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ExperimentalTesting and Estimation of Welded Joint Strength using FEA Software

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Abstract

Gas Tungsten arc welding (GTAW), is likewise called as tungsten inert gas welding (TIG),this welding strategy is generally utilized for stainless steel ,titanium compound etc. for high welding quality better protection and comparatively lower equipment investment. In this arc welding process in which amalgamation is created by hating the workpiece with an electrical Arc struck between tungsten electrode and the job. During welding process the workpiece is subjected to considerable local heating and rapid cooling follows. Because of the sudden heating and cooling residual stresses maybe develop in the weld pool. The defect can be cause in wild due to residual stresses. The defect present in the weld result change in mechanical property that is strength and hardness of the weld joint.
In a present review, investigation of the resident stresses on a tension strength property austeniti 304 SS weld joint will be done through literature survey. After selecting desired working range a welding parameter that effect on the weld characteristics will be investigated using experimentation. The outcomeget by experimentation will be affirmed using Finite element software for simulation.

Keywords:*Tungsten inert gas welding, welding gas,residual stresses, austeniti 304 SS, finite element software*

1. Introduction

Tungsten inert gas welding (TIG) method was discover in the World War due to the American aircraft industry, for a method of welding magnesium and aluminum [1]. Russell Meredith exhibited the first TIG method of the welding of magnesium with a Tungsten electrode and helium gas in the late 1930's. TIG welding or GTAW (Gas Tungsten Arc Welding) utilized a non-consumable tungsten electrode protected by an inert gas. The electrode is either made of pure tungsten or tungsten blended with small amounts of oxides for improving the stability of the arc to makes it simpleto strike. Since the process utilized a non-consumable electrode, more filler material is basically added.

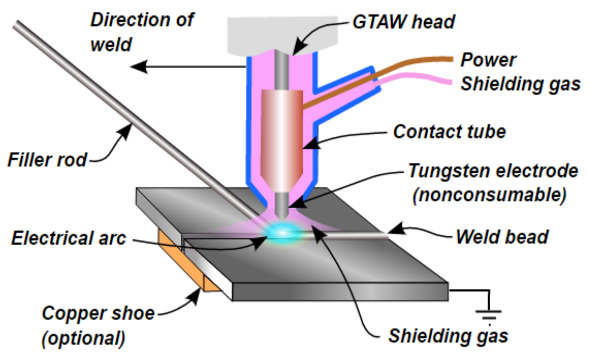

Fig.1 Principle of Operation of TIG Welding [1]

TIG is a welding process, given in Fig. 1, wherein amalgamation is generated by heating the work piece with an arc between a tungsten electrode and the job. The electrical discharge produce a plasma arc between the electrode tip and the workspaces to be weld. They are is basically initialized with a power supply with a very high freq. producer, which produces a little spark that provides the basic conducting flow through the air for the low voltage welding power. The arc consists of a high-temperature, approximately 6100o C, which melts the surface of metal to form a molten metal pool. A welding gas (argon, heliumetc.) is used.

All stainless steel contains iron as an important element and chromium in the range 11-30%. In certain stainless steel nickel is also added to reduce the thermal and electrical conductivity. Manganese and Molybdenum is also add in some of the stainless steels. This is popular processes for welding stainless steels are gas tungsten arc and gas metal arc welding [1].

Residual stresses have significant effect on strength of material. The defects present in the weld results changes in mechanical parameter of the weld joint. In the present study, investigation of residual stress on tension strength properties of austenitic 304 SS weld joint with experimentation and the results obtained by finite element software.

2. Literature review

Number of researchers worked on various welding processes and cause of different weld parameters on the process.

