEM model of the existing design. The existing design has two curved plates. Both plate are given an axial loading for checking failure ultimate strength of a weld joint. The material used for Finite Element Analysis is Non Linear. The FEM Model having 6 freedoms: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The boundary conditions applied for the plates are equally axial and loading is applied on the both end of plate as shown in the figure 7 and then meshing of the plates done shown in figure 8.

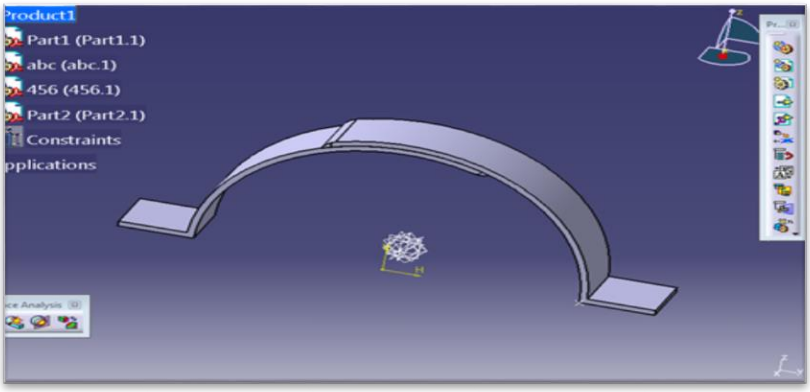


Figure 4. Assembly view in Catia

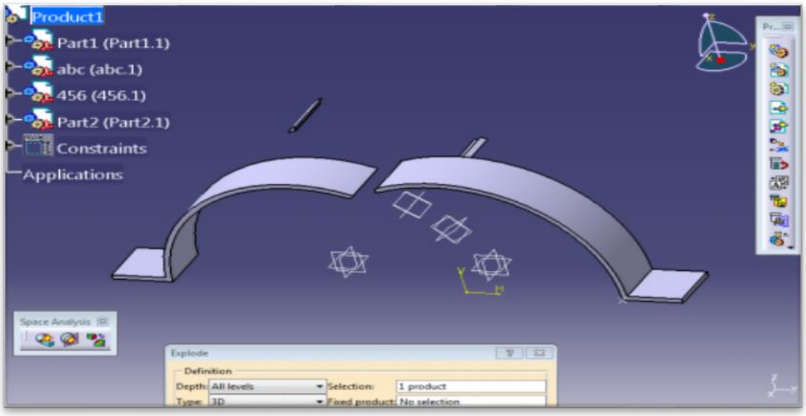


Figure 5. Exploded view of model

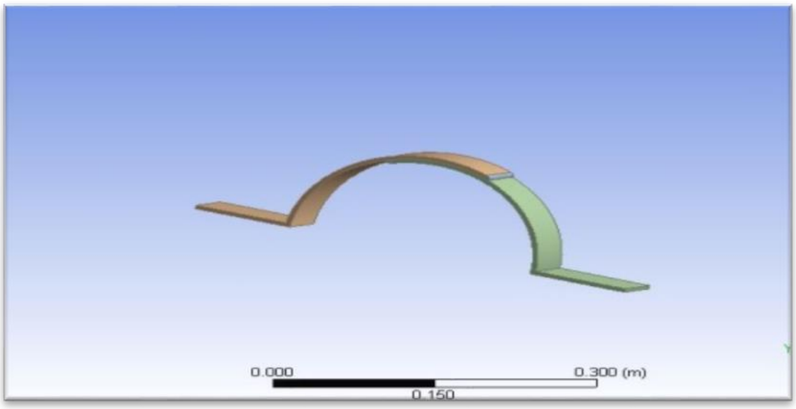


Figure 6. Applying boundry conditions

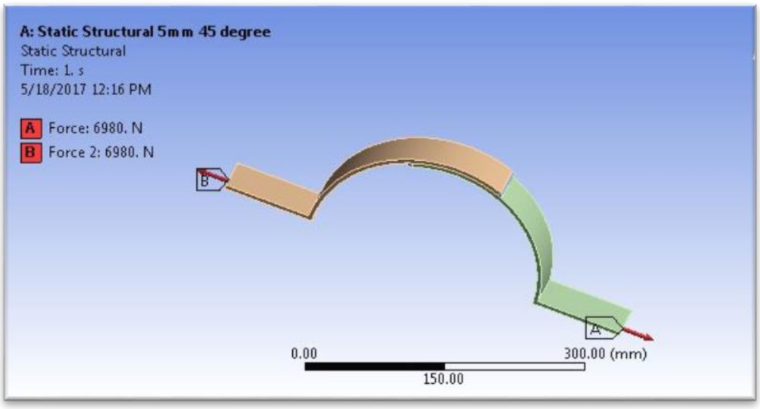


Figure 7. Applying boundry condition & equal forces on both sides

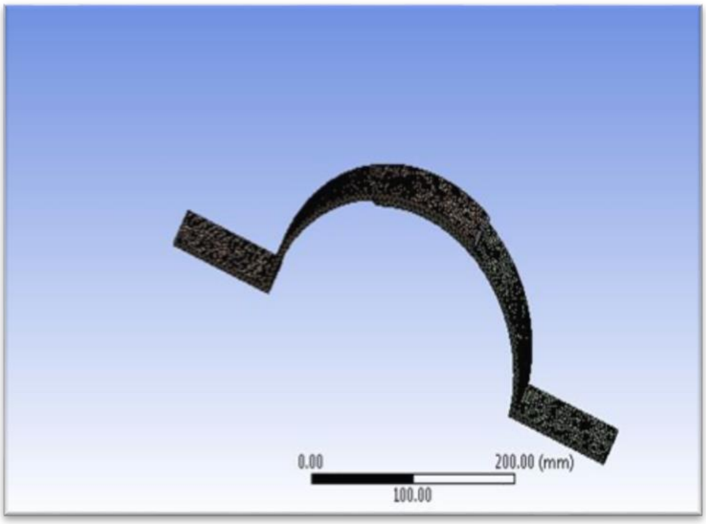
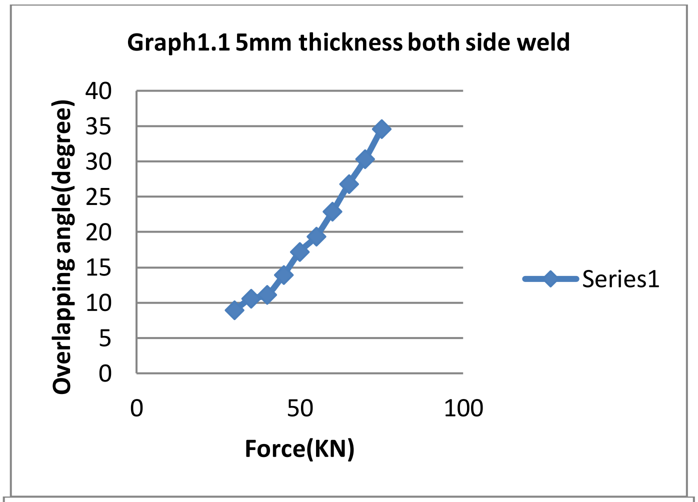


