Optimization of tube-flange welded joints under Torsional loading

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Abstract - *Numerous geometrical and environmental parameters affect the durability and strength of the weld junction. Geometric characteristics that determine weld joint strength can be adjusted, but environmental conditions that influence weld joints are difficult to manage. The geometric optimization parameters are h,, and t. This optimization technique would produce the responses for equivalent stress, shear stress, and fatigue life along with the sensitivity of each optimization variable, h,, and t. ANSYS software is used to generate the CAD model of the weld joint and to carry out the FEA analysis. Since h has the highest sensitivity to shear stress and normal stress out of the three variables chosen for investigation, it should be given top consideration when designing weld joints.*

Key Words: FEA, Weld joint, Response Surface Method

1. INTRODUCTION

The two metals are connected during the welding process under the proper thermo physical conditions. Temperature, pressure, and metallurgical conditions are examples of these thermo physical circumstances. The range of working temperatures and pressures affects the welding process. Because welding allows for direct stress transfer between components and also helps to minimise weight, it eliminates the need for any gussets or plates. All industries, whether small or large, employ welding extensively. It is the main method for fabricating or mending metals, and it has applications in space as well.

1.2 Weld Defects

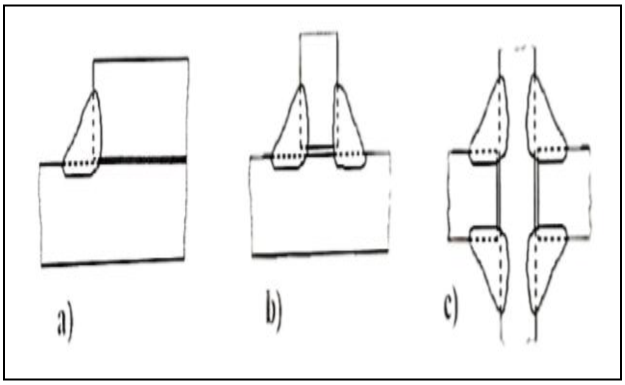

Figure 1.3 - Fillet welds in different joints a) Lap joint b) T-joint c) Cross joint [1]

The mechanical properties of weld joint are drastically affected by porosity, crack, internal concavity and lack of penetration. These defects cause fatigue failure which are critical. The incomplete penetration induces stress and when subjected to pressure it may cause crack

The fillet and butt weld are the most common types of weld used as shown in figure 1.2 and figure 1.3. Out of which the perpendicular pieces are welded using fillet weld and parallel surfaces are welded using butt weld.

The weld dimensions have to be done by taking consideration of three critical sections as shown in figure 1.4 below. These are section I, section II and section III. The crack initiation takes place in section III and while section II and section I corresponds weld toe crack propagation. There are three possible modes of failure in weld joint which are toe crack at ends and root crack at bottom mid as shown in figure 1.5 below.

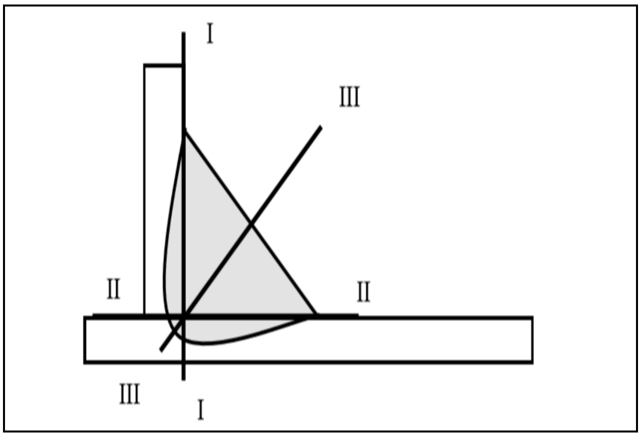

Figure 1.4: Sections of interest in a weld [1]

