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EFFECT OF WELD PENETRATION ON FATIGUE LIFE

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Abstract

The present work shows the effect of weld penetration levels on the stress level and the fatigue life at the weld joints. Finite element analysis was used to estimate stress pattern of welded joints having different levels of penetration for "Bend Loading" and "Tensile loading" were selected for studies. Specimens with variation in the penetrated throat length between 1.80mm to 0.60 mm were selected. Study has clearly highlighted the corresponding fluctuations observed in the fatigue life with change in weld penetrations. A side loading will be more detrimental than a tensile loading

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Keywords: weld penetration, fatigue life, finite element analysis, tensile loading, side loading, S-N curve

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1. Introduction

Most of the fabrication vendors in the recent times face the challenge of meeting the production volumes & achieving the quality standards in terms of finish, accuracies and "welding qualities" at economical costs. Understanding the strength of welded joints is very critical in complex welded structures like construction equipment's chassis, Revolving frame, Boom, Arm etc. Discussion with manufacturer reflects the necessity for conducting such kind of weld penetration research. Based on the root cause analysis, most of the failures

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encountered attributes to insufficient weld penetration. The major parameters used for judging the quality of weld, its physical strength and strength of the metal around the weld joint. The most common weld defects include: a) Lack of fusion, b) Lack of penetration c) Porosity d) Slag inclusions and e) Crack initiation. One of the most significant factors affecting the fatigue life of the weld is depth of penetration. This can be described by the minimum throat. The main parameters that affect the minimum throat are essentially weld joint preparations (beveling), weld dress-up, surface condition of the parent materials, type of weld, welding process parameters like filler material, base material, welding process employed, torch angle, welder skills, etc.

2. Weld Bead Penetrations

Fatigue is defined as cumulative, localized and, not to forget, permanent damage caused by repeated fluctuations of stresses usually below the static design stresses of the structure. It should be noted, that welded components are less tolerant to the fluctuating loads than their non-welded counter parts for the following three reasons:

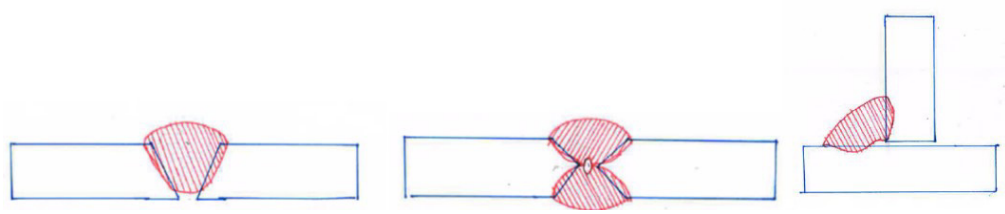
- Welds contain internal flaws which act as initiation site for crack propagation.
- Welds create external stress raisers which act as initiation site for crack propagation.
- The process of welding introduces residual stresses in the region of weld exacerbating the applied fluctuating stresses.

Welded joint must be manufactured based on strict weld acceptance criteria as per AWS and ISO standard. These criteria shall guarantee reliable standards regarding the fatigue life of those joints whilst not impairing the feasibility of weld manufacture (Costing).

2.1. Incomplete penetration

This type of defect is found in any of three ways shown in figure and discarding the major weld defects, fatigue cracks originate from the weld toe. [5]

When the weld bead does not penetrate the entire thickness of the base plate.



Fig, 1a, 1b, 1c: Incomplete Penetration

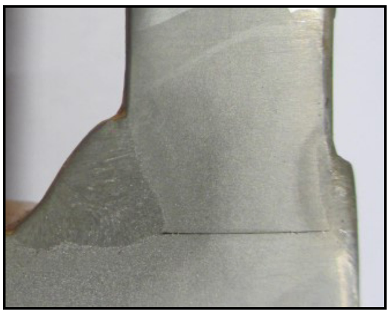


Fig.2. A good penetrations into the root and also a good sidewall fusion

3. Results and Discussion

The stress pattern of welded joints with different levels of fusion and penetration are subsequently estimated via finite element modelling. Two types of loading commonly encountered, namely “Bending loading” and “Tensile loading”. The different aspect of mesh refinement on weld toe and root was studied to detect the suitability of element size. [3]

Fig. 3 describes the geometry for the load pattern having bending load on the plate with different wall penetration.

Based on weld geometry and criticality of loading, three locations for "Bending Loading" and one location for "Tensile Loading" have been identified for comparison. Occurrence of the toe crack is due to the stress concentration at weld toe area. [4] These locations represent potential "Stress Raisers". The specimens for testing have been selected, with variation in the “penetrated throat length” between 1.80mm to 0.60mm. In order to enhance understand the behaviour of weld penetration, one more specimens with penetration have been considered.

