International Journal of Research in Engineering, Science and Management
Volume-1, Issue-9, September-2018
www.ijresm.com | ISSN (Online): 2581-5782

Experimental Analysis of Residual Stress of Welded Joint through Mechanical Vibrations

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***Abstract*—Welded joints are used for construction of many structures. Welding is a joining or repair process which induces high residual stress field, which combines with stresses resulting from in-service loads, strongly influencing in-service behavior of welded components. When compared with stresses due to service loads, tensile residual stress reduces crack initiation life, accelerates growth rate of pre-existing or service-induced defects, and increases the susceptibility of structure to failure by fracture. Also, welding residual stresses are formed in a structure as a result of differential contractions which occur as the weld metal solidifies and cools to ambient temperature.**

Previously some of the methods like heat treatment and peening kind techniques were used for reduction of residual stress. However, those methods need special equipment and are time consuming. In this, we are proposing a new method for reduction of residual stress using vibration during welding. For this Mechanical vibrations will be used as vibration load. This vibration will be achieved by low frequency vibration of which frequency nearer to the natural frequency of the specimen. In this proposed work the residual stresses on the welded joints of the given specimen are analyzed through mechanical vibrations.

***Index Terms*— Welding, Vibration, Residual stress**

I. Introduction

Welding is widely used for construction of many structures. Since welding is a process using locally given heat, residual stress is generated near the bead.Residual stresses are defined as the stresses which remain within a structure when all external loads or reactions are removed, hence they must be self-balanced within the structure itself.

It is well accepted that the residual stresses commonly arise from permanent changes in the shape of the body.The residual stresses generated during welding may hamper the functional efficiency of the component leading to failure of the engineering structures. It may also lead to brittle fracture of the welded structures causing enormous damage to resources and loss of human life. Residual stresses are the major constituents of a stress field around a crack which may lead to cracking. Tensile residual stresses reduce fatigue strength and corrosion resistance while compressive residual stresses diminish the stability limit. Also, while tensile residual stresses may initiate the failure due to fracture, the compressive residual stresses near a weld can reduce the capacity of the structural member in buckling and collapsing.

Some reduction methods of residual stress have been presented for example, heat treatment and shot peening techniques are used. However, those methods need special equipment and are time consuming. In this, we are proposing a new method for reduction of residual stress using vibration during welding.

II. Problem Definition

1. Earlier times heat treatment and shot peening are practically used for reduction of residual stresses. However, those methods need special tools and time consuming.
2. In this paper a new method for reduction of residual stresses using vibrational load during welding.
3. Estimation of residual stresses nearer to weld bead in two directions (i.e. Longitudinal and Transverse direction and on the bead).
4. Two thin plates are supported to supporting device and are butt welded by using Arc welding machine.
5. Residual stresses in the direction of bead is measured by using Multi channel strain indicator strain values are obtained.
6. These results are converted to stress values by hole drilling method, later on Finite element Method is used to compare the practical values in Ansys.

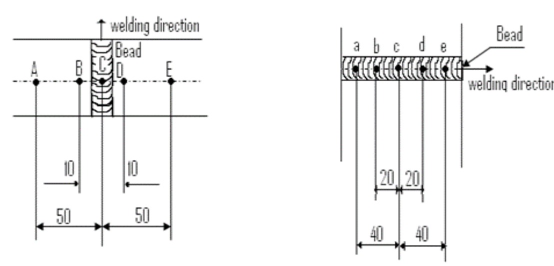

Fig. 1. Welding direction

III. Experimental Setup

Reduction of residual stress on both sides of the specimen using vibrational load is examined experimentally.

The Fig. 2, shows the specimen used in this experiment. Material of specimen is Mild steel(Is2062) Two thin plates are

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supported on to supporting devices by bolts as shown in fig.1. Specimens are vibrated by a vibromotor during welding specimens are butt-welded using an arc welding machine. In order to examine the effect on excitation frequency on reduction residual stress amplitudes of excitation frequencies are chosen as 70, 80, 84 and 90Hz. The frequencies are measured by the vibrometer. Size and shape of specimen made of mild steel for general structure (mm) in Fig. 3.