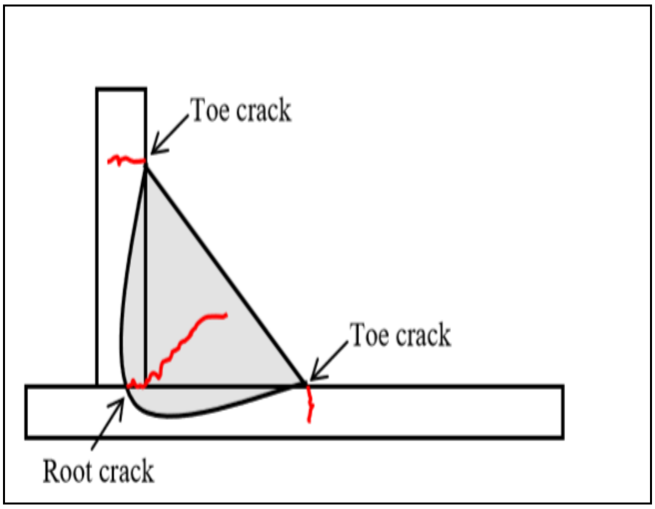

Figure 1.5: Possible failure modes [1]

For simplicity in simulations, the fillet welds are considered to be isosceles triangle as shown in figure 1.6 below. The nominal throat thickness is the height of largest triangle that can be fitted between the joint faces and the weld surface. The weld penetration determines throat thickness. The throat thickness a_0 is the dimension used in various manufacturing drawings

1.3 Detailed objectives:

1> Using ANSYS design modeller, CAD modelling of the tube flange welded joint illustrated in the previous figure

2> FEA structural analysis using ANSYS software and torsional loading conditions

3. Calculating shear stress, deformation, fatigue life, and additional stresses.

4> Choosing the optimization variables h and

5> Using Taguchi design of experiments to generate design points.

6> Creating linear graphs with reactions to loads, deformation, and fatigue life Creating sensitivity charts for the factors stated above.

8> Shear stress versus. edge curve distance

2. METHODOLOGY AND EXPECTED OUTCOMES

2.2 Methodology and modelling

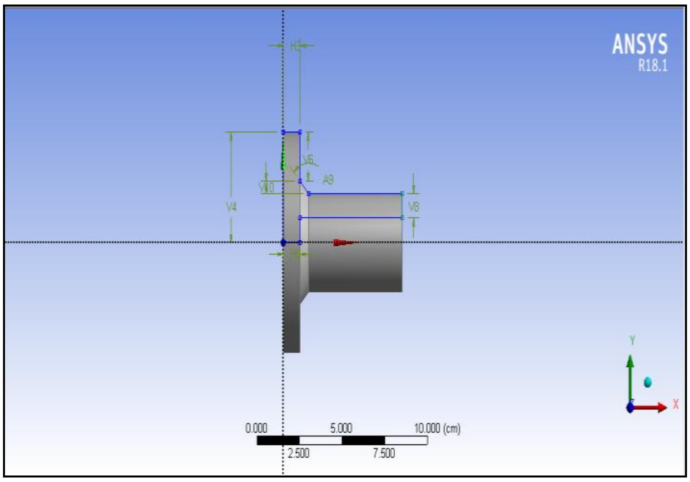

Figure 4.1: a> Quarter model b>Parameters definition [27]

The CAD model of geometry is developed as per literature [27] using ANSYS design modeler. Initially sketch is developed as shown by blue coloured cross section in figure 4.1 above. The dimensions are defined as per table 4.1 above. The sketch is then revolved to 360^0 angle to developed full model.

2.3 Results for Carbon Steel

The carbon steel weld joint is the subject of the FEA analysis. The shear stress plot for a carbon steel weld is generated and can be seen in figure 1.2678MPa. It is largest at the corners (the red zone), and it decreases along the length of the tube.