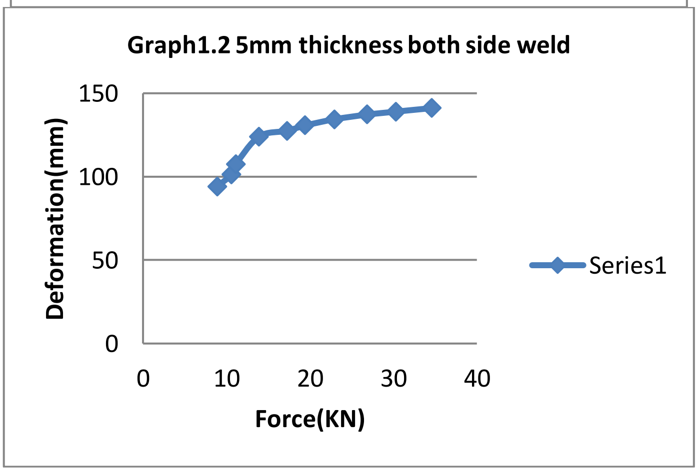
Figure 8. Meshing of weld & plates

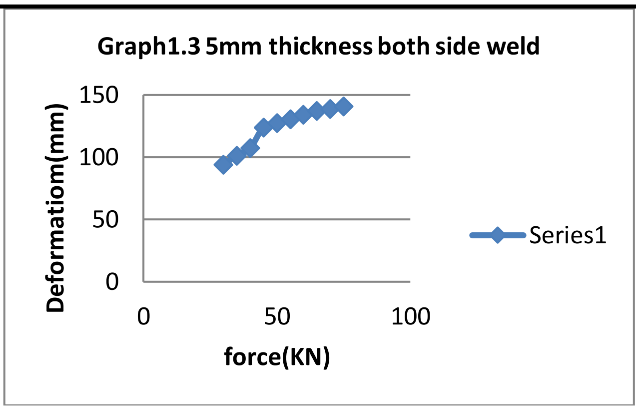
Results

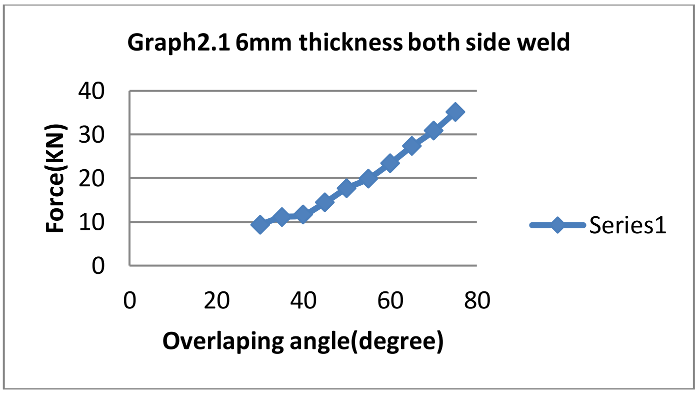
3.4.1 Experimentation results

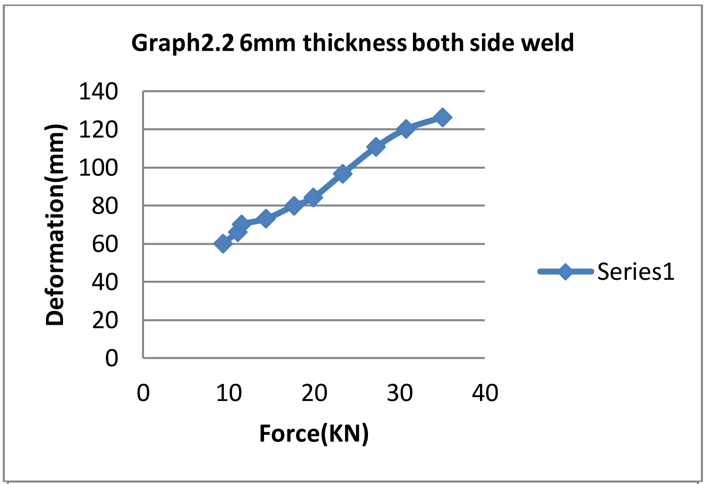
An experiment is a methodical trial and error procedure carried out with the goal of verifying or establishing the validity of a hypothesis. Experiments vary greatly in their goal and scale, but always rely on repeatable procedure and logical analysis of the results.