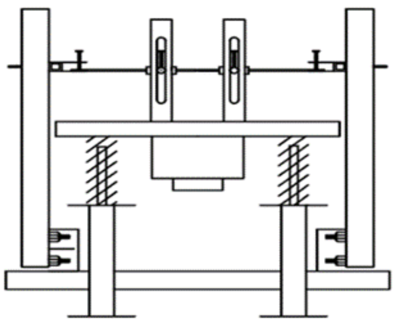


Fig. 2. Supporting device for welding

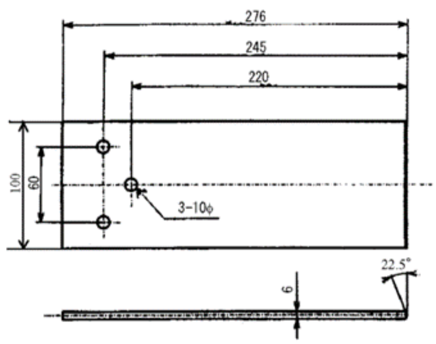


Fig. 3. Size and shape of specimen made of mild steel for general structure

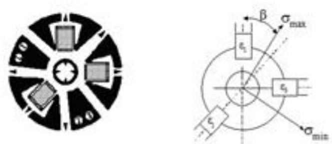
After completion of welding the specimens are taken to the multi-channel strain indicator for measuring strains. In this method, therefore, strain gauges in the form of a three element rosette are placed in the area under consideration. A through-thickness hole is drilled in the centre of the strain gauge rosette. In this way the residual stresses in the area surrounding the drilled hole are relaxed and the relieved radial strains can be measured with a suitable multi-channel strain gauge.

Fig. 4. Strain gauges are bonded to the specimens

Fig. 5. Strains are measured by multi-channel strain indicator

IV. Calculation

Hole drilling Method: According to this popular and well established method residual stress is determined by measuring the relieved radial strain when drilling a small through-hole into the weld plate. Two principal stresses,



$$\sigma_{max}, \sigma_{min} = \frac{\varepsilon_3 + \varepsilon_1}{4\bar{A}} \pm \frac{\sqrt{(\varepsilon_3 - \varepsilon_1)^2 + (\varepsilon_3 + \varepsilon_1 - 2\varepsilon_2)^2}}{4\bar{B}} \quad \text{Equation 1}$$

$$\beta = \frac{1}{2}\arctan\left[\frac{\varepsilon_1 + \varepsilon_3 - 2\varepsilon_2}{\varepsilon_3 - \varepsilon_1}\right] \text{ where:} \quad \text{Equation 2}$$

σ_{max}, σ_{min} - Maximum and minimum principal stresses (Pa);

ε_1, ε_2, ε_3 - Measured strains at gauges 1, 2 and 3;

$\bar{A}$ and $\bar{B}$ - Constants (material and rosette dependant);

β - Angle between the measured principal stress and gauge 1.

V. Observations

From the above experimental setup, through the multi-channel strain indicator the following are the observations of residual stresses values are shown in tables.

TABLE I
RESIDUAL STRESS VALUES AT DIFFERENT FREQUENCIES AT FIRST SIDE PERPENDICULAR TO THE BEAD

DISTANCE	RESIDUAL STRESS (Mpa)				
	WITHOUT	70 HZ	80 HZ	84Hz	90Hz
-50	73	180	53	35	115
-30	230	88	150	76	224
-10	270	112	157	98	170
0	446	218	360	201	562
10	270	112	157	98	170
30	230	88	150	76	224
50	73	180	53	35	115

TABLE II
RESIDUAL STRESS VALUES AT DIFFERENT FREQUENCIES AT FIRST SIDE PERPENDICULAR TO THE BEAD

DISTANCE	RESIDUAL STRESS (Mpa)				
	WITHOUT	70HZ	80HZ	84Hz	90Hz
-50	174	12	13	7	269
-30	215	122	150	119	328
-10	391	199	183	128	397
0	397	219	275	137	434
10	391	199	183	128	397
30	215	122	150	119	328
50	174	12	13	7	269

