Fatigue Analysis of Butt Weld Joint using Theoretical and Experimental Approach

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Abstract— This work describe an investigation on the fatigue behaviour of the ductile iron strip by the use of computational method as well as actual fatigue testing. Understanding a failure behaviour and its enlargement will lead to a better appreciation of welded joints for reliability. The paper includes two main domains, the first section will focus on obtaining equivalent stress(von-misses) and fatigue life of the welded joint on the ANSYS 19.2, while second part depicts actual results which carried out on fatigue testing machine. At the end of both 1parts both approach will be compared. The mean stress, maximum stress, stress ratio and amplitude ratio with number of cycle has been reported in this work.

Keywords: ANSYS, Solidworks Modelling, Fatigue Testing

I. Introduction

Fatigue of the materials is a very complex process, which is still today not understood despite of vast research. Welded joints are vulnerable to fatigue damage when subjected to repeated loading. Welding strongly affects the material by heating and subsequently cooling as well as addition of filler material gives rise to inhomogeneous and different material than the base material. Also welds are not uniform as it is having pores, inclusions, cavities etc. Also residual stresses and distortions resulting because of welding process affect the fatigue behaviour.

As we know, fatigue failures appear in welded structure mostly in the welded area than in the base metal. Improper knowledge of fatigue actions is one of the major sources of fatigue damage. Hence fatigue analysis of welded joint becomes of high interest in areas where the part is subjected to repeated loading such as railcars, cranes, bridge ships etc. One of the known approach to predict fatigue life of welded structure is conventional method.

A better understanding of limit of various design methods and impact of fatigue strength due to weld quality will enhance the development of new fatigue loaded products. The understanding of weld quality and welding process could enable manufacturers to increase the utilization of fatigue loaded welded structures.

II. Objectives

Design validation of a fatigue analysis of weld joint which is most likely to be failed against fatigue. Hence it needs to find out fatigue life of welded component in advance using nonlinear fatigue analysis.

The main objectives of this work are as follows:

1) To carry out nonlinear fatigue analysis of specimen using ANSYS Classic Version 19.2. This is done to find out equivalent (Von Misses) stresses.
2) To obtain fatigue life estimation of welded-joint by using S-N approach method.
3) To compare the fatigue behaviour obtained from ANSYS and practical approach.

III. Double V-Groove Weld Specimen Analysis

As it is necessary to do analysis before going for any practical experiment. Here modelling is done in SOLLIDWORKS followed by analysis in the ANSYS 19.2. Steps for doing theoretical analysis are as follows:

A. Solidworks Modelling

Here two plates of dimension 135*25*4 (all are in mm) of ductile iron are joint by the weld material of mild steel because electrode use for this experiment is E6013.

