VOL. 11, NO. 18, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

STRENGTH IMPROVEMENT OF WELDED JOINT BY USING RANDOM 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 behaviour of weld components. A new method is proposed to reduce non uniformity of molten metal occurring because of pores and residual stresses during welding process. In the proposed model work has been made to attain the uniformity of molten metal imparting vibrations to the work piece which in turn transferred to the molten metal of the weld bead. This results in uniform molten metal with minimal formation of voids or gaps, resulting in increase of strength and hardness of weld bead. Vibration techniques have been used in welding for improving the mechanical properties of metals in the last few decades. In the present, vibrating table setup has been used for inducing random mechanical vibrations into the weld pool during welding. The designed vibratory setup produces the random vibrations in terms of rpm given to the work piece by cam shaft mechanism. An increase in the hardness of the weld pieces in the heat affected zone (HAZ) and weld bead has been observed. The above mechanism is responsible for the improvement in ultimate tensile strength of work pieces welded with vibratory setup compared to without vibration and with vibrations during welding.

Keywords: welding, residual stress, heat treatment, peening, random mechanical vibrations, weld pool, hardness, heat affected zone, ultimate tensile strength.

INTRODUCTION
Welding is extensively used in the fabrication industry including ships, offshore structures, steel bridges, nuclear power plants and pressure vessels. Welding is a process using locally given heat as a result of thermally induced plastic deformation during the welding process, the internal stresses namely residual stresses remain in the component and structures. The residual stress distribution and distortion in weld joints and structures are strongly influenced by the parameters like structural(Geometry and joint type), material parameters(physical and mechanical properties) and welding process parameters (current, voltage, arc travel speed).The residual stresses has a strong impact on weld deformation, fatigue, creep, fracture. Therefore, it is important to monitor and control the residual stresses. For this reason, it is important to have reliable methods for the measurement of these stresses and to understand the level of information they can provide for the improvement of fatigue strength of weld bead.

Welding defects
- To relieve some of the residual stresses caused by the welding process, the structure deforms, causing distortion
- Porosity will be formed if welding is done with dirt surfaces
- Welding of high coefficient of expansion materials without preheating causes surface cracks.
- Due to magnetic arc blow spatter may form.
- Incorrect torch angle may cause crater defect which is a spherical depression at the end of the weld bead.

The major defects are porosity, spatter, blowholes, residual stresses etc. In these porosity, residual stresses majorly reducing the fatigue strength of the weld bead and leading to the distortion of the weld bead. So majorly concerning the reduction of residual stresses in the weld bead and improving the strength and durability of weld bead.

Methods for controlling the stresses
Welding for critical application frequently demands relieving residual stresses of weld joints by thermal or mechanical methods. Relieving of residual stresses is primarily based on the fact of releasing the locked-in strain by developing conditions to facilitate plastic flow so as to relieve stresses.

a) Thermal method
It is based on the fact that the yield strength and hardness of the metals decrease with increase of temperature which in turn facilitates the release of locked in strain thus relieves residual stresses. Reduction in residual stresses depends "how far reduction in yield strength and hardness take place with increase temperature". Greater is softening more will be relieving of residual stresses. Therefore, in general, higher is temperature of thermal treatment of the weld joint greater will be reduction in residual stresses.

b) Mechanical method
Based on the principle of relieving residual stresses by applying external load beyond yield strength level to cause plastic deformation so as to release locked-in strain. External load is applied in area which is expected to have peak residual stresses.

c) Mechanical vibration of a frequency close to natural frequency

Mechanical Vibration of a frequency close to natural frequency of welded joint applied on the component to be stress relieved. The vibratory stress can be applied in whole of the components or in localized manner using pulsators. The development of resonance state of mechanical vibrations on the welded joints helps to release the locked in strains so to reduce residual stresses.

LITERATURE REVIEW

The cooling rates in arc welding are faster than other welding, so that a lower value of maximum hardness in the welded joint is expected. In vibratory welding, stirrer produce a disturbance in weld pool during solidification. After completion of nucleation, the solidification process will continue with nucleus growth. Increasing the growth rate will reduce the grain size of metal. heat source interacts with the material, the severity of thermal excursions experienced by the material varies from region to region, resulting in three distinct regions in the weldment.

The effects of the vibratory weld conditioning on the residual stress and distortion in multi pass girth-butt welded pipes and also discussed about how vibratory weld conditioning reduce the residual hoop stresses at the outer surface and the radial distortion significantly. The improvement of welded structure's properties fatigue damage resistance, stress corrosion cracking and fracture resistance due to vibratory weld conditioning [1].The effect of vibratory stress on the welding microstructure and residual stress distribution of steel welded joints [2]. The applications of vibration during submerged arc multi-pass welding to improve welded valve quality. The reduction in residual deformation and stress due to vibratory weld conditioning[3].Method for reducing the residual stress using random vibrations during welding[4].Improvements on yield strength, ultimate tensile strength and breaking strength on shielded metal arc welded joints due to vibratory conditions like longitudinal vibration and frequency. The drop in percentage of elongation due to the vibratory conditions [5].The optimization of parameters in butt weld for calculating minimum residual stresses [6].The grain refinement occurred and the mechanical properties were improved in castings due to the application of vibration during casting. It has been established that both 'during-welding' and 'post-weld' vibration treatments can reduce residual stresses. It has also been established that uniaxial stress causes a change in the grain orientation, and vibratory stress causes grain refinement in cast irons. From the above findings, it was postulated that, like uniaxial stress, vibratory stress would influence grain orientation during the process of cooling. It was assumed that there might be a relationship between the reduction in residual stresses and change in the grain orientation and grain refinement. This study was carried out to explore the relationship between the residual stresses, grain structures and change in hardness of the materials [7].