George and Diamantakos [2] undergone a study the cause of residual stress on intensity and crack propagation angle develop in the residual stress

areaunder mixed mode loading condition.Gurinder and Rakesh [3] find the effect of residual stresses on the butt weld by using SolidWorks finite element software.Blandford et-al. [5] is done standard tensile testing of roundworkpiecein accordance by ASTM procedure. Two steel alloys 304L and 316L were test in this study. Quasi static tensile experiment was performed at room temperature using UTM. These estimated curves may be suitable for plastic analysis. Molak et-al. [6] underwent a study to find the mechanical behavior of welding material from a single pass weld bead set on a 316L steel plate. It is found that the change in mechanical behavior of the material examined with the use of micro samples and standard samples are significant.Mousavi and Miresmaeili [9] analyzed the residual stress found in the weld process. It is found that, the rise in base metal temperature result in non-uniform distribution of thermal strain, which further result in accumulation of residual stress. Zhu and Chao [11] underwent a study to search the effect of each temperature dependent material property on the temperature, residual and distortion in computational simulation by FEA of welding process. The residual stresses developed in the regionof the weld are highest. Zhao et-al. [13] developed the nonlinear dynamic comparison between the weld pool geometry reflecting the weld quality and the weld parameters in order to overcome the welding process.
From the above study of various researchers comment it is observed that more study is required to investigate effect of residual stress on tension strength properties of austenitic type 304 SS weld joint for the TIG welding.

3. Tensile strength analysis of weld joint

The experiments were carried out to find the effect of tensile strength of the weld. This gives an overall of the experimental procedure.

3.1 Objectives

1) To analyze effect of weld on strength of butt weld.
2) To process out the experimental and simulation.
3) To investigate residual stresses using George Labeas model for austenitic 304 SS butt welded joint.
4) To study stress strain bearing of 304 SS butt joint in tension by experimentation using ASTM E8 standard

3.2TIG welding machine

In present study a TIG welding machine, is used for joining the SS304 work pieces. The technical details for the TIG weld machine are given as below

Make	: APS-400
Input supply voltage 3PH	: 440
Output	: DC
Welding current range	: 10-400A
Approximate dimensions (L x M x H) mm	: 711 x 762 x 546

3.3 Properties of 304 SS

The 304 SS has wide variety of applications,
1) Opposition to corrosion
2) Protection of job contamination
3) Opposition to Oxidation
4) Excellent formability

Table 1 Mechanicalproperty at room temperature

	304	
	Typical	Minimum
Tensile Strength, Mpa	600	515
Proof Strength, (Offset 0.2 %) Mpa	310	205
Elongation (Present in 50 mm)	60	40
Hardness (Brinell)	170	-
Endurance (fatigue) limit,	240	-

Table 2 Elevation temperature tensile strength [14]

Temperature, ^{o}C	600	700	800	900	1000
Tensile Strength, Mpa	380	270	170	90	50

3.4 Work piece specification

For study SS304 is selected, it has lot of application in the process industry. The material selected is six plates of 3mm as shown in Fig. The plate size selected is 150mm X 200mm as per ASTM standards. The chemical structure of the plate is given in table 3.

Table 3 Chemical composition of work piece

	%C	%Mn	%Cr	%Ni	%Si	%S	%P
3 mm	0.017	1.27	18.40	8.36	0.27	0.020	0.027

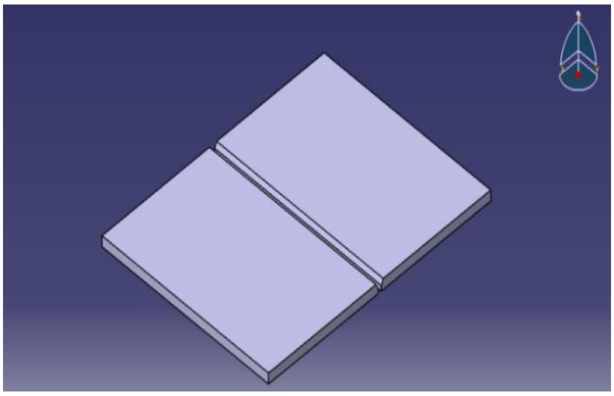

Fig. 2 Specimen drawing

The SS304 sheet is converted in the desired work piece size by using shearing operation. The V-notch is prepared by using the shearing operation. The angle of V-notch is kept 60^{0}. The specimen is shown in Fig. 2.