TABLE III
RESIDUAL STRESS VALUES AT DIFFERENT FREQUENCIES AT FIRST SIDE PERPENDICULAR TO THE BEAD

DISTANCE	RESIDUAL STRESS (Mpa)				
	WITHOUT	70 HZ	80 HZ	84HZ	90Hz
-50	95	29	87	26	76
-30	137	99	167	77	147
-10	236	128	213	106	223
0	318	317	307	261	369
10	236	128	213	106	223
30	137	99	167	77	147
50	95	29	87	26	76

VI. RESULTS

From the above observations tables the residual values are analyses and are shown in graphs.

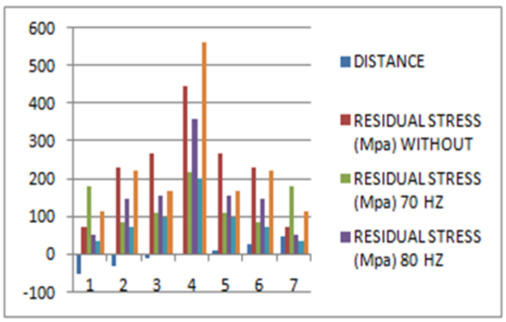


Fig. 6. (Graph-1) Residual stress values at different frequencies at first side perpendicular to the bead

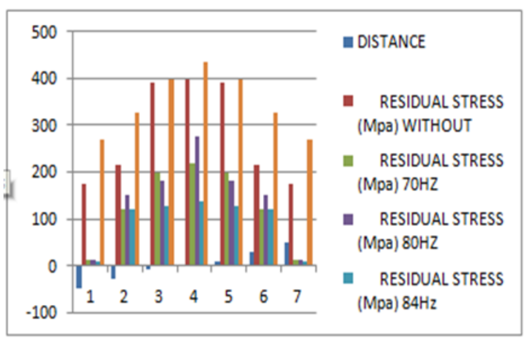


Fig. 7. (Graph-2) Residual stress values at different frequencies at first side parallel to the bead

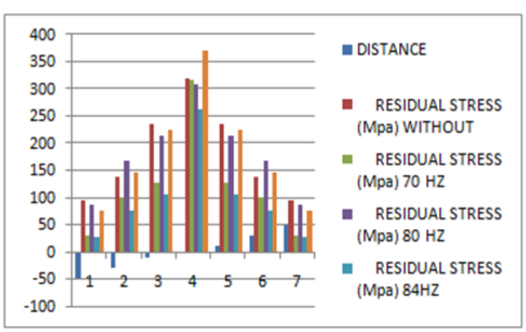


Fig. 8. (Graph-3) Residual stress values at different frequencies at second side perpendicular to the bead

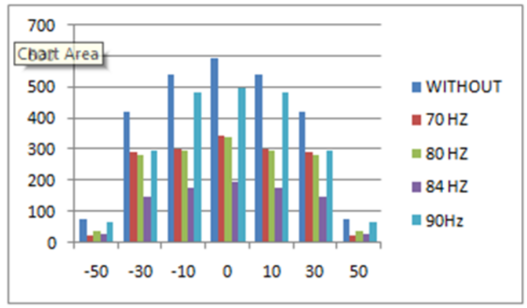


Fig. 9. (Graph-4) Residual stress values at different frequencies at second side parallel to the bead

VII. CONCLUSION

1. A method for reduction of residual stresses vibrational load during welding is proposed. The proposed method is examined experimentally for some conditions. Two thin plates are supported on the supporting device and butt welded.
2. By doing the experimentation the natural frequency was found by using at 70Hz, 80Hz, 84Hz. For these frequencies residual stresses greatly reduced at natural frequency of 84Hz.
3. Second-side welding process was performed for which the residual stress slightly increased from 77Mpa to 78Mpa.
4. Hence we can be concluded that the residual stresses can be greatly reduced by maintaining frequency of forced vibration nearer to the natural frequency of the specimen.

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