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DEVELOPING AND ASSESSING THE LONGEVITY OF WELDED JOINTS WITH VARIED EDGE PROFILES THROUGH FINITE ELEMENT METHOD (FEM)

Rohit Bhumarkar[1], Ramnarayan Sahu[2], Yogesh Mishra[3]

[1]Research Scholar, Master of Technology (APS) Department of Mechanical Engineering, NIIST, Bhopal, India.

[2]Assistant Professor, Department of Mechanical Engineering, NIIST, Bhopal, India.

[3]Assistant Professor & Head Department of Mechanical Engineering, NIIST, Bhopal, India.

ABSTRACT

This research concentrates on examining the fatigue behaviour of stainless-steel bridges and the influence of diverse edge profiles on the fatigue life of welded joints. Fillet-welded joints are specifically studied due to their common occurrence in load-bearing elements susceptible to fatigue damage. The investigation delves into the impact of various edge profiles, encompassing concave shapes with different arc radii, chamfering with varying radii, and the positioning of the edge profile relative to the sample profile. Utilizing numerical simulations, the analysis reveals that the fillet profile with a 140 mm radius on the perpendicular side demonstrates the highest joint lifespan compared to other profiles. This discovery underscores the substantial role that the selection of an edge profile can play in determining the fatigue performance of welded joints in stainless-steel bridges. Given the recent advancements in the design and construction of stainless-steel bridges, the outcomes of this research hold significant relevance.

Keywords: Welding, Joint, FEM, Edge, Developing and Profile.

1. INTRODUCTION

Welding, a widely employed method for joining metals, finds application across diverse settings such as rural farms, construction sites, indoor factories, and job shops. The welding process, known for its general ease of comprehension, allows for the relatively swift acquisition of fundamental techniques. Essentially, welding involves the molecular-level bonding of metals, resulting in a homogeneous joint that exhibits strength surpassing that of the base metals. Various welding techniques, such as MIG, TIG, stick, and flux-cored welding, offer distinct characteristics tailored to different project requirements. Welding is a process that involves four basic components: metals, a heat source, a filler metal, and a shield from air. The metals are heated to their melting point while being protected from the air, and then a filler metal is added to create a single piece of metal. This process can be performed with or without pressure, and with or without filler metal. Several types of welding techniques are used today, including Gas Metal Arc Welding (GMAW) or MIG, Gas Tungsten Arc Welding (GTAW) or TIG, Flux Core Arc Welding, and Stick Welding, which are commonly found in industrial environments. Unlike brazing and soldering, welding involves melting the base metal and typically adding a filler material to create a pool of molten material that cools to form a joint, which can be stronger than the base material based on the weld configuration. Pressure may also be applied to produce a weld. A shield is required to protect the filler or melted metals from contamination or oxidation. Various energy sources, including gas flame, electric arc, laser, electron beam, friction, and ultrasound, can be used for welding. Welding can be performed in many different environments, such as open air, underwater, or in outer space, but it requires precautions to prevent hazards such as burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation. A butt joint is created by joining two workpieces along their edges when they are aligned on the same plane. This type of joint is preferred for applications where high strength is crucial as it is highly dependable and can withstand stress better than any other welding technique. As shown in figure 1.

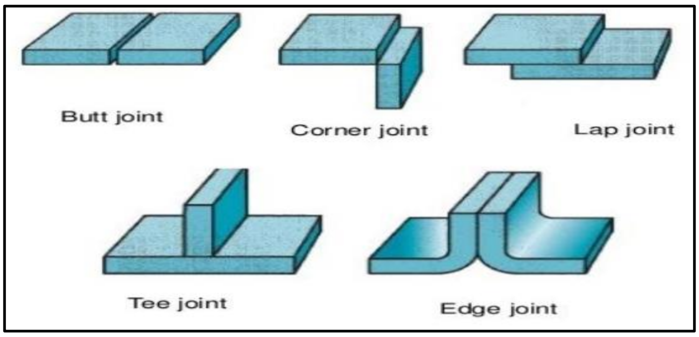

Fig. 1 Different Types of Welded Joints

2. LITERATURE REVIEW

Literature reviews are integral components of academic research papers, theses, dissertations, and scholarly articles. They serve to situate the research within the existing body of knowledge, demonstrate the researcher's familiarity with prior work, and justify the need for new investigations.