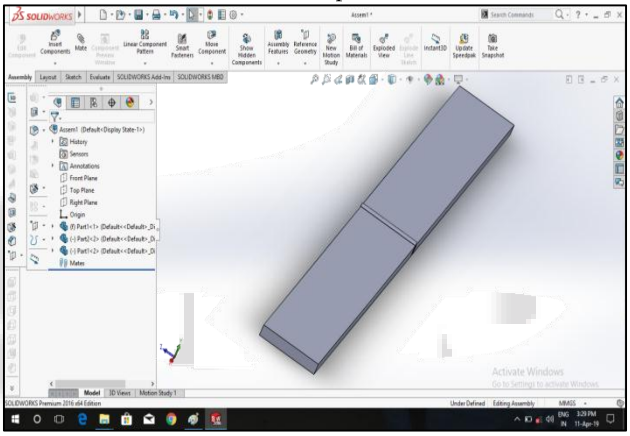

Fig. 1: Solidworks Model

B. Analysis in ANSYS

Life	Load magnitude	Min. stress	Max. stress
156000	28 kN	10.67 MPa	367 MPa

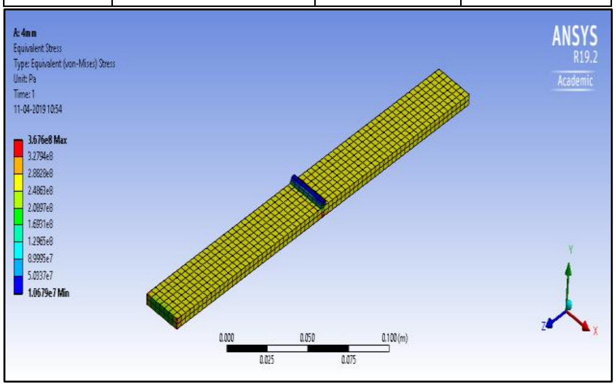

Fig. 2: Equivalent Stress at 28 kN

Life	Load magnitude	Min. stress	Max. stress
336000	22 kN	8.39 MPa	288 MPa

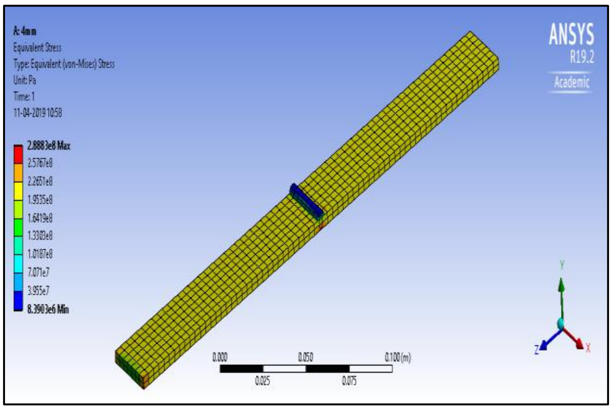

Fig. 3: Equivalent Stress at 22 kN

Life	Load magnitude	Min. stress	Max. stress
1213200	18 kN	6.86 MPa	236MPa

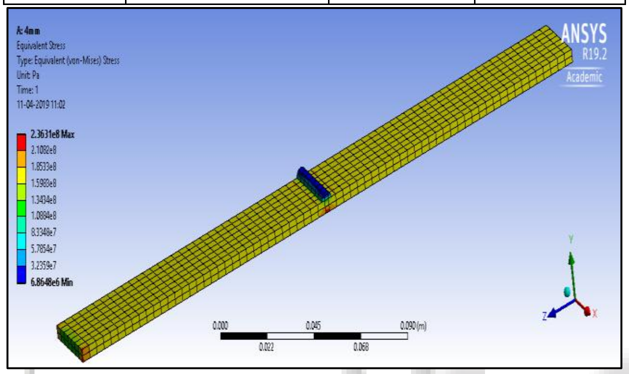

Fig. 4: Equivalent Stress at 18 kN

Life	Load magnitude	Min. stress	Max. stress
35000000	10 kN	3.81 MPa	963MPa

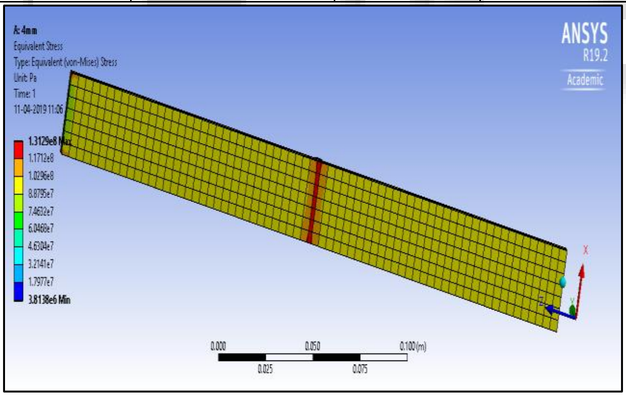

Fig. 5: Equivalent Stress at 10 kN

Life	Load magnitude	Min. stress	Max. stress
35000000	6 kN	2.28MPa	78.7 MPa

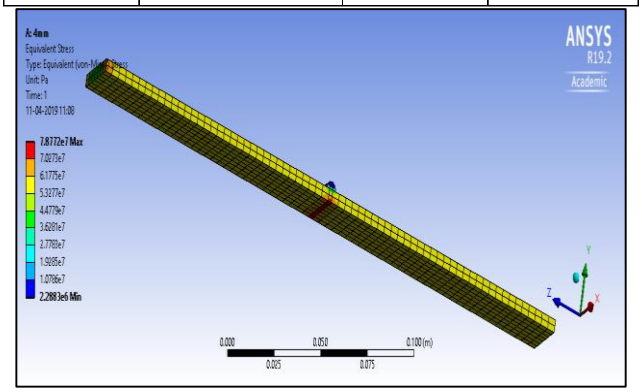

Fig. 6: Equivalent Stress at 6 kN

IV. DOUBLE V-GROOVE WELD SPECIMEN EXPERIMENTATION TESTING

Following are the details of the procedure to obtain S-N curve by the fatigue testing as per ASTM E606 standard.

A. *Specimen Preparation*

In this work, ductile iron plate of 4 mm thickness is used and the mechanical properties of ductile iron are as follows.
Elastic Limit: 322.996 MPa
Ultimate Tensile Strength: 403.407 MPa
Elastic Modulus: 1.2×10^{11} MPa
Mass Density: 7000 $\frac{Kg}{m^3}$

Double V-grooved specimens were prepared with ASTM E606. Two plates of size 135×25×4 mm is taken for welding with the bevel angle of 30 degrees, root face 1.5 mm are prepared.

