Experimental Investigation on the Effect of Post Weld Heat Treatment on the Mechanical Properties of SS304 Weldment Fabricated by Vibratory Welding Process

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Abstract - *In this work, the mechanical properties of the weldment are improved by improving the density of molten weld metal by using vibratory welding process. Two types of weldments are prepared in this work; one made of vibratory arc welding and another made of normal arc welding process. The specimens are made of SS 304 and welded using the electrode NC 38, selected according to the standard ASME/AWS A 5.4 E308-16. They are then subject to destructive techniques like impact test and tension test following the ASTM standards E23 and E8/E8M-11 respectively. The measured properties of these weldments with and without heat treatment are compared with those of base metal, thus facilitating the measurement of residual stresses quantitatively and their relieving. The obtained results highlight the selection of proper heat treatment method for the improvement of properties and the proposed vibratory welding process is beneficial in improving the root strength of the weldment.*

Keywords*:* *vibratory arc welding, heat treatment, mechanical testing, ASTM standards*

I. INTRODUCTION

Welding plays major role in the fabrication in many engineering applications. But the suitability of the process affects the strength of the weldment during its service conditions. Austenitic steels are used in many applications owing to its strength and corrosive resistance. Lot of research has been carried out on the austenitic steels to study the various process parameters and efficiency of welding techniques. Juang et. al [1] adopted the modified taguchi method to study the effect of process parameters for optimizing the weld pool geometry. Zacharia et. al [2] performed the simulation of heat flow and fluid flow in weld pool in gas tungsten arc welding and laser beam welding of SS 304 under transient conditions. Zhu and Chao [3] studied the variation of residual stress and transient temperature in friction stir welding of SS 304. Numerical simulations for three dimensional non-linear thermo-mechanical analysis using finite element method and Neutron diffraction technique were implemented in this study.

Jun Yan et. al [4] investigated the suitability to weld SS 304 plates tungsten inert gas welding, laser welding and laser-TIG hybrid welding. X-ray diffraction technique is implemented to study the phase composition and microstructure is studied using electron microscopy. Kahraman et. al [5] studied the effect on interface in explosive welding of SS 304/titanium plates at different explosive ratios. Microstructure at the interface is studied using the optical and electron microscopy. Ahmet et. al [6] investigated the bonding ability of copper and steel with explosive welding for different standoff distances and explosive ratios. Root strength was determined by performing the bending test and microstructures are studied. Okagawa et. al [7] studied the influence of nitrogen on SS 304 weldments.

In this work, effect of post weld heat treatment on the mechanical properties of SS 304 weldments made of normal arc welding and vibratory welding is studied.

II. SPECIMEN PREPARATION

In this work, the specimens to be tested are prepared according to the respective ASTM standards. The base material used is SS 304. Following tests are performed on the raw and welded specimens.

1) ***Tension Test***: The specimens are prepared according to the ASTM standard E8/E8M-11. The shape and size of the geometry are given in fig. 1.

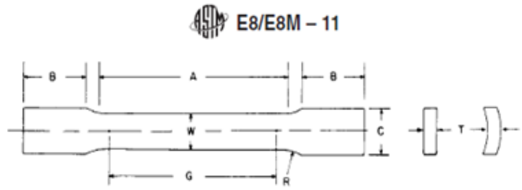

Fig.1 Tension test specimen

In this work, Specimen-5 dimensions according to the E8/E8M-11 are considered.

Gauge length -100 mm

Length of reduced section - 120 mm

Fillet radius - 25 mm

Length of the gripping section - 75 mm Width of the grip section - 25 mm

Width in gauge length - 20 mm
Thickness of the specimen - 5 mm

2) ***Charpy Impact test***

In this work, the specimens are prepared according to the standard ASTM E23, ISO 148-1 or EN 10045-1. According to this standard, three specimens are suggested – Type A, B & C. In this work, type-A specimen is adopted as shown in fig .2.

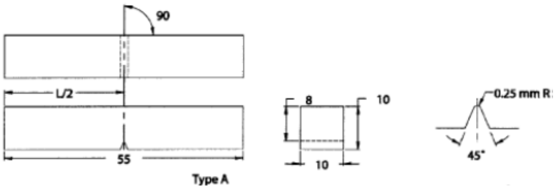

Fig. 2. Impact test specimen

Initially SS 304 plates are taken and grinded properly, since the surface finish effects the mechanical properties obtained in mechanical testing. Later the plates are cut according to the required size for tension and impact tests as mentioned in fig.1 and fig.2 respectively. After cutting the plates, they are welded following the normal arc welding process and proposed vibratory welding process.

III. WELDING PROCESS

According to the Boiler codes, the suitable electrode for the welding of SS 304 is found to be NC 38, which is used in general applications. The specimens are prepared by dividing the total gauge length into two equal parts. These individual parts are joined by welding process.

1) ***Normal arc welding process***

Using normal welding process, the base metals are welded.

2) **Vibratory arc welding process**

In the normal welding process, the density of material in the weld pool is affected by various welding parameters like weld speed, depth of penetration, arc gap, intensity of current etc., With an aim of improving the mechanical properties of weld joints through inducing of favorable 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 favorable microstructural effects. This setup produces the required frequency with the amplitude in terms of voltages.

