Optimization of The Response Surface of Tube-Flange Welded Joints Subjected To Torsional Loading

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Abstract- *The environmental factors influencing weld joints are difficult to control but geometric dimensions affecting the strength of weld joints can be optimized. The three geometric optimization parameters are h, α, and t. This optimization technique would produce the fatigue life, shear stress, and equivalent stress responses along with the sensitivities of each optimization variable, h, α, and t. With ANSYS design modeller, a CAD model of the weld joint is created, and ANSYS software is used for FEA analysis. Out of the three variables selected for analysis h has the highest sensitivity for shear stress and normal stress and therefore should be given the highest priority in the design of weld joints.*

Keywords- FEA, Weld joint, Response Surface Method.

I. INTRODUCTION

The welding has been very economical as well as a dependable means of metal joining. The widely used weld types are fillet weld due to economy, and adaptability. The fillet weld can be of concave shape or convex shape. The concave shape is better transition between connected parts thus reducing stress concentration as against convex fillet shape. The cracking and shrinkage make it more vulnerable to failure. The fillet welds are of 2 types:

1. End fillet: This kind of fillet weld is very strong and has very little flexibility. Weld metal develops the same amount of stress as weld.
2. Side Weld: The weld axis and load axis are parallel which limits the weld strength to half of the weld metal tensile strength. The advantage is higher ductility.

Weld Defects

The mechanical properties of weld joints are drastically affected by porosity, crack, internal concavity, and lack of penetration. These defects cause critical fatigue failure. The incomplete penetration induces stress and when subjected to pressure it may cause crack initiation. These types appear as dark straight lines. The concavity defect is caused by weld pool slag.

As seen in Figure 1. below, the fillet welds are treated as an isosceles triangle for simulation simplicity. The greatest triangle that fits between the joint sides and the weld surface is the nominal throat thickness. The thickness of the throat is determined by weld penetration. The dimension that is utilized in different manufacturing drawings is the throat thickness a_0.

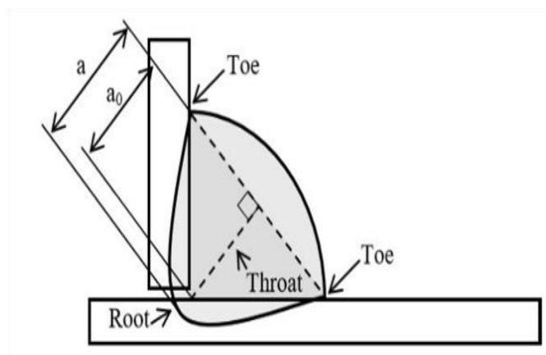


Figure 1 Parts of a fillet weld

II. LITRATURE REVIEW

T. Ninh Nguyen and M. A. Wahab et al. have investigated misalignments in welded joints and concluded that eccentricity and angular distortion are its two types. The force due to the misaligned weld joint causes fatigue failure leading to crack initiation and propagation. This force can be resolved into axial and bending.

Kyungwoo Lee et al. Investigated a cantilever beam using Butcher's 1st-order Runge-Kutta method. The large-scale deflection study involved both geometric and material nonlinearity and the numerical method served as a viable method in the study of welded joints concerning its fatigue failure.

Robb C Wilcox et al. analyzed various approaches in the design of weld joints. The limitation of the conventional method of designing which treats loading in fillet weld as longitudinal provides partial results and doesn’t account for transverse loading effects.

Mahapatra et al. have analyzed the angular distortion caused due to constraints in one side fillet using experimental techniques. The findings have suggested that properly positioned constraints could counter welding distortion.

Teng et al.'s FEA thermal analysis of butt weld was done to ascertain the impact of the expected transverse residual stresses and the weld circumstances. The FEA study was carried out for stress points spaced at both 10 and 15 millimeters.

Tekriwal et al. has determined the location of residual stresses from the ABAQUS finite element analysis package. The findings have shown that maximum stress is developed in the vicinity of heat heat-affected zone (HAZ) boundary with max stress points located on both top and bottom surfaces.

T. Lassen et al conducted random fatigue life analysis on weld joints and findings have shown that fatigue behavior in weld toe doesn’t match with the experimental bilinear S-N curve.