Li et al. (2023) This study focuses on evaluating the fatigue performance of Q420C steel fillet-welded joints at low temperatures. To begin with, tensile tests and Charpy V-notch tests were conducted to assess the mechanical properties of Q420C steel fillet-welded joints at both room temperature and low temperatures. It was found that as the temperature decreased from 20°C to -50°C, the yield and ultimate strengths increased. The Charpy impact energy transition temperature was determined to be -33.67°C. Afterwards, a fatigue test was conducted on cruciform joint specimens of Q420C steel fillet-welded joints at temperatures ranging from -50°C to 40°C, and considering three stress ranges (0.0-0.5 ftw, 0.0-0.7 ftw, and 0.0-0.9 ftw), where ftw was the design strength of the fillet weld**. [1]**

Wang et al. (2023) The study examined the fatigue behavior of fifty longitudinal fillet welded lap joints at room and low temperatures (-40°C, -20°C, 0°C). The S-N curves were fitted and compared with the design curves from GB50017, Eurocode3, and ANSI/AISC 360. A crack propagation analysis was performed to predict the fatigue lives, and the ANSYS software was used to validate the finite element model. A parametric study was conducted to investigate the impact of factors such as spacing between the crack and fillet weld termination, aspect ratio of the crack, overlapping plate width, and fillet weld size on the lap joint's crack propagation life**. [2]**

Zhao et al. (2022) This study utilized an efficient finite element (FE) computation to address the engineering problem at hand. The study estimated the inherent deformations of typical welded joints in a mock-up welded structure using thermal elastic plastic FE (TEP FE) analysis. Next, the study computed the welding distortion of the mock-up welded structure via elastic FE analysis, in which the inherent deformation was applied as a mechanical load. **[3]**

Li et.al (2022) The fatigue problem of orthotropic steel bridge slabs under traffic loads has been extensively studied in this paper. In particular, the cracking of diaphragms due to fatigue significantly affects the application and development of orthotropic bridge slabs. Experimental tests were conducted to investigate the stress distribution states of an orthotropic deck diaphragm of a large-span bridge, based on its cracking status. A finite element model of the orthotropic deck diaphragm was established using the ABAQUS software, and numerical simulation was performed based on the experimental results. **[4]**

Pradana et.al (2022) The purpose of this paper is to introduce two simplified methods for calculating Effective Notch Stress (ENS) on non-overlapping circular hollow section (CHS) K-joints. Traditional ENS calculation methods can be challenging for joints with complex geometries, such as CHS joints. The proposed methods aim to address these modeling difficulties. The first method is an extension of the extrapolation method used in the widely-used Structural Hot-Spot Stress (SHSS) approach. The second method estimates ENS based on the parametric relationship between ENS and SHSS. The study focuses on balanced brace axial loading of K-joints within a practical geometric range. The methods have been successfully applied to CHS X-joints. **[5]**

Shen et.al (2021) This study proposes a method for estimating the fatigue crack initiation life by considering welding residual stresses as initial stresses. The proposed numerical method allows for a quantitative analysis of the influence of residual stresses on the cumulative fatigue damage. To obtain the distribution of weld-induced residual stresses, both FE analyses and measurements were conducted. The analysis of damage parameters was performed based on the critical plane approach, considering both welding residual stress and biaxial loads. The proposed numerical method was validated by analysing fatigue test results for several typical welded joints. **[6]**

Vodzyk et.al (2021) This paper focuses on the failure of welded joints under cyclic operational conditions due to fatigue, which can occur at stress levels below the material's yield strength. To prevent such failures and detect internal flaws early, damage tolerance design philosophy is essential, as it saves time, money, and lives. Computational analysis of welded structures is an important tool for conducting fatigue analysis of welded structures, in addition to conventional experimental tests. In this study, an algorithm was developed using VrSuite software to perform fracture mechanics analysis and fatigue analysis for the assessment of the residual life of welded structures. **[7]**

Yamada et.al (2021) This study examines the state of over 150,000 highway bridges in Japan, with nearly 47 percent of them projected to be over 50 years old by 2026.