Construction:

The vibratory table is fabricated by welding the equal dimensional channels on the four sides. Then we have welded four small square plates as shown in the below figure. Then four cylindrical rods are welded to the four square plates and four springs are coiled around the four cylindrical rods. The edges of the springs are welded to the mounted table as shown in the fig. 3.

Fig. 3 Vibratory table setup

The motor is located on the table as shown in fig. 3 to meet the required rate of vibration. Fabricated material is located at the edge of the table with the support of two C-clamps so that due to vibration there will not be any deviation of the specimen.

The base plates are fixed between the clamps and the motor is switched on. With the help of cams provided the plates starts vibrating such that the amplitude of vibration is adjusted to 2.1mm/sec. To absorb the excessive vibrations, the plate is supported on the springs at four corners as shown in the fig.3. Now the welding torch is made to move slowly over the edges, which are to be welded. Because of the vibrations, gap between the edges is completed filled with more liquid metal thereby increasing the density of the molten metal in the weld pool. After welding the specimens are as shown in fig. 4.

Fig. 4 Welded specimen for Tension Test

Fig. 5 Welded specimen for Impact Test

Finally the welded specimens are finished by grinding process before testing.

IV. HEAT TREATMENT & TESTING

The weldments are heat treated in the furnace to improve the mechanical properties like weld strength, hardness, toughness etc., In this work, we have chosen the following methods:-

- Annealing
- Normalizing
- Quenching (water)

TABLE I
SPECIFICATIONS OF THE FURNACE

Digital Heat Treatment Furnace Specifications (BSPIL-HTF-2200)	
Temperature range	30 to 1000^0 C
Measuring and controlling device	3.5 digit LED Temperature indicating controller
Internal chamber size	30 cm x 15 cm

Three types of specimens are tested in this work:

1. Base metal
2. Untreated Welded specimens
3. Heat treated welded specimens

The specimens prepared are tested on Computerized Universal Testing machine and Impact testing machine to determine the % elongation, ultimate tensile strength and energy absorbed respectively.

V. RESULTS AND DISCUSSION

(i) Energy absorbed

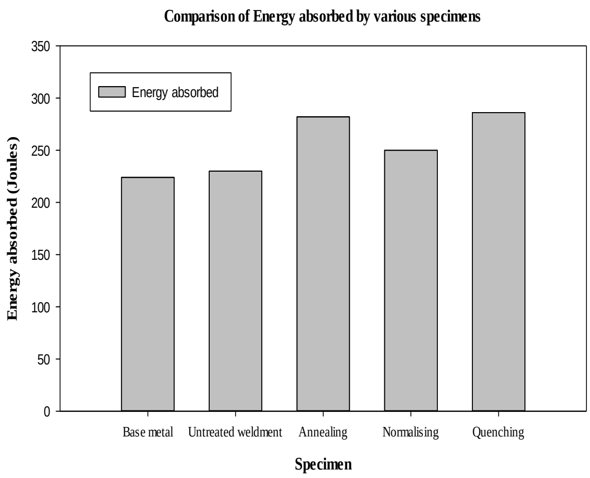

Fig. 6 (a) Normal welding specimen

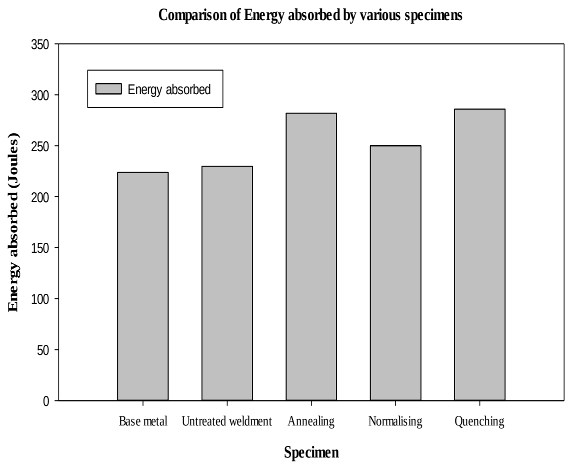

Fig. 6 (b) Vibratory welding specimen

Fig.6(a) and fig.6(b) represents the comparison of energy absorbed by various specimens prepared by normal welding and vibratory welding process respectively in impact test. From the graphs, it has been observed that the quenched specimen has absorbed more energy in impact loading. This indicates that the fracture toughness is high resulting in need for much higher loads for a crack to propagate. It also that quenched specimen has higher fracture toughness than base metal. This indicates the quenched specimen can absorb more energy before fracture than base metal.