3.1. Load Pattern (Bending Load)

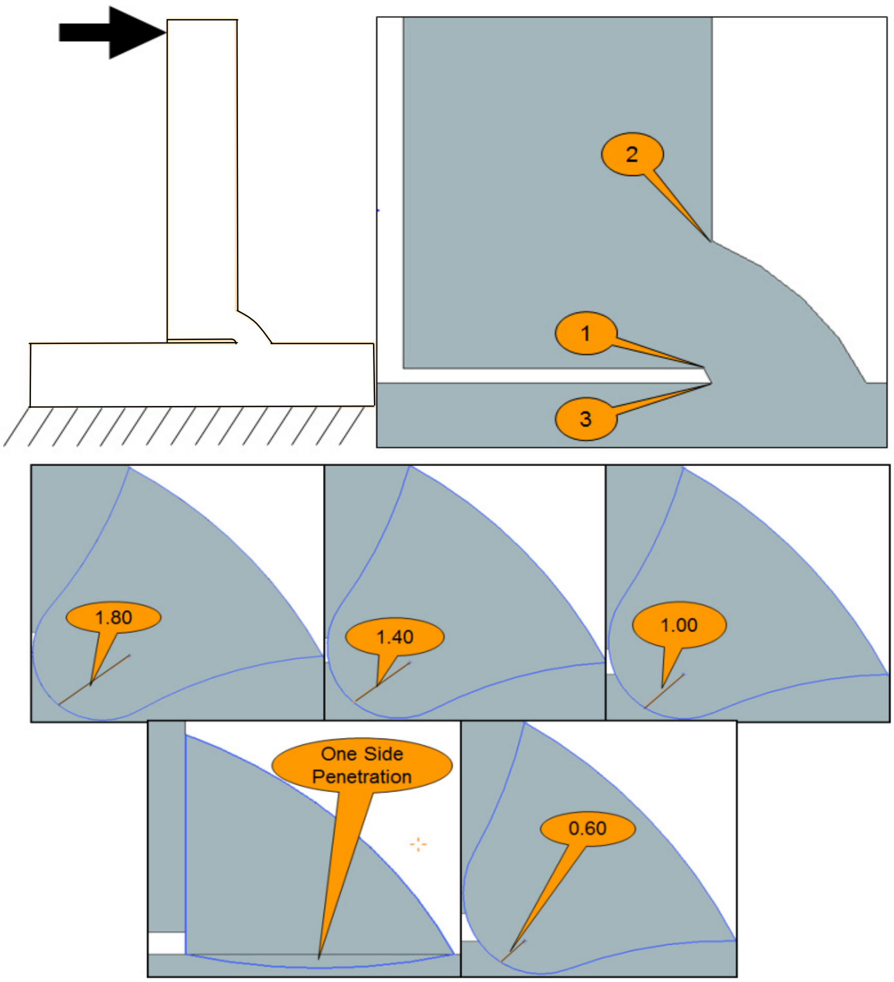


Fig. 3 Geometry for Load Pattern 01

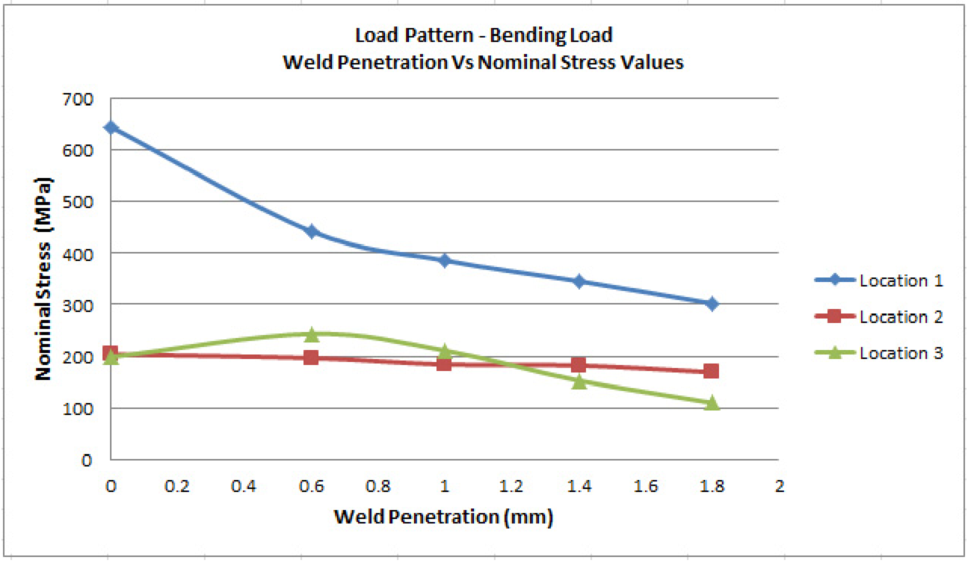
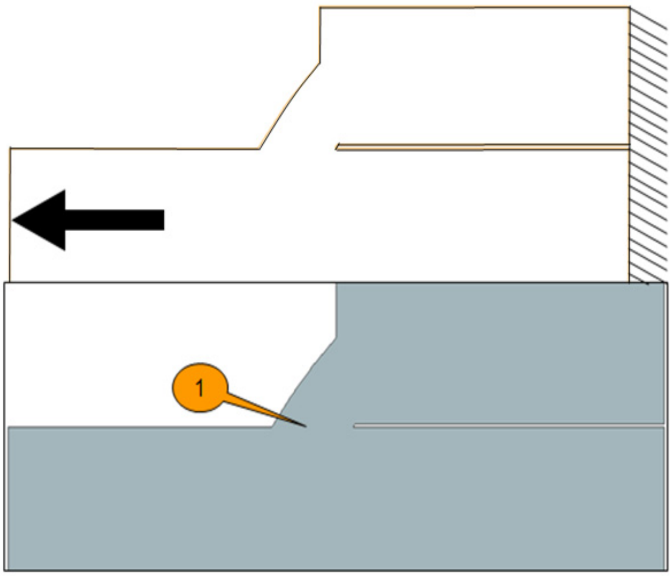


Fig.4. Weld Penetration vs. Nominal Stress

- In Location 1, as the amount of weld penetration goes from 1.80mm to 0.60mm, the stresses at all the locations keep increasing at a variable rate.
- Location 2 & 3, higher variation in nominal stress [1] values as weld penetration goes from 1.8mm to 0.6mm