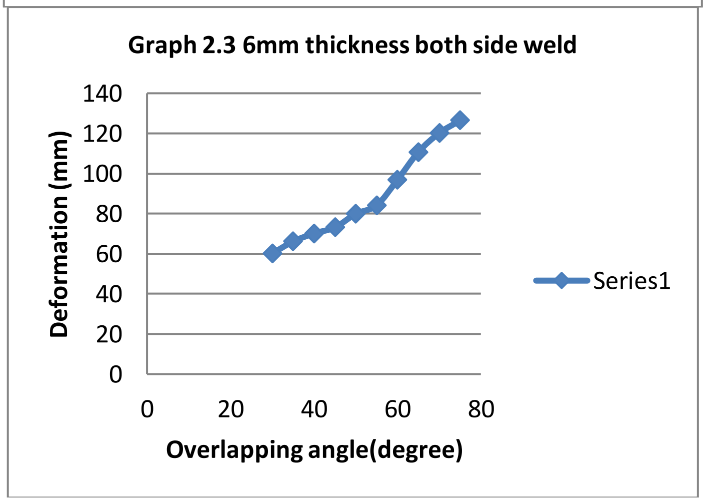


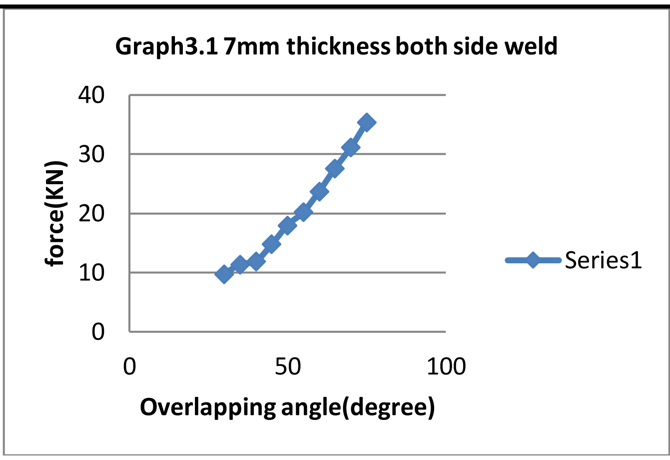


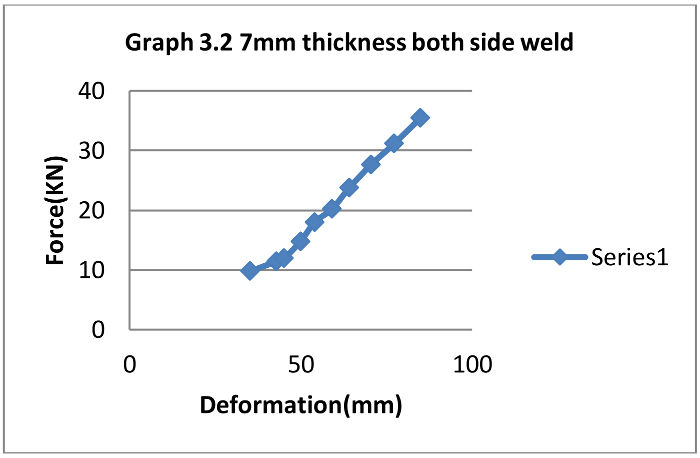

Graph1.3 5mm thickness both side weld
Deformatiom(mm)
150
100
50
0
0
50
100
force(KN)
Series1