(ii) % Elongation

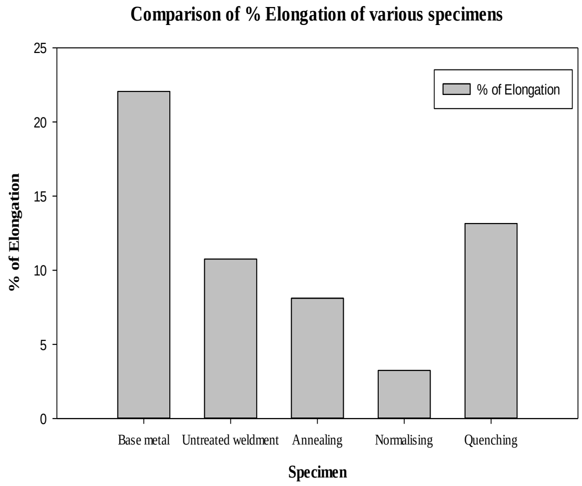

Fig. 7 (a) Normal welding specimen

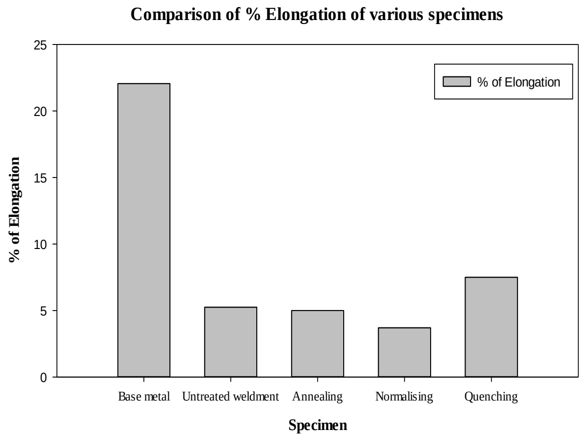

Fig. 7 (b) Vibratory welding specimen

Fig.7(a) and fig.7(b) compares of % elongation of various specimens. It has been observed that, of all the welded specimens, quenched specimen has highest % elongation. This indicates that the quenched specimen has high ductility and can undergo sufficient plastic deformation before fracture (breaking into pieces). Also normalized specimen has least % elongation. This indicates that the normalized specimen fails suddenly in a brittle fashion without much plastic deformation. When ductility is the important factor in the case of welded joints, quenching is the suitable heat treatment process.

(iii) Ultimate tensile strength

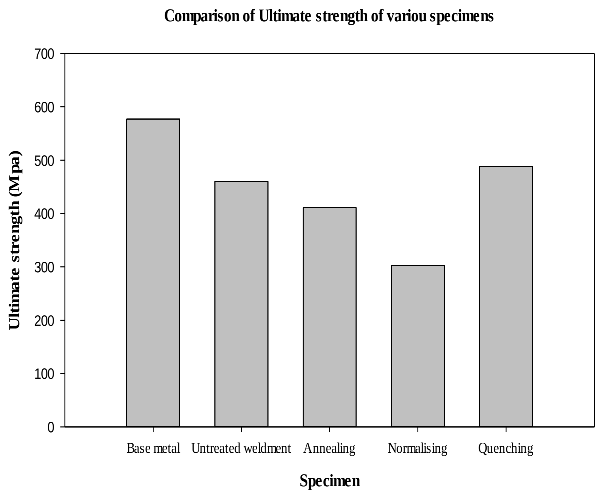

Fig. 8 (a) Normal welding specimen

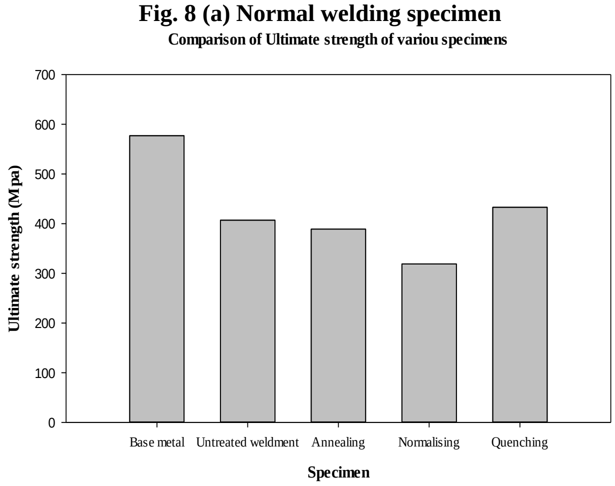

Fig. 8(b) Vibratory welding specimen

Fig.8(a) and fig.8(b) compares the ultimate strength of various specimens. Next to base metal, the quenched specimen is having higher ultimate tensile strength. This indicates that the quenched specimen can undergo larger deformations before necking. This supports the comments written for fig.7(a) and fig.7(b).

VI. CONCLUSION

In this work, the impact strength and ultimate strength of SS 304 specimens are compared under various conditions. The specimens include base metal, untreated weldment (butt joint) and treated weldments. The weldments underwent destructive testing and the following conclusions are drawn.

- The impact strength of quenched weldment is higher than all the specimens. Hence to avoid the fast fracture, weldment is to be quenched before setting for any application.
- The % elongation and ultimate strength of the quenched specimens are higher than other treated and untreated weldments. This indicates that the quenched specimen can undergo larger plastic deformations; which enables the engineer to take preventive measures before the crack initiates in a material.
- If the vibrations created in the table and welding parameters are controlled properly, then the density of molten weld pool can be further increased which results in better results.

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