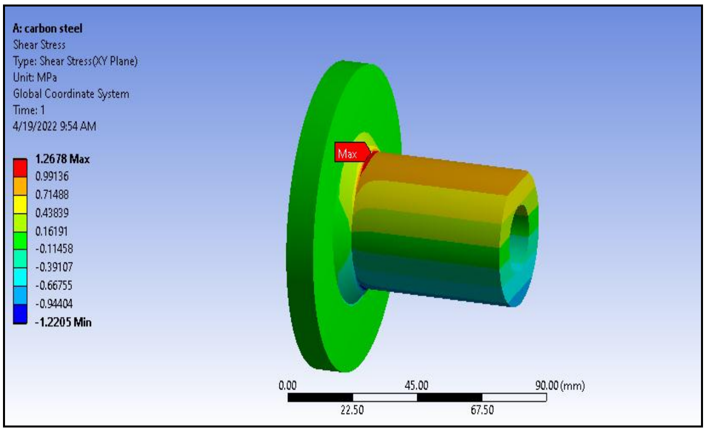

Figure 5.2: Shear stress plot for carbon steel

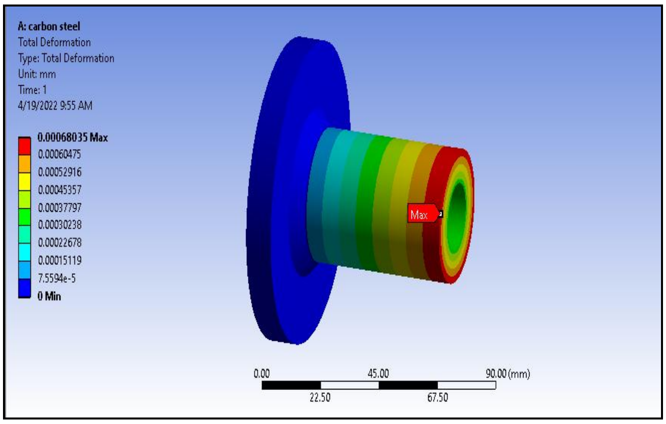

Figure 5.3: Total deformation plot for carbon steel

The maximum deformation is observed at the free end of tube with magnitude of .00068mm and it reduces towards the supported end which is shown in dark blue color.

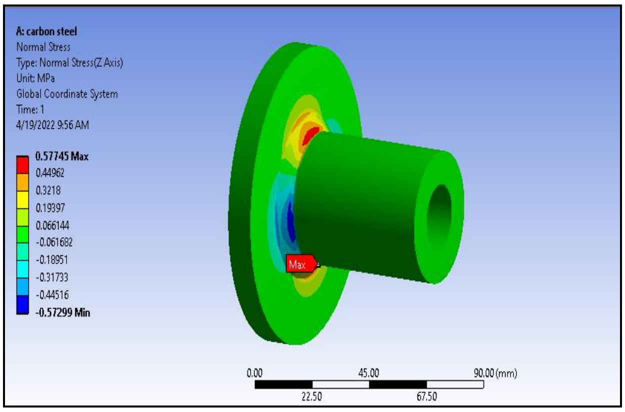

Figure 5.4: Normal stress plot for carbon steel

The normal stress plot is generated for carbon steel tube flange weld joint as shown in figure 5.4 above. The maximum normal stress of .57745MPa is observed at the intersection.

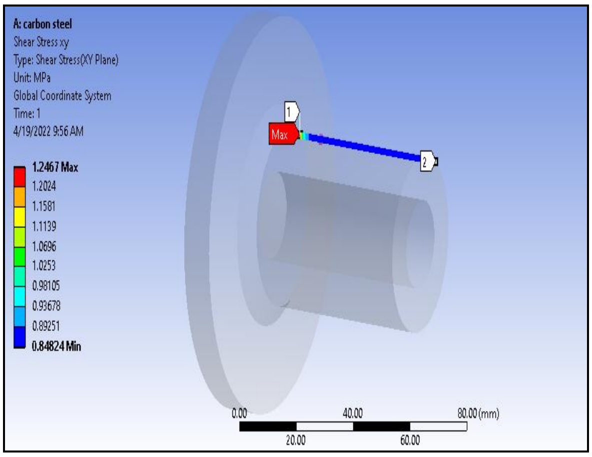

Figure 5.5: Shear stress plot for carbon steel

The shear stress value is plotted along the curve on tube region as shown in figure 5.5 above. The maximum shear stress is observed at the intersection region with magnitude of 1.2467MPa which reduces along the length. The variation of shear stress along the length is shown in curve (figure 5.6 below).