3.2. Load Pattern (Tensile Loading)

Fig.5, shows geometry for tensile loading,



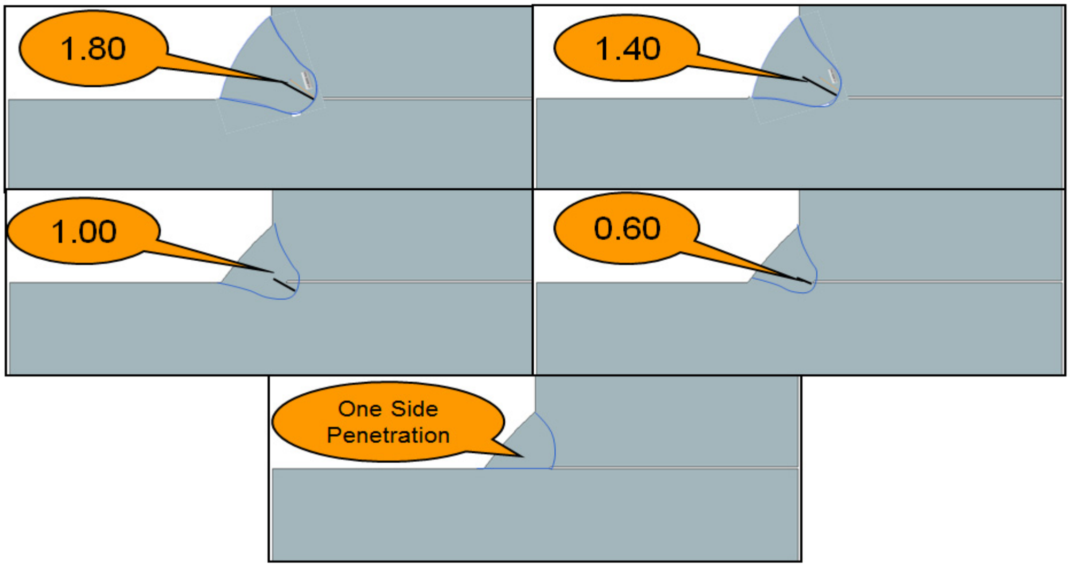


Fig.5. Geometry for Load Pattern 02

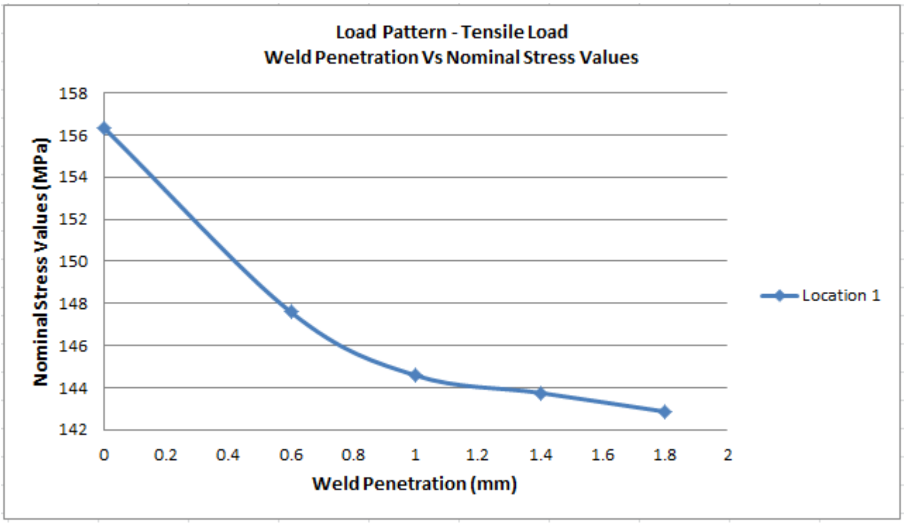


Fig. 6 Weld penetration Vs. Nominal Stress Values

From the tensile loading analysis, it is palpable that

- Depth of weld penetration goes on decreasing from 1.80mm to 0.60mm the stresses at all the locations keeps increasing at a variable rate.

4. Fatigue Life Prediction

Based on the type of weld -joint, weld geometry, loading and crack initiation point, welds are classified into classes governed by BS 7608 For Load Pattern-01 (Bending Loading), Location-01 It is classified under F2 Class. [4]