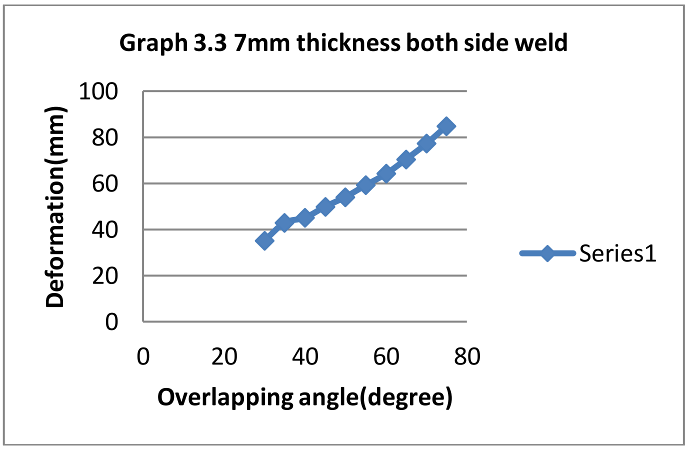

Graph2.1 6mm thickness both side weld
Force(KN)
40
30
20
10
0
0
20
40
60
80
Overlaping angle(degree)
Series1

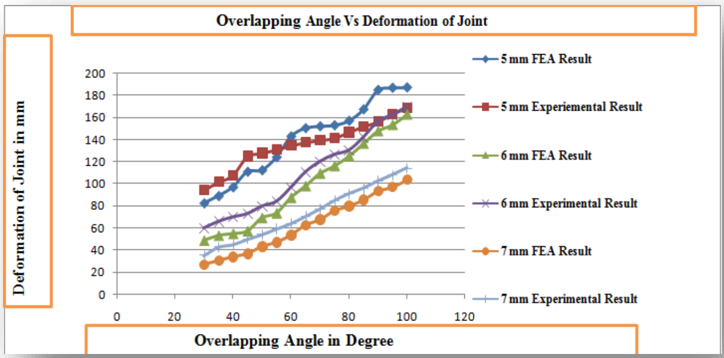

Graph2.2 6mm thickness both side weld
Deformation(mm)
140
120
100
80
60
40
20
0
0
10
20
30
40
Force(KN)
Series1


Graph 2.3 6mm thickness both side weld
Deformation (mm)
140
120
100
80
60
40
20
0
0
20
40
60
80
Overlapping angle(degree)
Series1









Graph 4.0: Combination of 5, 6 and 7mm thickness welded curved plate

The function is expressed in mathematical form are as

$y = -0.006x^2 + 2.428x + 13.08$ Where, x = Overlap angle of a welded Curved plate in Degree.
Y = Failure strength of Welded joint of Curved plate in KN

In this article the curve fitting technique is utilized to find the relation between angles of overlap with the failure strength of Welded curved plate. The angle of overlap is defined as the common angle prescribed by the two plates over each other. Total six data points (three for each of the perforated welded plate) are adopted from the failure force to determine the curve fitting functions. It should be pointed out that when the overlap angle approaches to zero i.e. both plates are weld in front of each other like Butt weld no appropriate curve fitting function can found between the failure strength (force) and angle of overlap of Welded Curved Plate. In fact distribution of failure force is quite linear. In particular when overlap angle approaches the slope of fitting curve become normal and found appropriately to process the curve fitting and function is obtained. This function can be used to predict the trend of failure strength of a welded curved plate in a diagonal array.

In this case only both side weld is used and we are analyzing the force required to break the lap joint by changing the overlapping angle and thickness of curved plate. We are taking 30 degree as overlapping angle for first analysis, then increasing the overlapping angle by 5 degree and analyzing the force required to break the lap joint and corresponding deformation. Total no of analysis will be 3.The following are the results for the analysis i.e force required to break the lap joint and corresponding deformation shown in figure 9,10.