3.5 Tension test

The work pieces cut by wire cutting are tested for breaking load on UTMThe specifications of universal testing machine used for study are follows

Name of machine : UTM
Type : Tension
Maximum Capacity :600 kN
Model : UTN 60

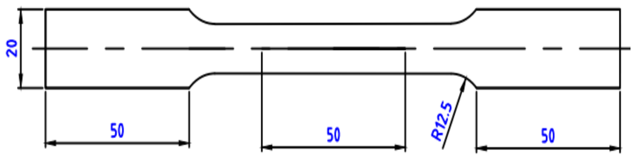

Fig. 3 Tension test specimen

For strength analysis of weld joint consider the two basic conditions.In longitudinal tensile testing take four specimens and the center of these specimens are at a distance of 20, 25, 30 and 35mm offset to the weld center. In transverse tensile testing take five specimens of the weld plate takes.

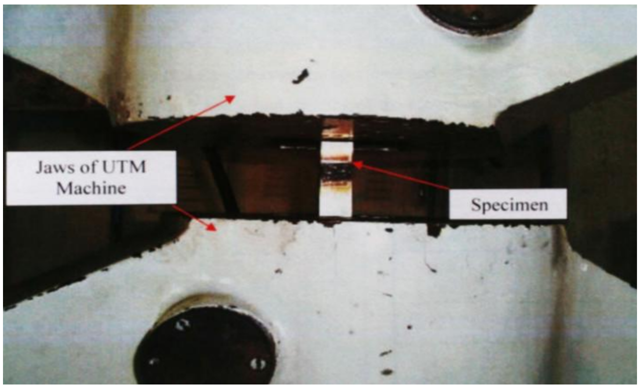

Fig.4 Universal testing machine (operation)

3.5.1 Transverse Tension Test

For transverse tension test, we consider here basic three transverse regions of the welded plates i.e.1st region is the first 50mm distance from the start of weld, 2nd region is the middle region of the plate i.e. after 100mm distance and the third region is at end .For this test specimens are cut as per give ASTM E8 standard.

Table 4 Values of maximum tensile stress along Y-axis

Distance from center of the plate (mm)	Maximum Tensile stress (N/mm^2)
60	726.09
40	745.27
20	711.64
0	716.85
75	690.17

3.5.2 Longitudinal tension test

For longitudinal tension test, we take four specimens of the specifications given i.e. as per ASTM E8 standard. These four specimens are offset from the weld center. The center of specimens and weld center is offset by 20mm, 25mm, 30mm and 35mm respectively. After tension test of these specimens we get the Load versus strain graph of the specimen by experimentation.

Table 5 Values of maximum tensile strength along x-axis

Dist. From weld center (mm)	Max. tensile stress (N/mm^2)
20	784.5
25	786.1
30	840.2
35	777.3

3.6 Residual stresses

The cause of residual stresses on the welding region is studied using two different considerations. The longitudinal residual stress division is consideringto be constant through the thickness. In another case, both longitudinal and transversal residual stress are consider into account; Out of these two cases the second case which is having both the longitudinal and transverse residual stress distribution.

$$\sigma_x = \sigma_{0x}\left(0.5 + \frac{z}{t}\right)e^{-\left(\frac{x}{a}\right)^2}\left[1 - 12\left(\frac{y}{L}\right)^2\right] \quad \text{---- (1)}$$

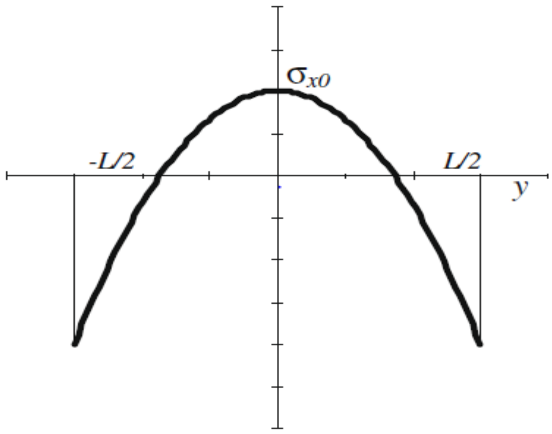

Fig.5 Transverse residual stress distribution [2]

