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FINITE ELEMENT ANALYSIS OF RESIDUAL STRESSES IN WELDED JOINTS

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ABSTRACT

Welding process is one of the widely used joining and fabrication process used in industrial and structural applications. 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. Residual stress remains as a single largest unknown factor in industrial damage situations. Residual stresses have a significant effect on corrosion, fracture resistance; creep and corrosion/fatigue performance and reduction of these stresses are normally desirable. Welding process induces high residual stress field, which combines with stresses resulting from in-service loads, strongly influencing in-service behavior of welded components. When compared to 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. Residual stress in weld elements can be reduced by applying heat treatment and peening techniques. However these methods need special equipment and are time consuming. In the present project work, a novel method for reducing the residual stresses using vibration during welding is proposed. For this mechanical vibrations will be used as vibration load. The plates to be welded will be held fixed and excited by an external source such as motor at lower frequencies which are closer to the natural frequency of the specimen plates. In the proposed work, Finite Element Method (FEM) will be used for assessment of welding residual stresses and subsequent life assessment. Finite element method (FEM) will be used to get the effective vibration equations and theoretical values. For this, simulation software like ANSYS has been used. A Finite Element Model has been generated and thermal analysis, structural analysis, modal analysis; Harmonic analysis has been carried out. It is observed that, when the excited frequency is closer to the natural frequency of the specimen plates, the residual stresses are minimized compared to the specimen plates which are welded without any vibration.

Keywords: FEM, ANSYS, Fabrication, welding

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 [1].

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 [2].

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 [3]. Some reduction methods of residual stress have been presented for example, heat treatment and shot penning 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 [4].

PROBLEM DEFINITION

1. Earlier times heat treatment and shot penning 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 vibration 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).

3. Experimental setup

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

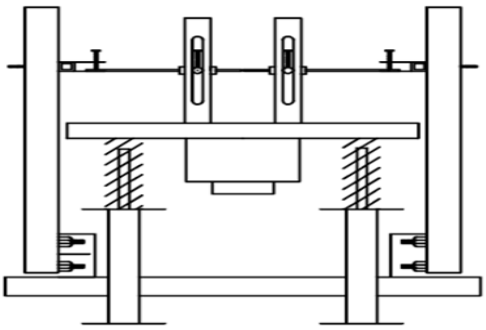

Fig.1: Supporting device for welding.

Fig. 1 shows the specimen used in this experiment. Material of specimen is EN8 Two thin plates are supported on to supporting devices by bolts as shown in fig.1[5]. 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 [6]. The frequencies are measured by the vibrometer. Size and shape of specimen made of mild steel for general structure (mm) in fig 2. .

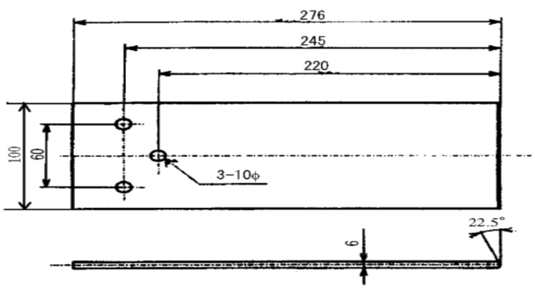

Fig.2: Size and shape of specimen made of EN8 steel for general structure

Fig3: welded specimen plates without vibration load

Fig 4: welded specimen plates with vibration load

OBSERVATIONS

From the above experimental setup, after completion of welding the plates due to the weld bead strength the FEM analysis is done following are the observations of residual stresses values are shown in tables.

Table1: Residual stress values at different frequencies at first side perpendicular to the bead.

First side perpendicular to the bead					
Distance in mm	Without	75HZ	80HZ	85HZ	90HZ
-30	86	28	54	10	75
-10	144	50	95	24	100
0	288	104	270	35	250
10	144	50	95	24	100
30	86	28	54	10	75

Table 2: Residual stress values at different frequencies at first side along the bead.

First side along the bead					
Distance in mm	Without	75HZ	80HZ	85HZ	90HZ
-30	45	55	70	27	151
-10	77	56	95	44	177

0	115	129	100	70	282
10	77	56	95	44	177
30	45	55	70	27	151

Table 3: Residual stress values at different frequencies at second side perpendicular to the bead.

Second side perpendicular to the bead					
Distance in mm	Without	75HZ	80HZ	85HZ	90HZ
-30	140	94	170	79	148
-10	237	126	213	105	220
0	321	315	310	262	369
10	237	126	213	105	220
30	140	94	170	79	148

Table 4: Residual stress values at different frequencies at second side along to the bead.

Second side along the bead					
Distance in mm	Without	75HZ	80HZ	85HZ	90HZ
-30	420	296	281	150	300
-10	550	300	300	175	479
0	590	350	340	200	500
10	550	300	300	175	479
30	420	296	281	150	300

FINITE ELEMENT MODEL

The welding process of a butt-weld joint of two EN8 steel plates with the dimensions shown in Fig.1 was simulated. Due to high temperature and stress gradients near the weld, the finite element model has a relatively fine mesh in both sides of the weld center line. The eight-node brick elements with linear shape functions are used in meshing the model. To simulate the moving heat source it is necessary to model the heat source during each time increment. In this analysis the moving heat source is simplified by assuming the welding arc stayed at an element with a constant specific volume heat generation, and then moved to the next element at the end of the load step as the welding was finished. The element type SOLID70, which has a single degree of freedom, was used for the thermal analysis. For the structural analysis the element type SOLID45, with three translational degree of freedom at each node, was used.

RESULTS AND ANALYSIS

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

CONCLUSION

Thermal and Structural analysis are used to find out the residual stresses in the EN8 Steel weldments .

The residual stresses was found to be 142MPa for the front side and 151MPa for the back side of the weldment.

Modal analysis reveals that the natural frequency of the weld specimen to be 85.757, 464.589 and 984.513Hz for the first three modes.

For the frequencies between 75Hz to 90Hz coupled thermo-mechanical analysis was performed and it is found that residual stresses are greatly reduced at frequency of 85Hz.

For the front side welding the residual stresses was greatly reduced to 113 MPa at frequency nearer to the natural frequency of the plate.Back side welding process was performed for which residual stresses are 114MPa

It is observed that weld bead quality of the specimen welded nearer to natural frequency was good compared to other specimen plates.

Hence it can be concluded that the residual stress can be greatly reduced by maintaining frequency of forced vibration nearer to the natural frequency of the specimen and increasing the welding speed.

FUTURE SCOPE

The present work can be extended to other metals also to increase the weld strength by reducing the residual stresses.

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