ISSN No:-2456-2165

"Notch stress analysis and fatigue strength assessment of tube flange welded joints under torsional loading"

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Abstract:- Welded joints are used in various mechanical and civil structures. The welding process involves joining of two materials (through coalescence). The strength of welded joint is significantly affected by heat effected zone, strength of material. The fatigue life of welded joint is significantly affected by repetitive cyclic loadings. The current research reviews the existing work conducted on improving the strength of weld joint using both experimental and numerical techniques. The effect of temperature, filler material and operating conditions is thoroughly investigated by various scholars.

Keywords:- *FEA, Weld joint, Optimization.*

I. INTRODUCTION

Welding is the process of permanently joining two materials by means of localized coalescence resulting from an appropriate combination of temperature, pressure and metallurgical conditions. Depending on the "combination of temperature and pressure, from high temperature without pressure to high pressure with low temperature, a wide variety of welding processes have been developed. Welding allows for direct stress transfer between elements, eliminating the butt plates and connection plates required for bolted structures. The weight of the connection is therefore minimal. In the case of tensile elements, the absence of holes improves the efficiency of the section"[1].

Fig. 1: Schematic of fillet weld joint

Welding is used as a manufacturing process in every industry, large and small. It is the main tool for the production and repair of metal products. The process is efficient, economical and reliable as a means of joining metals. This is the only process that has been tried in space. The process finds its application in the air, under water and in space. Fillet welds are widely used because of their economy, ease of manufacture and adaptability.

II. LITERATURE REVIEW

Li et.al (2018) [1] have conducted research on bridge steel structure subjected to heavy traffic loading. The effect of loading fatigue life analysis and stress analysis of steel welded structures of bridge. The analysis is conducted to determine orthotropic bridge cracking. The experimental testing results are in close agreement with numerical results.

Pradana et.al (2017) [2] have conducted research on stress analysis of circular hollow section. The analysis is conducted to determine "effective notch stress (ENS)" and "circular hollow section (CHS)". The conventional ENS calculation on welded joints has over predicted the values.

Shen et al. (2017) [3] have conducted research on estimation of fatigue crack for welded joint. A numerical method can be "used to quantitatively analyze the effect of residual stresses on cumulative fatigue damage. In order to obtain the distribution of welding-induced residual stresses, FE analyzes were performed as well as measurements. Based on the critical plane approach, an analysis of damage parameters was performed considering both welding residual stress and biaxial loading" [3].

Vodzyk et.al (2016) [4] have conducted research on fatigue life assessment of welded joints. The analysis of welded joints is conducted under cyclic loading conditions to determine the fatigue failure. Such stresses incur below the yield strength of the material.

The author stresses for early fault detection in welded joints in order to mitigate the effect of these cracks on damage.

Yamada et.al (2015) [5] have conducted research on fatigue cracking in steel girders. The steel girders have welded joints which are subjected to fatigue repetitive cycle loads. The orthotropic cracks are induced on welded joints. The procedures to avoid these fatigue cracks are also presented.

Rong et.al [6] In the given review, orthotropic steel bridge decks are used in girder and cable-stayed bridges. Fatigue cracks in the vertical welded joint of the rib and the deck were detected in some bridges. In this paper, "a Structural Hot Stress (SHSS) approach is used to evaluate the fatigue of the rib and deck. Enhanced volume models are created using the multi-sub model technique. Stresses around the weld tip are analysed and the effects of weld profile, weld tip radius, and mesh size are discussed. The SHSS is analysed using the surface stress extrapolation method, the stress linearization method, and the 1 mm stress method" [6].

Tecchio et.al [7] have conducted research on steel bridge structure subjected to repetitive cyclic loading conditions. The effect of traffic load on transverse filleted weld joints is evaluated. The effect of self-weight on stresses induced is evaluated. The serviceability of welded joints is also evaluated. The effect of longitudinal ribs and stiffeners on stress is evaluated using experimental techniques.

Meneghetti et.al [8] have conducted research on filleted weld joints using numerical and experimental techniques. The fatigue life is determined using notch stress intensity factors (NSIF). The research findings have predicted the local stresses in welded joint. Fillet weld joints carrying "transverse loads can fail either at the heel or at the heel, depending on the geometry. At the peak, the local stresses in mode I are singular with respect to the flank angles usually encountered in practice, while the stresses in mode II are not" [8].

Aygul et.al [9] have conducted research on orthotropic bridge structure made of steel material. The research on welded joints of bridge structure is conducted using techniques of FEM. From the FEA analysis, the critical regions of hot spot stress and notch stress is determined.