Longitudinal residual stresses are described by the following relationship.

$$\sigma_y = \sigma_{0y}\left(0.5 + \frac{z}{t}\right)\frac{1 - \left(\frac{x}{c_0}\right)^2}{1 + \left(\frac{x}{c_0}\right)^4} \quad \text{----- (2)}$$

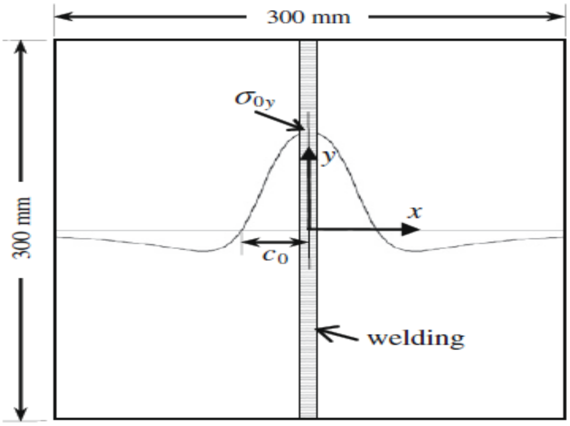

Fig.6 Longitudinal residual stress distribution [2]

3.6.1 Transversal Residual Stress

The values of transverse residual stress are calculate from the equation (1) for that the value of maximum tension stress is obtained from the graphs of tension test of the required specimen which is given in table 4.

Table6 Variation of transversal residual stress along y-axis

Dist. From Center of the plate(mm)	Transverse Residual stress (N/mm^2)
60	-29.14
40	194.77
20	313.92
0	358.93
20	313.92
40	194.77
60	-29.14

3.6.2 Longitudinal residual stress

The values of longitudinal residual stress are calculate from the equation (2) for that the value of maximum tension stress is obtained from the graphs of tension test of the required specimen which is given in table 3.

Table7 Variation of longitudinal residual stress along x-axis

Dist. From Center of the plate(mm)	Longitudinal Residual Stress (N/mm^2)
-35	-40.67
-30	0
-25	81.04
-20	181.99
0	358.43
20	181.99
25	81.04
30	0
35	-40.67

4. Simulation of weld joint stresses using FEA

The finite element method is used for calculating the structural analysis, thermal analysis of the engineering component.

4.1 Geometry of the specimen

The geometry of the specimen was created in Catia-V. The specimen is symmetrical so for analysis we take here the quarter part of geometry of the specimen. The quarter part geometry of specimen is shown in Fig. 6.

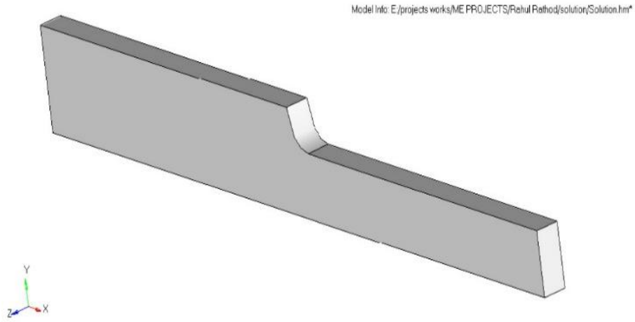

Fig.7 Geometry of the Specimen

4.2 Elements used for analysis

The meshing of the geometry is done in Hyper-mesh. The elements used for analysis are plane stress element and plane strain element i.e.CPE4 and CPS4, both these are the 4 node bilinear elements. The total number of elements used for the analysis is 342 and total number of nodes used is 624 of C3D81 type of elements. The shape of elements is hexahedral type.The material given tofor analysis is steel. The Young's modulus is 200 Gpa and the value of Poisson's ratio for 304 SS is 0.29. The plasticity of the steel material is given as at 400 N the plastic strain is zero. The section is solid and homogeneous.