EXPERIMENTATION

With an aim of improving the mechanical properties of weld joints through inducing of favourable changes in the weld microstructures, an auxiliary vibratory set up capable of inducing mechanical vibrations into the weld pool during manual metal arc welding is designed and developed. Different frequencies and with different amplitude are applied along the weld length, just trailing behind the welding arc so that weld pool could be mechanically stirred in order to induce favourable micro structural effects. This setup produces the required frequency with the amplitude in terms of voltages.

Vibration equipment design:

We have used Pro-E to model the equipment

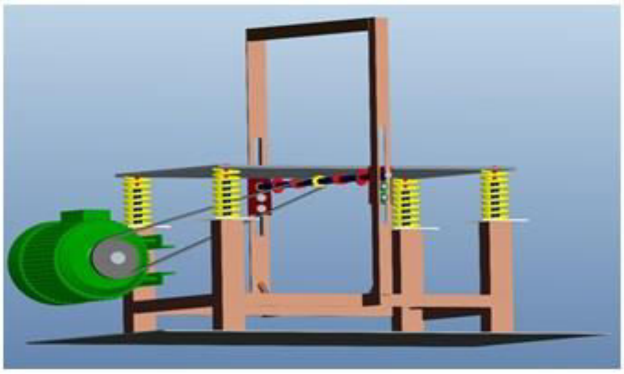

Figure-1. Vibratory table set-up.

Vibration equipment setup

A platform made of steel is used to place the specimen is equipped with four springs along each the corner as shown in Figure-1. The springs are fixed to four channels on four corners which are in turn supported by angles. The vibration platform is generated by cam and shaft mechanism. Four cams are welded at equal distances on the shaft and pulley is pinned at the center of shaft. The shaft is supported by two ball bearings-6202 to ensure free rotation. A belt drive is connected between pulley of shaft and pulley of 12V DC motor. Dimmer stat, voltmeter are attached to control motor to generate the vibrations.

Figure-2. Experimental setup.

Dimmer stat is connected to power source and connections from the dimmer stat are connected to the terminals of the DC motor. When power source is switched on, belt drive is driven by the motor. Then motion is transferred to the shaft by means of pulley fixed to the shaft, which in turn freely rotated by the ball bearings fixed at both ends of the shaft. The cams which are fixed to the shaft then hit the metallic plate alternatively in the order of 1-4-2-3.This process continues to generate vibrations on to the plate. Required voltage is given to the motor by dimmer stat by varying dimmer stat voltage between 0-240V.The actual voltage required for generating vibrations is between 90-120V.Rheostat is used to control the flow of current.

After creating required vibrational environment the work pieces(100mm*50mm*5mm) are placed on the work table by creating spot weld on both ends of the work piece to prevent movement of work pieces during welding. Then fixing required parameters for the experiment, arc welding is done to the faying surfaces of the work pieces. Initially welding is done to the work pieces without vibrational environment. Then vibrations at different RPM are generated and arc welding at each RPM is done.

The speed of motor, which in turn controlled by the dimmer stat is measured by the tachometer by placing a sensor on the motor. By creating vibrations during welding to the work pieces, uniform molten metal is flown all along the faying surfaces. The required work pieces are tested for the required mechanical properties like strength and hardness.
Below figures are welded at different RPM's.

Figure-3. Without vibrations.

Figure-4. Weld bead at 400 rpm.

Figure-5. Weld bead at 500-550 rpm.

Figure-6. Weld bead at 550-650 rpm.

RESULTS & DISCUSSIONS

Brinell hardness test

The work pieces with and without vibrations are tested to measure the hardness as shown in fig 4.1, 4.2, 4.3 &4.4. The work pieces are sized as per requirement of the test, for easy testing the work pieces are made smaller in size to suit for the equipment. Then the requirements for the test are made and procedure for the test is followed. Brinell hardness test is carried at two positions

a) Center of weld bead
b) HAZ

Table-1. Test showing results of Brinell hardness test.