Sim et.al [10] have conducted research on orthotropic steel decks using experimental testing. The analysis is conducted on two full scale models and fatigue life of welded joints are determined to evaluate the fatigue properties of partial rib-to-deck penetration (PJP) groove weld joints. The "test results showed that the rib-to-deck connections are more susceptible to fatigue cracks in the deck plate than in the rib wall. A shallower weld penetration (eg 80% PJP) appeared to have slightly higher fatigue resistance than a deeper weld penetration" [10].

Saiprasertkit et.al [11] This work deals with the study between base metal and weld deposit. Low-cycle and high-cycle fatigue tests were performed on specimens with five matching conditions and two sizes of incomplete penetration. Observation of the specimens revealed that the crack propagation paths differ under low and high cyclic loading conditions and that the crack life is dominated by crack propagation.

Alam et al. al [12] In this paper, simplified fatigue and fracture mechanics based assessment methods are widely used in industry to determine the structural integrity significance of postulated cracks, manufacturing defects, service cracking or suspected degradation of structural components under normal and abnormal service. load.

Sonsino et. al [13] have conducted research on welded joint structure to determine its durability under different loading conditions and spectrum shape. The structures investigated are offshore structures, automotive engineering structures made from different design codes. The effect of different operational and design parameters on strength of welded joints are evaluated.

Baik et al. [14] have conducted research on filleted welded joints. The fillet type used in the analysis is "single sided fillet" and "cross filleted weld". The fatigue failure analysis is conducted on weld joints which has shown the formation of fatigue cracks. The shape of these fatigue cracks are elliptical in shape. These cracks propagate and reaches nearly 70% of thickness of plate.

Gustafsson et.al [15] have conducted research on welded joints using experimental techniques. The effect of sheet thickness on strength of welded joints is evaluated. The sheet thickness taken for the analysis is 25mm. The earlier researches are conducted on the sheet thickness ranging from 14nm to 190nm. The research findings have shown that fatigue life reduces with increase in sheet thickness and vice versa.

Connor et al. [16] have conducted research on bridge design structure subjected to fatigue loading conditions. The bridge design is "rib-to-rib" type with the use of cut outs. The fatigue resistance of bridge structure is determined by full scale lab tests. The range of fatigue values are determined for different loading conditions.

Huo et al. [17] have conducted research on determination and improvement of fatigue life for welded joints. The analysis conducted is constant amplitude type and variable amplitude type. The specimen under test was 16Mn steel. The specimen was tested for 3 different conditions i.e. TIG treatment and ultrasonic treatment.

Livieri et al. [18] have conducted research on weld bead using experimental techniques. The analysis is conducted to weld bead and the effect of toe radius and heel shape is investigated. The research findings have shown an asymptomatic stress distribution for V shaped notch having null radius. The asymptomatic stress distribution is evaluated using "notch stress intensity factors (NSIF)" [18].

Atzori et al. [19] In this paper, as the notch root ρ decreases, the theoretical stress concentration factor Kt increases and the fatigue limit of the notched component decreases. Below a given critical value for ρ, the "fatigue limit is no longer controlled by Kt and the notch behaves as a crack of equal depth. In welded joints, conventional welding procedures result in a small weld tip and weld root radius" [19].

Taylor et al. [20] have conducted research on butt weld joint and T shaped weld joint. The analysis is conducted for determination of high cycle fatigue behaviour of T shaped weld joint. The crack propagation and in plane fatigue behaviour is investigated using techniques of FEM. The analytical approach is also presented to determine the effect of stress concentration and notches on strength of welded joints.

Roy et al. al. [21] have conducted research on fatigue life assessment of welded joints. The research has shown that fatigue life of welded joints improved significantly by ultrasonic impact treatment (UIT) method. The "UIT"

ISSN No:-2456-2165

technique is used for 18 rolled beam specimens having yield strength of 380MPa. The use of transverse stiffeners also shown improvement in fatigue life of welded joints.

Dong et al. [22] have conducted experimental and numerical investigation on welded joint to determine fatigue failure. The analytical theory is also presented for determination of fatigue life. The numerical results obtained are in close agreement with the experimental results. The numerical investigation is conducted by varying mesh size and the results didn't vary much. The FEA has shown to be viable tool in analysing welded structures.

III. CONCLUSION

The strength of weld joint was analyzed by existing researches using numerical and experimental techniques. The critical regions of high stresses and deformation are obtained for transverse weld joints and filleted weld joints. The experimental results have shown maximum stresses at the weld joe and is most susceptible region to incur damage in the form of crack. The presence of high stresses at the weld toe results in reduction of fatigue life

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