3Aluminium Alloy Results

The FEA analysis is conducted on aluminium alloy weld joint. The shear stress plot is generated for aluminium alloy weld as shown in figure 1.2671MPa which is maximum at the corner regions (red colored region) and it reduces along the length of tube.

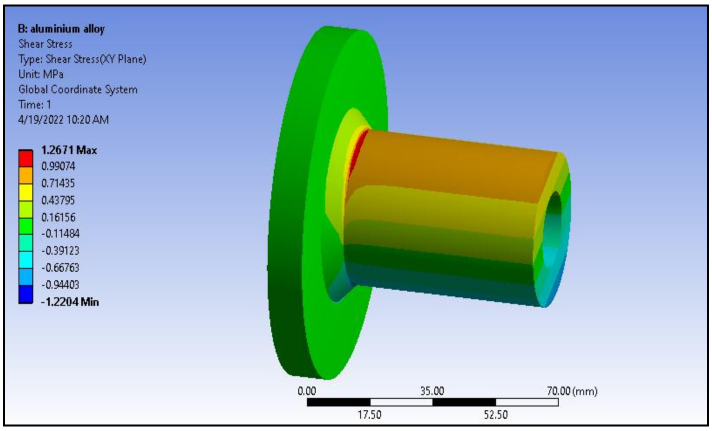

Figure 5.7: Shear stress plot for aluminium alloy

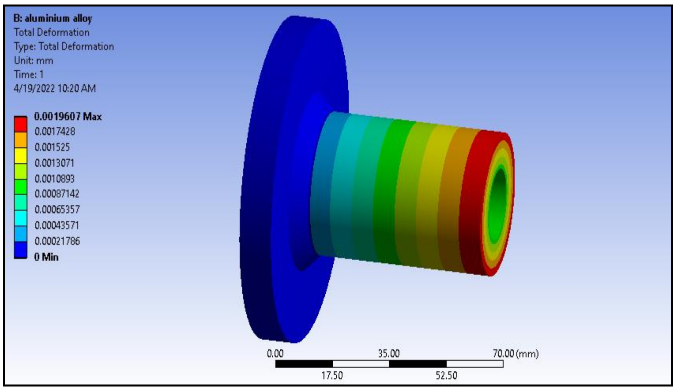

Figure 5.8: Total deformation plot for aluminium alloy

The maximum deformation is observed at the free end of aluminium alloy tube with magnitude of .0019607mm and it reduces towards the supported end which is shown in dark blue color.

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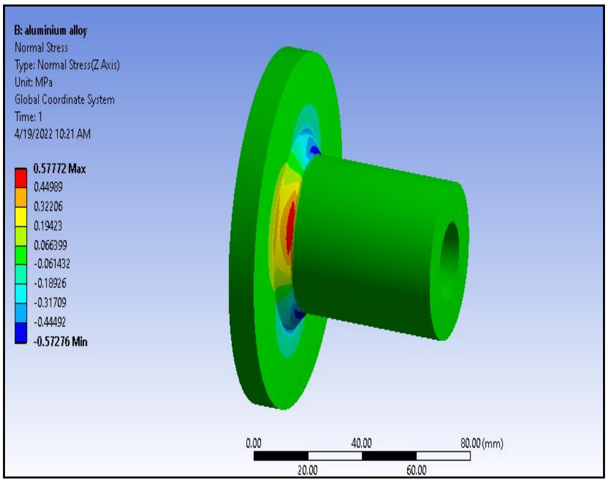

Figure 5.9: Normal stress plot for aluminium alloy

The normal stress plot is generated for carbon steel tube flange weld joint as shown in figure 5.9 above. The maximum normal stress of .5777MPa is observed at the intersection.