	Without Vibration	With Vibration		
		At 400 RPM	At 500-550 RPM	At 550-650 RPM
On Weld Bead	4.8mm	4.7mm	4.6mm	3.7mm
Heat Affected Zone	5.3mm	5.2mm	5.1mm	4.9mm

Brinell hardness test calculations

Indenter Diameter (D) =10mm
Type of Indenter material: Steel Ball.
Load (P) = 3000 kgf
Formula:

$$BHN = \frac{2P}{\pi D\sqrt{D-\left(D^2-d^2\right)}}$$

1) Without Vibration:
i) On weld bead:
Indentation Diameter on weld bead (d) = 4.8mm

$$BHN = \frac{2\times3000}{\pi\times10\sqrt{10-\left(10^2-4.8^2\right)}}$$

BHN=156 kgf/mm2
ii) On Heat Affected Zone:
Indentation Diameter on Heat Affected Zone (d) = 5.3 mm

$$BHN = \frac{2\times3000}{\pi\times10\sqrt{10-\left(10^2-5.3^2\right)}}$$

BHN=126 kgf/mm2
2) With Vibration:
a) At 400 RPM
i) On Weld Bead:
Indentation Diameter on weld bead (d) = 4.7mm

$$BHN = \frac{2\times3000}{\pi\times10\sqrt{10-\left(10^2-4.7^2\right)}}$$

=163 kgf/mm2

ii) On Heat Affected Zone:
Indentation Diameter on Heat Affected Zone (d) = 5.2 mm

$$BHN = \frac{2\times3000}{\pi\times10\sqrt{10-\left(10^2-5.2^2\right)}}$$

=131 kgf/mm2

Similarly at different speeds for different indentation diameter on weld bead as well as on heat affected zone are performed and listed in table 4.2.

Strength calculations and Results:
Ultimate Tensile Strength (UTS) = Hardness*K
For mild steel (K) =3.38
Percentage Increase in Strength

$$\frac{\text{(Strength with vibration}-\text{Strength without vibration)}}{\text{Strength without vibration}}\text{ X }100\%$$

On weld bead
a) Without vibration:
UTS =156 X 3.38
UTS = 527.28 MPa
b) With vibration:
i) At 400 RPM
UTS =163 X 3.38
UTS = 550.94 MPa
Percentage Increase in Strength

$$=\frac{550.94-527.8}{527.8}\times100\% = 4.48\%$$

b) On HAZ:
Without vibration;
UTS =126 X 3.38
UTS = 425.88 MPa
With vibration;
i) At 400 RPM
UTS =131 X 3.38
UTS = 442.78 MPa
Percentage Increase in Strength

$$=\frac{442.78-425.88}{425.88}\times100\% = 3.81\%$$

Similarly, for all different RPM'S strength and percentage increase in strength is calculated and listed in Table-3.

Figure-7. Without vibrations.

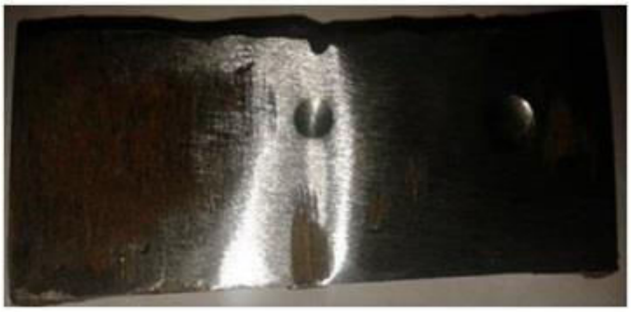

Figure-8. With vibrations (400-450rpm).

Figure-9. With vibrations (500-550 rpm).

Figure-10. With vibrations (550-650 rpm).

Table-2. Maximum hardness increase in Brinell hardness numbers.

	Without Vibration BHN	With Vibration BHN		
		At 400 rpm	At 500-550 rpm	At 550-650 rpm
On Weld Bead	156	163	170	176
Heat Affected Zone	126	131	137	149
Maximum increase in hardness on Bead	-	4.5%	9.0%	12.82%
In HAZ	-	4.0%	8.7%	18.2%

Table-3.UTS at different RPM.

S.NO	RPM applied	Hardness on Weld bead H_1 (Kgf/mm²)	UTS on weld bead = H_1 *K(MPa)	Increment in strength	Hardness in HAZ H_2 (Kgf/mm²)	UTS in HAZ $=H_2K$ (MPa)	Increment in strength
1	0	156	527.28	-	126	425.88	-
2	400	163	550.94	4.48%	131	442.78	3.81%
3	500-550	170	574.6	8.97%	139	463.06	8.95%
4	550-650	269	909.22	72.42%	147	503.62	18.35%

CONCLUSIONS

In this work the possibility of prediction of selected mechanical properties of mild steel by means of Brinell hardness tests was verified. It was shown that from all correlation relations established in the work it is practically applicable only the correlation between hardness HB and UTS (on the basis of known values HB, it is possible to predict the strength). Results of work clearly shows that, for the prediction of mechanical properties of mild steel with higher accuracy the influence of the micro structural parameters in the correlation equations is necessary to include.

The following are the conclusions made from the experimentation:

- The percentage increase in the hardness of weld bead with vibrations is improved, when compared to without vibrations.
- By the correlation between strength and hardness there is an increment in ultimate tensile strength with vibrations applied when compared to without vibrations.

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