FATIGUE ANALYSIS OF FACE-TO-FACE T-JOINTS IN MILD STEEL USING STRUCTURAL HOT SPOT STRESS METHOD

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Abstract- Fatigue is actually weakening of material caused due to cyclic loading i.e. repeatedly applied loads. It is of prime concern as a material can undergo progressive and localized structural damage due to this. Welding is the most effective and widely used joining technique for metallic structures due to its applicability to most of the geometric configurations and the principle failure mode in weld is fatigue cracking. In today's world where durability is of prime concern in anything, this definitely can't be overlooked. Through this paper, an analysis into the fatigue life of simple face-to-face T-Joints made of mild steel using FEA (finite element analysis) is done. Although there are methods to analyze this, but this analysis and assessment is done by using structural hot spot stress approach. This study is of prime importance because mild steel is the most commonly used material especially in developing countries such as India and face-to-face T-Joints are found in most of the welded structures.

Keywords- Face-To-Face T-Joints, Fatigue, Finite Element Analysis, Hot Spot Stress, Mild Steel.

I. INTRODUCTION

Welded joints are used in everyday life especially in engineering industries. Many machineries use welded joints for various operations that are subjected to cyclic loading. A large number of materials use T-Joints and that too face-to-face. So an analysis of fatigue is necessary to estimate the strength of such joints. Fatigue is actually weakening of material caused due to cyclic loading. An analysis of how crack might develop and propagate due to this fatigue loading is also of prime importance and that is the area where this paper attempts to emphasize on. We have taken mild steel for this research study because mild steel is the most commonly used steel especially in a country like India. Mild steel has relatively low tensile strength and hence has made this study even more interesting. We do this analysis by identifying the hot spots in the welded section, about the weld toe and determine the way in which the crack propagates.

Our analysis encompasses both solid as well as shell element. A lot of difficulty is faced in identifying the singularities at the weld toe and hence getting the actual peak stress directly at the weld toe is difficult to obtain. Structural hot spot stress method aids in an accurate analysis of the welded structures. The entire analysis is done in ANSYS analysis software used globally. Since it is a face-to-face T-Joint, it is a 'Type B hot spot stress'.

II. METHODOLOGY ADOPTED

The structural hot spot stress is an important approach as it analyzes fatigue accurately and is henceforth more preferable than nominal stress approach in this research work. Nominal stress approach is also difficult to apply for the said purpose because it poses difficulty in cases with geometric and/or loading complexities. Moreover nominal stress approach is also not accurate. Structural hot spot stress is the stress about or on the weld toe. It is of two type’s viz. 'Type A' and 'Type B'. The former one implies weld on surface while the latter implies weld on the edge. In this case, it is a 'Type B hot spot stress'.

Finite element analysis is used to obtain these 'hot spots'. Meshing and extrapolation (only in case of complex welded structures) are used for obtaining these hot spots or nodes. ANSYS software is used for this finite element analysis as it gives the deformed result accurately and also provides a virtual stimulation before the actual processes can take place. It also shows the resulting areas affected.

Mild steel specimens are used viz. solid t-joint (Fig. 1) and shell t-joint (Fig. 2) of plate thickness 5mm. So, this approach actually helps us in analyzing the path of the crack propagation from the weld toe.

Figure 1. Solid T-Joint  
Figure 2. Shell T-Joint

IV. OBJECTIVE & PROBLEM FORMULATION

Our objective is to find out the path and the way of deformation that face-to-face t-joints made of mild...
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Steel undergo when subjected to various loads about the weld toe. It is challenging enough due to the high tensile strength of mild steel. Henceforth, before making such joints design and similar analysis would be done and considered and hence weld parameters and/or criteria can be modified. Welding techniques and other parameters can also be modified.

V. IMPLEMENTATION

At first, designs are prepared using Pro-e 5.0. Fig. 3 and Fig. 4 show the designs created for both solid as well as shell T-Joints respectively replicating the specimens prepared (shown in Fig. 1 and Fig. 2). Then the designs are imported into ANSYS 14.0 and analyzed taking the following parameters into consideration:

- Solid type element 10 node 187
- Global, free, fine meshing
- All degrees of freedom constrained
- Attributes:
  a) Young's Modulus = 210000 MPa
  b) Poisson's Ratio = 0.303
  c) Plate thickness = 5mm

Deformation is determined qualitatively and the nodal solutions as well as elemental solutions are found out by applying various loads.

![Figure 3. Solid T-Joint in Pro-e 5.0](image)

![Figure 4. Shell T-Joint in Pro-e 5.0](image)

Then the designs are imported onto ANSYS 14.0 and analysis is started by fine meshing it with smart size = 1. Hence, the nodes/hot spots are obtained. Then the degrees of freedom are fixed on the three ends of T-Joint and various loads are applied at the weld toe as shown in Fig. 5 and Fig. 6 for solid and shell elements respectively.

![Figure 5. Application of load at weld toe of solid T-Joint in ANSYS 14.0](image)

![Figure 6. Application of load at weld toe of shell T-Joint in ANSYS 14.0](image)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Forces Applied</th>
<th>Shell</th>
<th>Solid</th>
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<tr>
<td>1</td>
<td>90000 N</td>
<td>90448 N</td>
<td>83572 N</td>
</tr>
<tr>
<td>2</td>
<td>120000 N</td>
<td>110970 N</td>
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<tr>
<td>10</td>
<td>330000 N</td>
<td>372890 N</td>
<td>325630 N</td>
</tr>
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</table>

(Comparison between T-Joint (shell and solid)

![TABLE I. Comparison with respect to maximum load applicable](image)
A graph showing the comparison is presented below in Fig. 7.

CONCLUSION

From our analysis, it is clear the shell T-Joint can undergo more fatigue stress than the solid T-Joint at the weld toe. The max fatigue for solid and shell are 325630 N and 372890 N respectively on application of 330000 N. For this analysis, we analyze that shell is better than solid of mild steel specimens and it can be concluded that in heavy applications like parts of machines, trusses, bridges etc. and structures of mild steel should use shell structure instead of solid as it would increase the life of such structures and can bear more fatigue stress.

REFERENCES


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