To ensure their safety and functionality, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) initiated a nationwide project to inspect and establish maintenance plans. A significant portion of the bridges are steel bridges with concrete slabs, and due to heavy truck traffic, including illegal overloading, severe damage to concrete slabs and fatigue cracks in steel girders and orthotropic steel decks have been observed. It is crucial to address such fatigue cracks in welded joints of steel bridges. Japan has attempted various methods to repair and rehabilitate such fatigue-cracked members, including improving the fatigue strength of welded joints and repairing cracked members. **[8]**

Tecchio et.al (2020) Fatigue is a major concern for steel bridges, as traffic load cycles have a significant impact on the serviceability limit stress values compared to the relatively low dead weights. Orthotropic steel decks, which are directly exposed to traffic loads, are especially susceptible to fatigue, with cracks often appearing in the top plates, longitudinal ribs, and bracing of the deck.

This paper presents a case study of a 20-year-old box girder bridge with an orthotropic steel deck spanning 152m and located on the heavily trafficked "Milan-Venice" A4 highway in Italy. **[9]**

Meneghetti et.al (2020) The focus of this paper is on using the Notch Stress Intensity Factors (NSIFs) to analyze the fatigue behavior of welded joints. In fillet-welded joints that carry transverse loads, failure can occur at the toe or the root, depending on the geometry.

Local stresses at the toe are singular in mode I, but not in mode II, due to the flank angles commonly encountered in practice. In contrast, at the root of the joints analyzed in this paper, both mode I and mode II stresses are singular and must be considered in fatigue assessments. Recently, a simplified finite element-based method called the Peak Stress Method (PSM) has been proposed to estimate the mode I NSIF and mode II SIF. This paper shows a link between peak stresses and the strain energy density averaged in a structural volume. **[10]**

Saiprasertkit et.al (2020) This paper examines the relationship between the base metal and weld deposit in terms of fatigue. Low and high cycle fatigue tests were conducted on specimens with varying matching conditions and two sizes of incomplete penetration.

It was observed that crack propagation paths differ between low and high cycle loading conditions, and that crack propagation dominates the failure life. Additionally, the study found that strength matching between the weld deposit and the base metal has a significant impact on the fatigue strength in the low cycle fatigue region, resulting in a significant reduction in fatigue life. **[11]**

Conclusion Drawn From The Literature Survey

- When cyclic loads are applied to welded joints, their performance can rapidly degrade. Therefore, it is crucial to optimize the parameters that affect welding strength to improve joint durability and prevent failures.
- In this study, the researchers focused on optimizing the fillet profile made at the end of the sample before welding to enhance the strength of welded joints. The fillet profile is the shape of the groove that is created at the end of the sample before welding. This profile affects the stress concentration and distribution in the welded joint and can significantly impact its fatigue performance.
- To conduct this study, different fillet profiles were designed and tested under cyclic loading conditions. The goal was to find the optimal fillet profile that could enhance the fatigue performance of the welded joint.

Objective of the work

- To perform a fatigue analysis of welded joints using Finite Element Analysis (FEA).
- To evaluate the effect of different shapes of fillet profiles on the performance of welded joints.
- To calculate the effect of different radii of curvature of fillet on the fatigue life of welded joints.

3. METHODOLOGY

The problem identified in this statement is that the performance of welded joints degrades due to stress concentration that occurs at the end of the component where welding is done.

This can lead to reduced strength and durability of the joint. The proposed solution to this problem is to use a fillet profile during welding to reduce or shift the stress concentration and increase the strength of the joint. The main objective is to optimize welding parameters and improve the performance of welded joints.

- Conduct a study on welded joints and their life criteria.
- Conduct a literature survey to identify the different process parameters that affect the fatigue life of joints.
- Develop a Finite Element Method (FEM) analysis model of the joint based on the experimental analysis performed by Cui et al.
- Develop a solid model of the joint based on the parameters mentioned during the experimental analysis.

4. RESULT AND DISCUSSION

In order to improve the strength and durability of welded joints, various welding parameters and component shapes must be considered. In this study, we examined the impact of different fillet profiles on the performance and longevity of welded joints through numerical analysis using the finite element method (FEM). To accomplish the goals, it is essential to create a finite element analysis model of the joint. Developing a solid model of the joint is the first step in creating this model. The solid model was created based on the geometric parameters used in the experimental analysis conducted by the geometric parameters of the joint are depicted in the figure below.