III. METHODOLOGY

CAD modelling

The schematic depicted in the image below is followed in developing the CAD model of geometry. The revolve tool and sketch are used in ANSYS design modeler to construct the model. The following measurements are made:
Table 4.1: Dimensions of geometry [27]

L	1 cm
H	2cm
h	.5cm
t	1cm
α	135^0

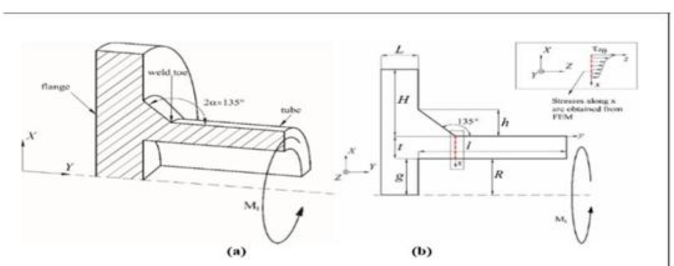
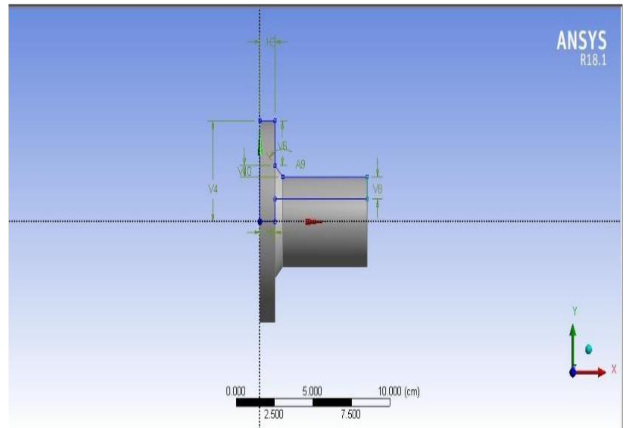


Figure 4.1: a> Quarter model b>Parameters definition [27]

Loads and Boundary Conditions

As seen in figures 4.4 and 4.5 below, the CAD model is applied with a fixed support at the left face of the geometry and a rotating moment of 10 N-m on the right face.



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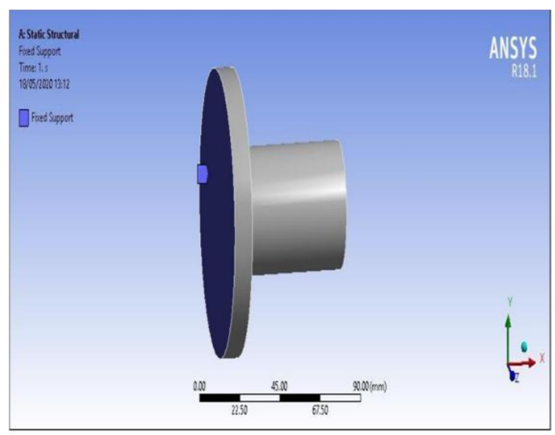
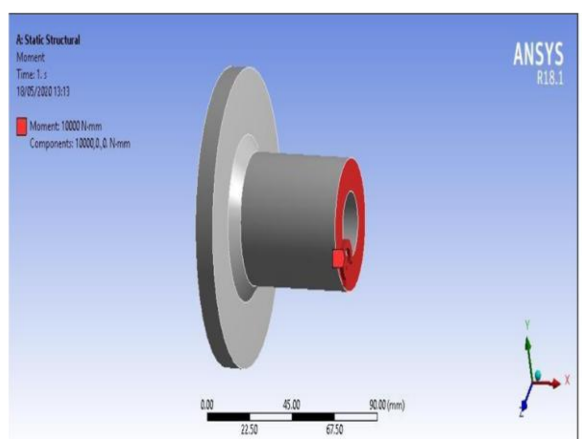
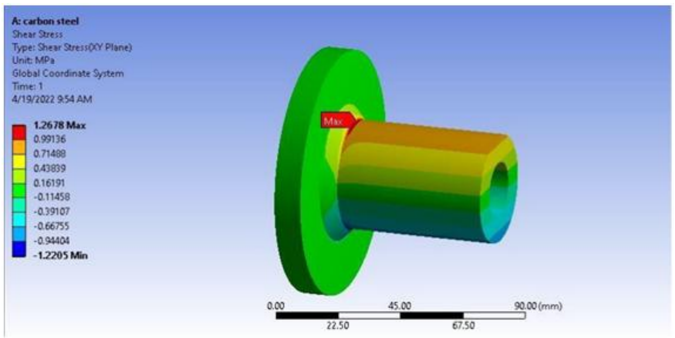




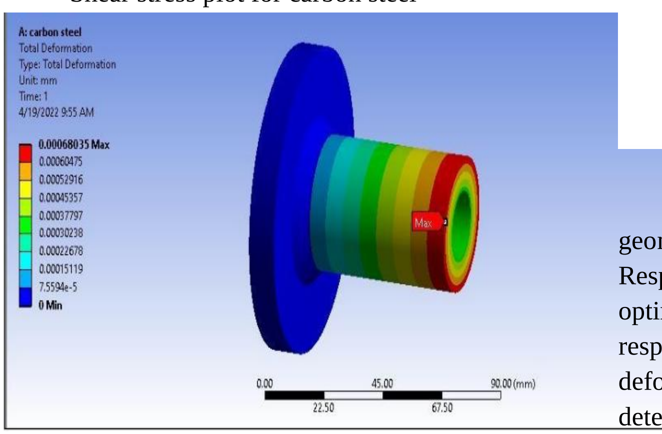
IV. RESULTS AND DISCUSSION

Carbon Steel Results

The FEA analysis is conducted on carbon steel weld joints. The shear stress plot is generated for carbon steel weld as shown in figure 1.2678MPa which is maximum at the corner regions (red colored region) and it reduces along the length of the tube.