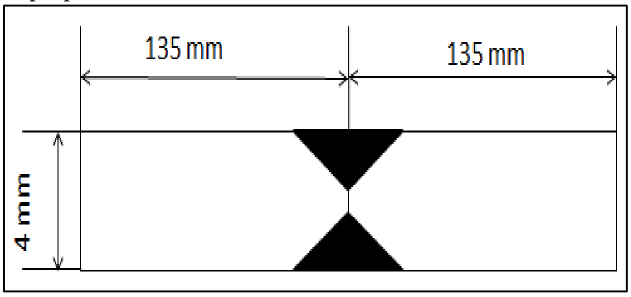

Fig. 7: Double V-grooved specimen foe experimental testing

Fig. 8: Specimen prepared for fatigue testing

B. *Experimental Testing*

To get actual S-N diagram weld materials were performed at Department Of Advanced Centre for Material Science, IIT-Kanpur. This is reputed material testing laboratory in India.

1) *Machine Specification*

Type of Machine	Hydraulic
Maximum Capacity	100 kN
Minimum Load can be Tested	0.01 kN
Type of test can be performed	Tensile, Compression,3-pt Bend,4-pt Bend, Loading-Unloading, Fatigue.
Temperature Tests	Low temp:- 20° C to 180° C (tensile, compression and fatigue) High temp:- upto 1000° C (tensile and fatigue)
Types of material can be tested	Metallic, plastic and composite
Available load cells	Tensile & compression:- 5 kN, 10 kN &100 kN
Type of sample can be tested	Round, CT, Flat and Sheet
Crosshead speed (strain rate)	Max:- 60 mm/sec Min:- 0.001 mm/sec

Crosshead displacement	Max:- +/- 80 mm
Type of test control	Stroke, load and strain
Type of extensometers	Room temp:- GL 12.5 mm (travel 2.5 mm), GL 12.5 mm (travel 0.5 mm) High temp:- GL 25 mm (travel 5mm) & COD-5 mm

2) *Picture of Fatigue Testing Machine*

Fig. 9: 100 kN Biss UTS Machine

C. *Experimental Results of Fatigue Test*

Sr.No.	Stress (MPa) Max.	Stress (MPa) Min.	No. of cycles	Alternating stress MPa	Mean stress MPa	Stress ratio (R)
1	280	28.0	38983	126	154.0	0.1
2	220	22.0	78591	99	121.0	0.1
3	180	18.0	242524	81	99.0	0.1
4	100	10.0	765262	45	55.0	0.1
5	60	6.0	300000	27	33.0	0.1

1) *S-N data from Fatigue Testing*

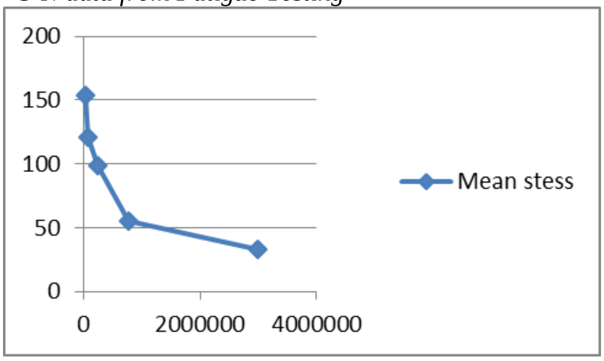

Fig. 20: S-N curve of test specimens

D. *Comparison*

	Load	Min. Stress	Mean Stress	Max. Stress	Life
Theoretical Result	28 KN	10.67 MPa	269 MPa	367 MPa	156000
practical Result	28 KN	28 MPa	154 MPa	280 MPa	38983

	Load	Min. Stress	Mean Stress	Max. Stress	Life
Theoretical Result	22 KN	8.39 MPa	211 MPa	288 MPa	336000
practical Result	22 KN	22 MPa	121 MPa	220 MPa	78591

	Load	Min. Stress	Mean Stress	Max. Stress	Life
Theoretical Result	18 KN	6.87 MPa	173 MPa	236 MPa	1213200
practical Result	18 KN	18 MPa	99 MPa	180 MPa	242524

	Load	Min. Stress	Mean Stress	Max. Stress	Life
Theoretical Result	10KN	3.81 MPa	96.3 MPa	131 MPa	35000000
practical Result	10 KN	10 MPa	55 MPa	100 MPa	765262

	Load	Min. Stress	Mean Stress	Max. Stress	Life
Theoretical Result	6 KN	2.28 MPa	57.8 MPa	78.7 MPa	35000000
practical Result	6 KN	6 MPa	33 MPa	60 MPa	3000000

V. CONCLUSION

1) Practical testing shows that fatigue strength of ductile iron welded strip is 18.57% of elastic limit. So based on the result this ductile iron welded appears to have low fatigue properties
2) The material specific S-N curve obtained from theoretical analysis is utilized to validate simulation data.
3) There is lot difference between theoretical and practical approach because of several environmental factor which affect fatigue life of welded assembly. Point such as temperature, moisture and location are considered part of the environment. Environment contains sea water may see decreased fatigue life due to increase in growth of crack rate.
4) Apart from this, there is lack of computational data in software so this simulation concept is not yet thoroughly apply in industry as well as academics which are designed and developed on fatigue failure concept are in initial stage of development.

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