4.3 Boundary conditions

Boundary conditions of the specimen are XASYMM given to set-l and ENCASTRE given to set-2 and the load is applied on set-3. The load given for the analysis is the yield point load which is already obtained from the experimentation. The load is applied on the nodes. The given boundary conditions and applied load are shown in Fig. 7

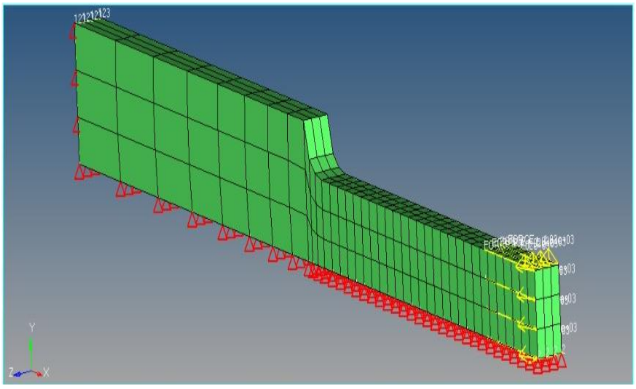

Fig.8 Boundary Conditions and Applied load of the specimen

After giving the boundary conditions and applied load next step is to run the model for full analysis and then note down the values of stress and strain at each node. The stress variation in the specimen through its length is shown in Fig. 9.

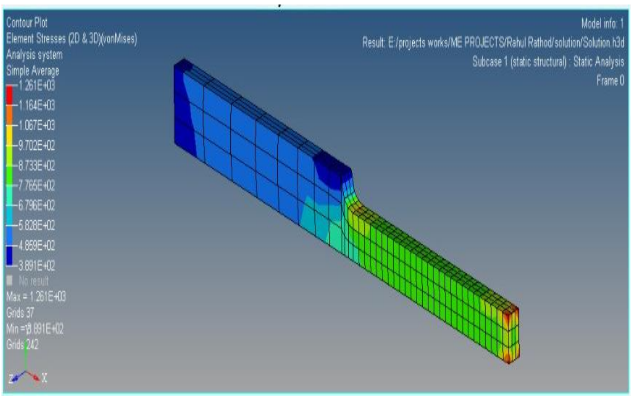

Fig. 9 Stress Analysis of the specimen

4.4 Transverse tension test

The values of stresses and strains at each node are note down after analysis, use that values for plotting a graph of stress verses strain of each specimen. From this stress strain graph we obtain the values of ultimate tensile values.

Table 8 Value of maximum tensile strength along Y-axis

Distance from center of the plate(in mm)	Maximum tensile stress (N/mm^2)
60	625.25
40	639.98
20	608.11
0	616.54
75	590.38

4.5 Longitudinal tension test

The values of stresses and strains at each node are note down after analysis, use that values for plotting a graph of stress verses strain of each specimen. From this stress strain graph we obtain the values of ultimate tensile values.

Table 9 Values of maximum tensile stress along X-axis

Distance from center of the plate(in mm)	Maximum tensile stress (N/mm^2)
20	622.75
25	620.05
30	537.16
35	617.02

4.6 Transverse residual stress

The values of transverse residual stress are calculate from the equation (1) for that the value of maximum tension stress is obtained from the graphs of tension test of the required specimen which is given in table 4.

Table 10 Variation of transversal residual stress along Y-axis

Distance from center of the plate(in mm)	Transverse Residual Stress (N/mm^2)
75	-211.2
60	-25.56
40	173.13
20	271.41
0	309.73
20	271.41
40	173.13
60	-25.56
75	-211.2

4.7 Longitudinal residual stress

The values of longitudinal residual stress are calculate from the equation (1) for that the value of maximum tension stress is obtained from the graphs of tension test of the required specimen which is given in table .