Shear stress plot for carbon steel



Total deformation plot for carbon steel

Result Comparison of different materials

Material	Carbon steel	Aluminium alloy	Stainless Steel
Shear stress	1.2678	1.2671	1.2676
Total deformation	.0006803	.0019607	.0007104
Normal Stress	.57745	.5777	.57753

FEA Analysis for Fatigue Life Determination

The stress life technique is used to analyze exhaustion. 50N-m is the applied load used to calculate fatigue life. Determining critical regions and reactions (effects) of optimization parameters on the fatigue life of a weld joint is the aim of fatigue life analysis. As seen in figure 6.1 below, the fatigue analysis is carried out with a constant amplitude load and a fully reversed cycle. Soderbergh is the mean stress correction that was chosen for examination.

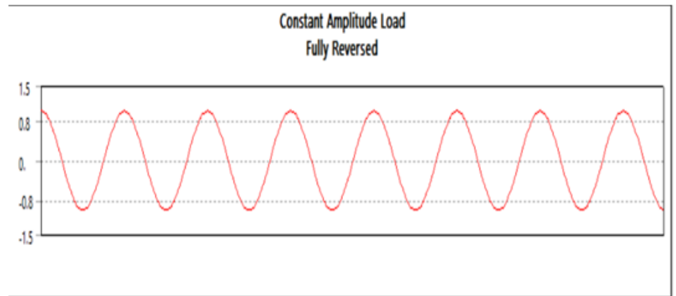


Figure 6.1: Constant amplitude fully reversed load

ANSYS software is used for the FEA study of the weld geometry, and the findings are analytically confirmed. Response surface methods and design of tests are used to optimize the weld parameters of geometry. Plots of the response surfaces are produced for shear stress and deformation. The response surface plots allow for the determination of the maximum and minimum values of shear stress, deformation, and safety factor, as well as the range of magnitude of the parameters (h, α, and t). Here are the specifics:

1. The maximum shear stress is developed at corner point thereby making it highly susceptible to fatigue failure. The magnitude of stress generated at corner is 1.2678MPa for carbon steel.
2. The shear stress vs distance curve plot shows that shear stress decreases on moving away from corner and becomes minimal towards the end whereas the deformation is highest on open end.
3. The alpha has 11.324(negative) sensitivity on total deformation. The negative sensitivity signifies that increasing alpha value would decrease total deformation and vice versa.
4. The h variable has 52.495(positive) sensitivity on total deformation. The positive sensitivity signifies

that increasing h value would increase total deformation and vice versa.

5. The t has 35.949(negative)sensitivity on total deformation. The negative sensitivity signifies that increasing h value would decrease total deformation and vice versa.
6. The alpha has 58.763(negative) sensitivity on normal stress. The negative sensitivity signifies that increasing alpha value would decrease normal stress and vice versa. The h variable has 34.376(positive) sensitivity on normal stress.
7. The t variable has 19.439 (negative) sensitivity on normal stress. The negative sensitivity signifies that increasing the t value would decrease normal stress and vice versa.
8. The alpha has 15.794 (negative) sensitivity to shear stress. The negative sensitivity signifies that increasing the alpha value would decrease shear stress and vice versa. The h variable has 43.125 (positive)sensitivity to shear stress.
9. Based on response surface optimization research on fatigue analysis, alpha values between 137^0 and 140^0 and t values between 1.1 and 1.2 cm are shown to have the highest safety factor.
10. Based on response surface optimization research on fatigue analysis, alpha values between 138^0 and 140^0 and h values between 45 and 0.46 cm are found to have the highest safety factor.
11. Response surface optimization research on fatigue analysis shows that the maximum safety factor is shown for t values between 1.1 and 1.2 cm and h values between.45 and.46 cm.

V. FUTURE SCOPE

There is a great deal of room for more research into welded joints to address issues with vibration, frequency response, and mode shape analysis. Determining the torsional stiffness of the welded joints would be useful future investigation. Determining how a weld will react to longitudinal loads and lateral forces are additional helpful measurements. The entire body refinement incorporating multiple or single welded joints will be aided by this research.

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