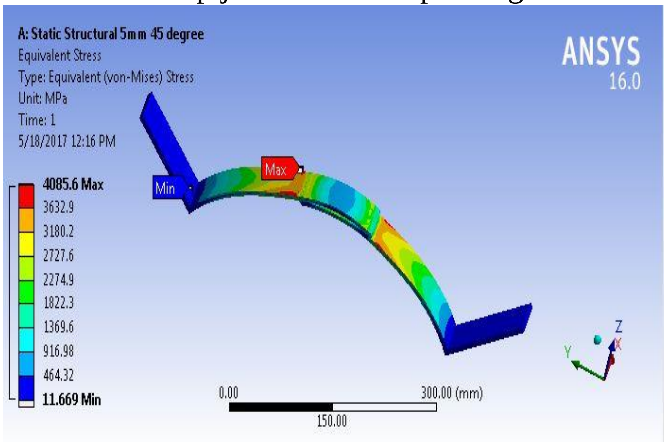


Figure 9: Results showing Equivalent deformation

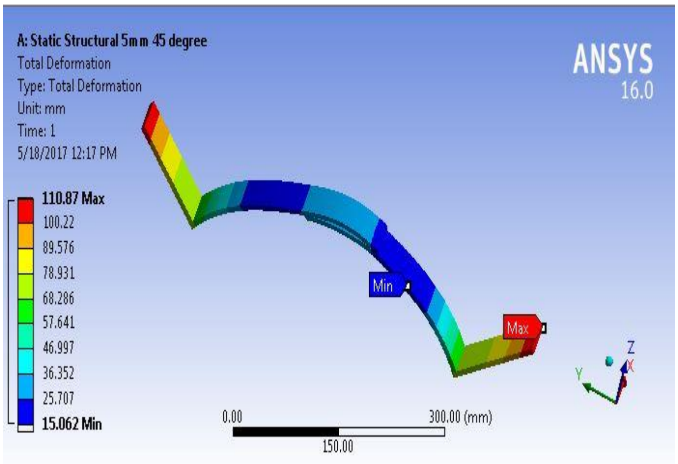


Figure 10: Results showing Total Deformation of Joint

Table 4: Analysis results for curved plate for 5 mm thickness and both side weld (Mesh size = 5mm)

Sr .no	Thickness (mm)	Inner diameter-outer diameter	Overlapping angle (degree)	Force required to break joint (KN)	Corresponding deformation (mm)
1	5	125-130	45	13.960	110.87
2	6	125-131	45	14.419	57.503
3	7	125-132	45	14.773	36.62

Table 5: Analysis results for curved plate for 5 mm thickness and both sid weld (Mesh size =8 mm)

Sr .no	Thickness (mm)	Inner diameter-outer diameter	Overlapping angle (degree)	Force required to break joint (KN)	Corresponding deformation (mm)
1	5	125-130	45	13.960	109.89
2	6	125-131	45	14.419	54.473
3	7	125-132	45	14.773	34.112

Table 6: Analysis results for curved plate for 5 mm thickness and both sid weld (Mesh size = 10mm)

Sr.no	**Thickness (mm)**	**Inner diameter-outer diameter**	**Overlapping angle (degree)**	**Force required to break joint (KN)**	**Corresponding deformation (mm)**
1	5	125-130	45	13.960	109.9
2	6	125-131	45	14.419	53.342
3	7	125-132	45	14.773	33.398

4. DISCUSSIONS

The aim of this paper is to give an background of fillet welding, purpose of the study, and research objectives of the project. An understanding on the welding behaviour under real world situation is presented. This information will be relevant throughout the dissertation and underlining the comparison of experiment test results with simulation results. The experimental testing is done on Universal Testing Machine (UTM) with standard shape and size of test specimen with fillet joint. The results are tabulated in the table no. 6,7,8. The tables contain FEA and Experimental results. The dimension of Welded Curved Plate is Non curved length of plate is 50 mm, Innermost Radius is 62.5 mm and Overlap angle is varying between 30 to 100 degree, Thickness of plate is 5 mm and width of plate is 50 mm. The experimental and FEA results of both side Welded Curved Plate is tabulated as follows

Table 7: Combined results between FEA and Experimental for welded plate having thickness of 5mm

Sr. No	**Thickness of Curved Plate(mm)**	**Angle of Overlapping Deg.**	**FEA Results**		**Experimental Results**		**% Difference of Deformation**
			Failure Load (KN)	**Deformation (δ) in mm**	**Failure Load (KN)**	**Deformation (δ) in mm**	
1	5	45	13.96	110.8	13.96	124.4	11
2	5	75	34.6	152.9	34.6	141.1	09
3	5	100	52.8	187.2	52.8	168.1	10