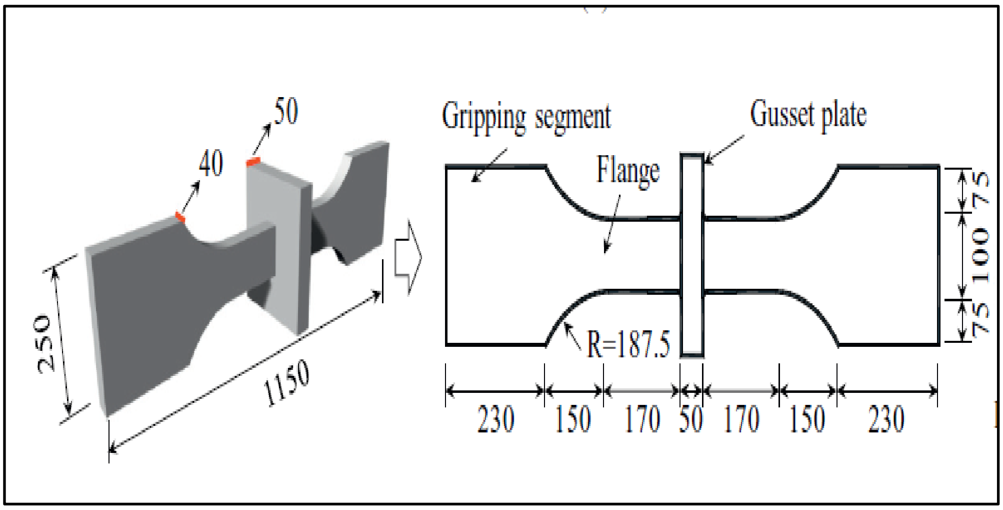

Fig.2 Geometric parameters of joint considered during FEM analysis

For performing the numerical analysis of joint the solid model of joint which is developed on the basis of geometric parameters as mention in the base paper and considered during the validation is shown in the below fig.

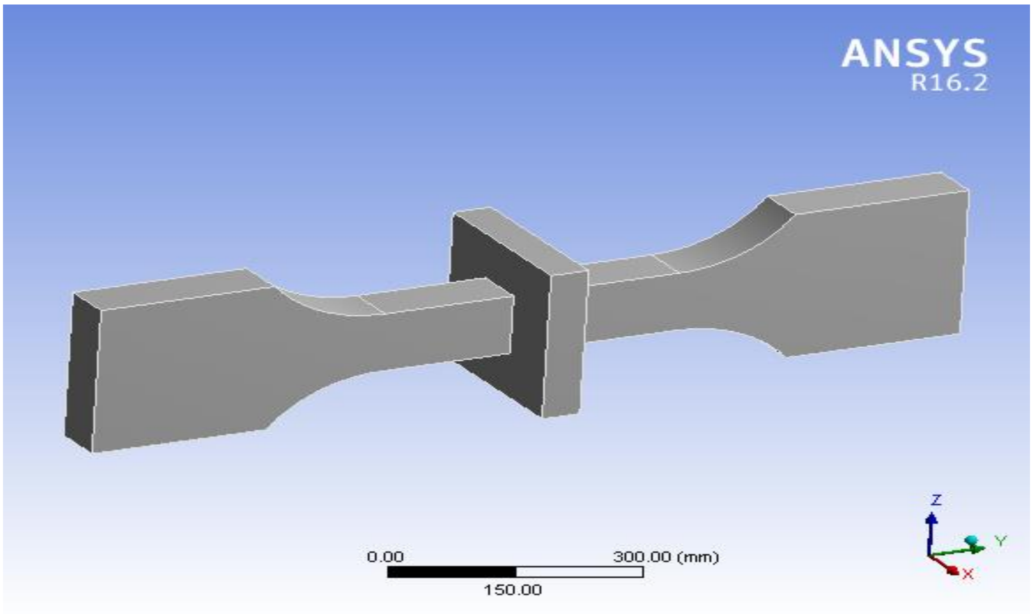

Fig.3 Solid model of joint considered during the numerical analysis

5. CONCLUSION

It is recommended to use FEM numerical analysis to analyse different joints and check their feasibility because it is a faster and more cost-effective method than experimental analysis. By using FEM numerical analysis, engineers can select the most suitable joint design that meets the required specifications in terms of fatigue life and other parameters.

- The fatigue life of the joint increases with an increase in the fillet radius.
- For the fillet joint, the perpendicular side of the fillet profile provides higher fatigue life than the alongside side of the profile for all fillet radii.
- Chamfering along the side and perpendicular side of the joint reduces the fatigue life of the sample compared to fillet profiles.

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