The Graph represented in fig. 7 show two S-N Curves [6]. The diamond point curve was derived from British Standard based on the calculations and the square point curve was obtained from the Analysis Results. A very close correlation can be observed between the curves. Based on appropriate cycle time and load history, a critical duty cycle can be decided for the loading and equivalent Fatigue life, in terms of hours

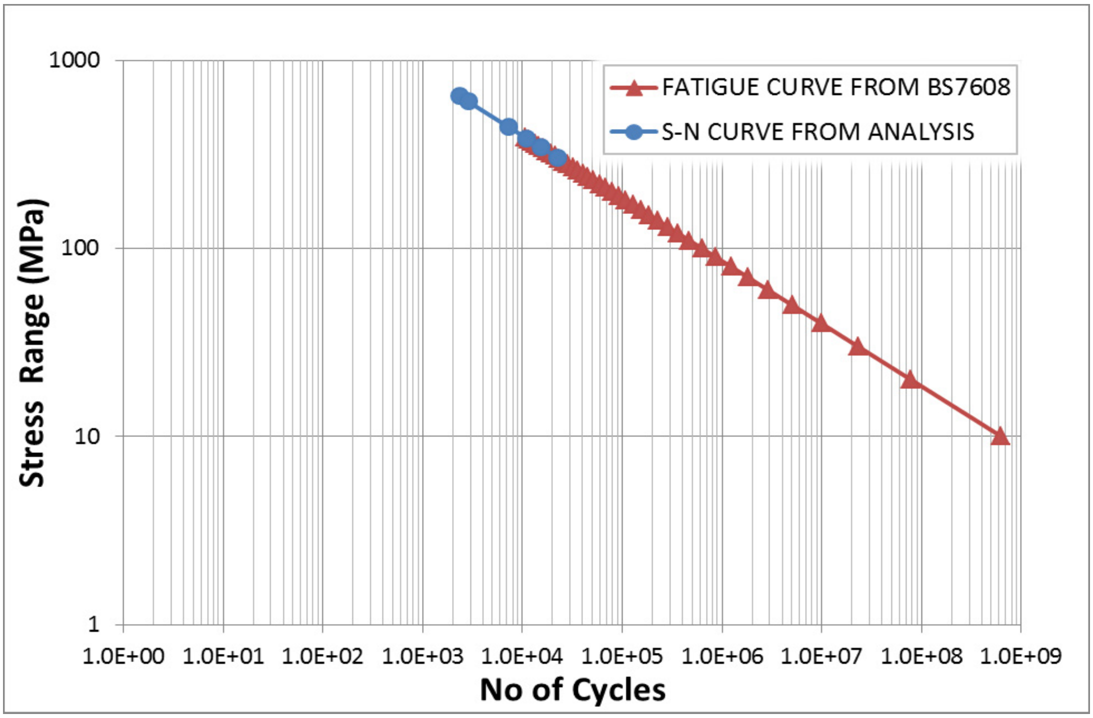


Fig.7. S-N Curve BS7068 Vs. Analysis Results

Fig.8, represent the load path in bending load [7] and its correppondig Nominal stress [1] distribution results near to weld toe [2] and Fig. 9 represent the load path in tensile load [7] and correposing nomial stress plot.