Table 8: Combined results between FEA and Experimental for welded plate having thickness of 7mm

Sr. No	Thickness of Curved Plate(mm)	Angle of Overlapping Deg.	FEA Results		Experimental Results		% Difference of Deformation
			Failure Load (KN)	Deformation (δ) in mm	Failure Load (KN)	Deformation (δ) in mm	
1	7	45	14.773	36.62	14.737	49.9	26
2	7	75	35.424	75.647	35.424	84.89	11
3	7	100	53.068	103.55	53.608	114.03	09

Aim is to analyze variation of weld parameters of curved plate with respect to different geometrical parameters of welded joint for various materials., to perform finite element analysis of above by varying geometric parameters like overlapping length, angle of plate, thickness of plate, to experimentally validate the results obtained by FEA analysis. The research outcome will help designer to estimate strength of welded structural component under dynamic load. Welding is the common engineering joining method used for various structures. The major construction projects in all the world are using cranes, earth moving equipment, those undergo dynamic loads, the marine ships another heavy welded structure which are also subjected to dynamic loads all the time. The body of transportation equipment is highly impacted by dynamic load which is focused in this analysis. Fatigue test and analysis of a T-joint with fillet welding in a typical connection is presented in this study. The paper will help to characterize the behavior of fillet welded joints.

In this study, finite element analysis software, ANSYS is used for a parametric study for effect of curved fillet welded joint on compression strength and tensile strength as it is an important tool for designing and analysis of engineering structures which do not facilitate model evaluation and result interpretation easily

CONCLUSIONS

The results obtained by experimental analysis and analytical results are carried out here to reach the conclusion. Based on the results following conclusions are made:

- Difference between deformation of welded curved plate in experimental result and analytical results are near about 13 to 15 %
- The maximum stress developed is near weld section, so failure occurred at that point. It observed that overlap length of joint increases, force required to break the joint is also increases.
- As thickness of base plate increases, the force required to break the joint is also increases
- The average value of maximum displacement for welded curved plate is increases as the overlap angle increases simultaneously the failure load are increase.
- As thickness of plate increases, its deformation decreases. It is clear that deformation is inversely proportional to the thickness of plate.

REFERENCES

I. S.R. Satish kumar and prof. A.R. SANTH KUMAR,” Design of steel structure “, Indian institute of technology madras

II. David Roy lance,” Finite element analysis “, department of material science and engineering , Massachusetts institute of technology Cambridge

III. Teng TL, Fung CHANG, Yang WC, Analysis of residual stresses and distortions in T-joint fillet weld int pressure vessels and piping (2001): 78: 523-38

IV. Barsoum Z Samuelsson J. fatigue assailment of cruciform joints welded with different methods. Steels res int(2006);77(12)

V. Barsoum Z, jonsson B. fatigue assessment and LEFM analysis of cruciform joints fabricated with different welding processes. International institute of welding doc no (13)-2175-07;(2007)

VI. Barsoum Z, residual stress analysis and fatigue of multi pass welded tubular structure. Eng. fail anal (2008);15(7):863-74

VII. Barsoum Z, barsoum I, residual stress effects of fatigue life of welded structures using LEFM. ENG Fail anal(2009);16(1):449-67

VIII. T. Kannan and N.Murugan, effect of flux cored arc welding process parameters on duplex stainless steel clad quality, journal of materials processing technology176 (2006)230-239

IX. A. aloraier r. Ibrahim, p. Thomson (FCAW)process to avoid the use of post weld heat treatment, int journal of pressure vessels and piping 83 (2006)394-398

X. khurshid M and Mumtaz N.A. (2012) ‘Ultimate strength and failure modes of fillet weld in high strength steels”, material and design vol.40, pp 36-42