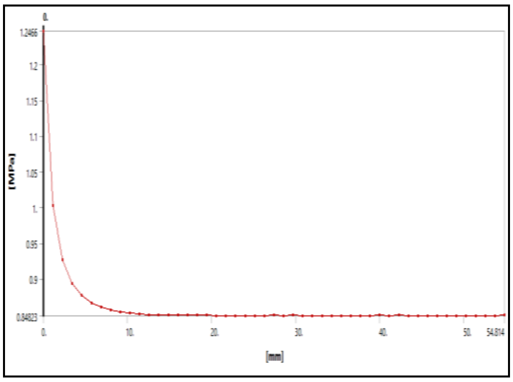

Figure 5.10: Shear stress vs length for aluminium alloy

The shear stress value is plotted along the curve on tube region as shown in figure 5.10 above. The maximum shear stress is observed at the intersection region with magnitude of 1.24676MPa which reduces along the length. The variation of shear stress along the length is shown in curve.

6Response Surface optimization

The design points are generated from Taguchi design of experiments is shown in table 5.2 below.

Table 5.2: Design points generated from Taguchi design of experiments

Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F	G	H	I
1	Name	P5 - Alpha (degree)	P6 - h (cm)	P7 - t (cm)	P2 - Total Deformation Maximum (mm)	P3 - Normal Stress Maximum (MPa)	P8 - Shear Stress 2 Minimum (MPa)	P12 - hs1 stress Maximum XY Shear (MPa)	P13 - hs2 stress Maximum XY Shear (MPa)
2	1	135	0.475	1.09	0.00064719	0.57587	0.79282	1.0055	0.92934
3	2	130	0.45	1.09	0.0006313	0.59523	0.75717	0.8613	0.82886
4	3	140	0.45	1.09	0.00062369	0.50353	0.75725	0.90179	0.93354
5	4	130	0.5	1.09	0.00067198	0.64274	0.83086	0.98684	0.94644
6	5	140	0.5	1.09	0.00066241	0.55798	0.7582	0.90568	1.1658
7	6	130	0.475	0.98	0.0006676	0.60051	0.81475	0.94462	0.90425
8	7	140	0.475	0.98	0.00065879	0.53356	0.8147	1.0221	1.0655
9	8	130	0.475	1.2	0.00064019	0.59136	0.77842	0.90433	0.87243
10	9	140	0.475	1.2	0.00063182	0.49788	0.7784	0.99144	1.0307
11	10	135	0.45	0.98	0.00064402	0.57344	0.77865	0.94054	0.8746
12	11	135	0.5	0.98	0.00068381	0.57762	0.85302	1.1399	1.0239
13	12	135	0.45	1.2	0.00061677	0.53827	0.74276	0.88624	0.84799
14	13	135	0.5	1.2	0.0006567	0.56576	0.81633	1.1334	1.0065

Using Taguchi response surface (DOE) method involving central composite design scheme various design points are generated. The stress, deformation corresponding to these design points are evaluated from FEA analysis. The compiled results are shown in table 5.2 above. The maximum and minimum values obtained from design of experiments are shown in table 5.3 below.

3. CONCLUSION AND FUTURE PERSPECTIVE

ANSYS software is used to do the FEA study of the weld geometry, and the results are analytically validated. Using response surface methods and design of experiments, the shape of the weld parameters is optimized. Plots of the response surface are produced for shear stress and deformation. The range of magnitude of the parameters (h,, and t) for the highest and minimum values of shear stress, deformation, and safety factor can be calculated using response surface plots. Here are the specifics:

1. Because the corner point develops the most shear stress, it is extremely prone to fatigue failure. For carbon steel, the amount of stress created at the corner is 1.2678MPa.

2. The shear stress vs. distance curve figure demonstrates that the shear stress drops as one moves away from the corner and becomes negligible as one moves near the end, whereas the deformation is greatest at the open end.

3. The alpha's sensitivity to overall deformation is 11.324 (negative). The negative sensitivity indicates that total deformation would decrease as alpha value increased and vice versa.

4. The h variable's sensitivity to overall deformation is 52.495(positive). The positive sensitivity indicates that the overall deformation would rise with an increase in h value and vice versa.

5. The t's sensitivity to total deformation is 35.949(negative). A negative sensitivity indicates that overall deformation would decrease as h value increased and vice versa.

6. The alpha's sensitivity to typical stress is 58.763 (negative). The negative sensitivity indicates that decreasing normal stress would occur with an increase in alpha value and vice versa. The h variable responds positively (34.376) to ordinary stress.

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