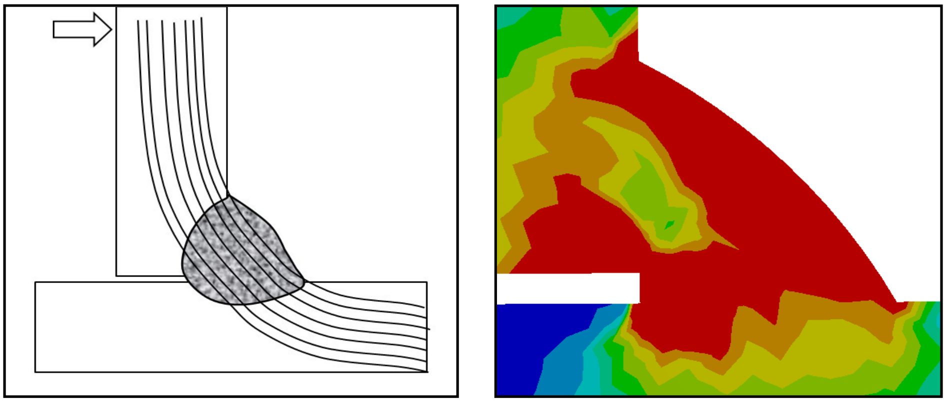


Fig. 8 A typical Stress flow pattern through Model for Bending Loading

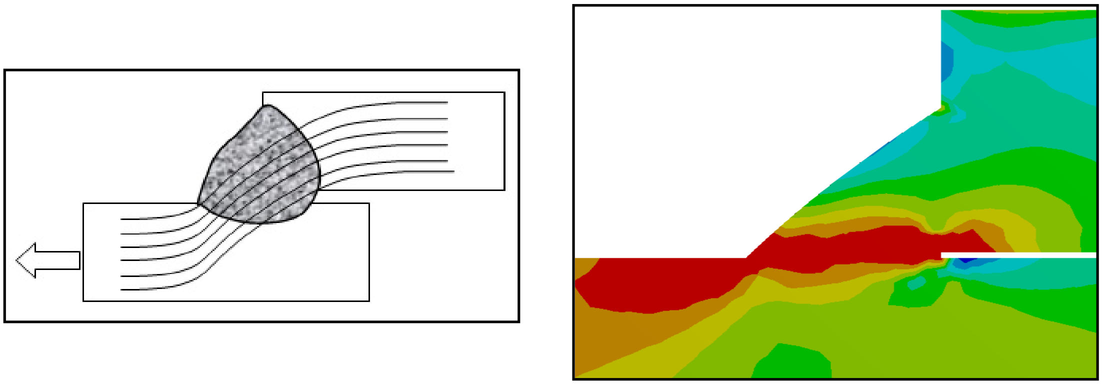


Fig. 9 A typical Stress flow pattern through Model for Tensile Loading

Considering configuration-1 with 1.80mm penetration as ideal, the results are highlight the corresponding percentage rise in stress range and the percentage reduction in Fatigue life at the targeted location. For example, comparing configuration 1 with a nominal stress range, say 60Mpa, and a fatigue life of, says 700000 cycles, configuration-5, an estimated nominal stress range of 102Mpa and a decreased Fatigue Life of 14000 cycles.

This study has been carried out for a chosen configuration with an arbitrary loading. The purpose of the entire study is to highlight the effect of weld penetration on a weld fatigue life.

Fatigue life should not be generalized, since the direction of loading and the complexity of field loading are important for calculating the load history required for precise fatigue life prediction.

5. Conclusions

Theoretically, an empirical formula cannot be generated for accurately defining depth of the penetration required at the various locations for the targeted fatigue life. However, the above study has clearly highlighted the corresponding fluctuations observed in the fatigue life with change in weld penetrations. It is observed that the lack of penetration allows a natural stress riser from which a crack may propagate. Measures should be taken to ensure that the weld attains sufficient penetration. Another conclusion which is evident from this study is detrimental effect of type of loading.

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