Table 11 Variation of longitudinal residual stress along X-axis

Distance from center of the plate(in mm)	Longitudinal Residual Stress (N/mm^2)
-35	-39.00
-30	0
-25	63.02
-20	144.18
0	308.73
20	144.18
25	63.02
30	0
35	-39.00

Data obtained from experimentation needs to be investigated by plotting the graphs of FEM simulation.

5. Test result

5.1 Test result of transverse tension

The result obtained from the FEA simulation and experimental is shown in Fig.10. Both the curves are identical having some difference. This difference is due to the, the values of loads given to the simulation is the yield point load values.

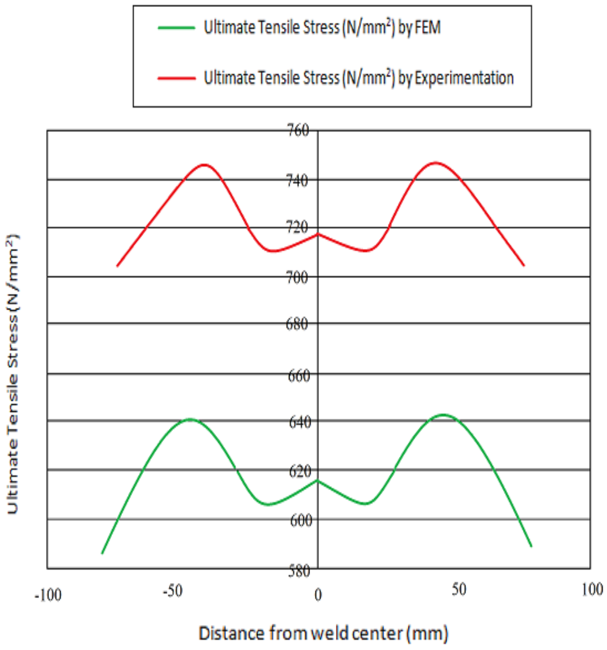

Fig.10 Comparison of ultimate tensile stresses of transverse tensile test

5.2 Longitudinal tension test result

The result obtained from the experimental and from FEM simulation is shown in Fig.11. Both the curves are identical having some difference. This difference is due to the, the values of loads given to the simulation is the yield load values.

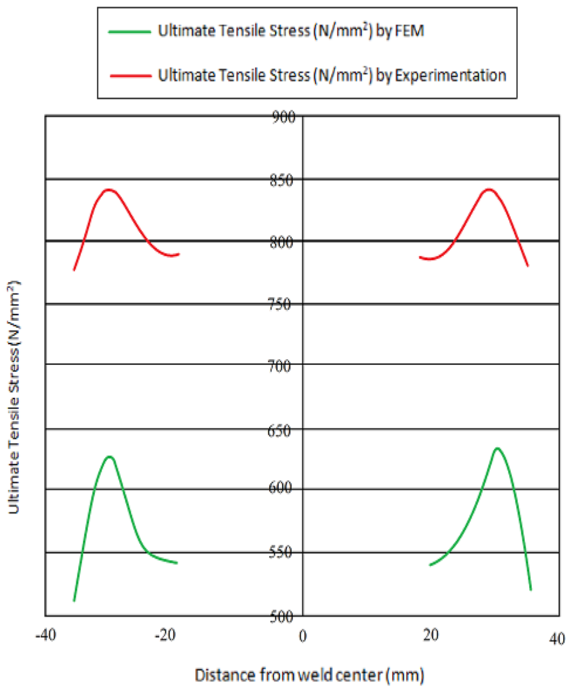

Fig. 11 Comparison of ultimate tensile stresses of longitudinal tensile test

5.3Transverse residual stresses comparison

The result obtained from the experimental and from FEM simulation is shown in Fig. 12. Both the curves are identical having some difference.

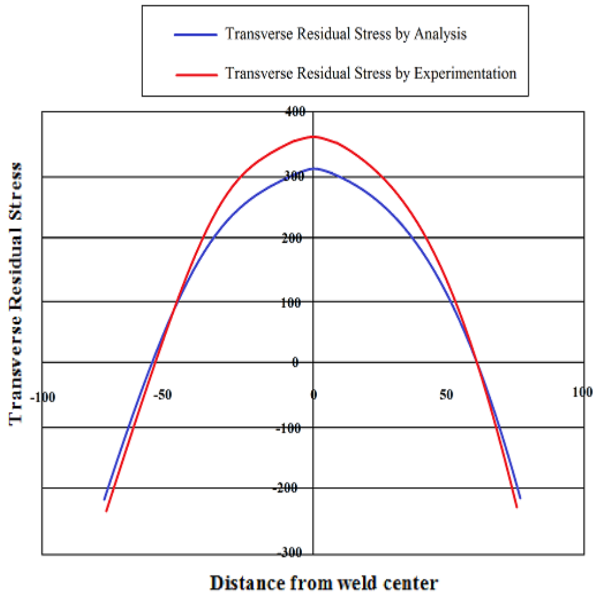

Fig. 12 Comparison of residual stresses of transverse tensile test

5.4 Longitudinal residual stresses comparison

The result obtained from the experimental and from FEM simulation is shown in Fig.13. Both the curves are identical having some difference. This difference is due to the, the values of loads given to the simulation is the yield load values.

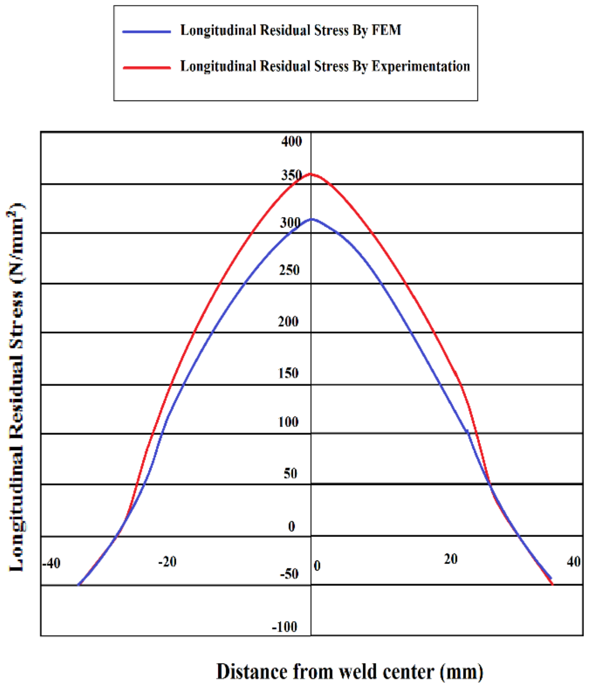

Fig. 13 Compassion of residual stresses of longitudinal tensile test

From the above results of comparisons, we say that all the results obtained from the FEM are similar to the results obtained from experimental analysis. There is a slight difference in the results that is due to, for the FEM the values of loads are given as yield point loads.

Conclusions

1. In the, investigation of residual stresses on tension strength properties of austenitic 304 SS weld joint with experimentation is carried out and it is found that for the longitudinal and transverse conditions the magnitude of residual stresses reaches their maximum values at the top of the plate and is linearly reduced to half at the plate bottom.
2. In the present case the value of longitudinal residual stress reaches to 355.8 N/mm2 by experimental analysis and 309.8 N/mm2 by FEM software, the values of transverse residual stress reaches to 358.43 N/mm2 by experimental analysis and 309.73 N/mm2 by FEM software.
3. It is found that the in longitudinal and transverse condition ultimate tensile stress magnitude reaches their maximum values in the region of 20mm to 40mm from weld center of the plate and is linearly reduced at the plate end. In the present case the value of longitudinal ultimate tensile stress reaches to 840.27 N/mm2 by experimental analysis and 623.74 N/mm2 by FEM software, the value of transverse ultimate tensile stress reaches to 726.09 N/mm2 by experimental analysis and 626.25 N/mm2 by FEM software.

Future scope:

1. The effect of the residual stresses for various thicknesses of plates can be analyzed further.
2. The effect of ultimate tensile stresses for various thicknesses of plates can be analyzed further.

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