Investigation on Microstructural and Micro Hardness of Microwave Welded Joint of EN-31

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Abstract - Welding is generally used as a manufacturing technique for joining two similar or dissimilar work pieces. A total of three stages of experiments were carried out on different EN-31 metal pieces to find out the best possible welding methods which could maximize the hardness of welding zone. The stages conducted have been divided into three groups. The first stage of experiments was conducted to study the oxyacetylene gas welding process in detail for the purpose of identifying the hardness of welding zone. In the second stage of experiments, welding of the EN-31 carried out by TIG welding. In the third stage of experiments, an alternative welding technique has been employed for joining of EN-31 i.e. Microwave welding. It can be concluded that width of weld bead is less in microwave welding when compare with oxy-acetylene welding and TIG welding, then amount of volatilization of carbon and other particles will less and this reduces the chances porosity. The minimum reduction in hardness of weld bead i.e. 34 HRC as compared to base metal hardness i.e. 63 HRC is noted at microwave welding. Scattered porosity defects occurred due to volatilization of carbon and ferrous particle during oxy- acetylene welding and TIG welding. The level of welding defects is low in Stage-III. Thus it is suggested to use microwave welding rather than oxy-acetylene gas welding and TIG welding in order to minimize the defects.

Key Words: Microwave welding, TIG welding, Gas welding, EN-31, Porosity.

I. INTRODUCTION

Welding is the primary technique used for joining structural components. Welding is practiced in almost every industry, and it is used extensively in civil construction, shipbuilding, railways, cars, aero planes, pipe lying, and boiler and nuclear plant component fabrication. It is also extensively used for the manufacture and repair of machine tools, jigs and fixtures, farm equipment, mining and machinery. Therefore, welding plays a crucial role in determining the cost and quality of finished products and structures. As a result of a history of thermal cycling and its attendant micro structural change, a welded joint may develop various discontinuities also known as welding defects. The welding defects can also be caused by inadequate or careless application of established welding technologies or by substandard operator training. The welded components must be either reworked or scrapped whenever welding defects occurred. This reduced productivity and increase cost of the product. Improper welding can results in in-service failures and loss of human life if left undetected.

Microwave radiation is a rapid and highly specific means of heating materials. Microwave heating has been used in many applications successfully, such as cooking of foodstuffs, chemical synthesis, and ceramics sintering and medical therapy. In the area of material technology, microwave heating has been used for vulcanizing rubber, processing of materials, joining and welding plastic parts, metallic parts, and polymerisation.

Teawon Kim et al. (2014) microwaves heat materials fast and efficiently via direct energy transfer, while conventional heating methods rely on conduction and convection. Carbon-based solid materials are suitable for microwave-heating due to the delocalized pi electrons from sp2-hybridized carbon networks. In this perspective review, research on the microwave heating of carbon-based solid materials is extensively investigated. Amit Bansal et al. (2013) fabricated the mild steel–mild steel (MS-MS) joints through microwave hybrid heating (MHH). The XRD spectrum of the developed joints shows substitution type of solid solution form in the joint zone. The back scattered electron (BSE) images of the joint obtained by SEM show complete melting of powder particle and consequently diffusion bonding takes place between the substrate and the powder particle. M. S. Srinath et al. (2012) work complements the experimental results of the microwave heating of bulk copper in a multimode microwave applicator. In electromagnetic processing, thermal dissipation in the bulk metal may be attributed to resistive heating, dielectric and magnetic losses. This dissipative mechanism is coupled to the fields by the conductivity, permittivity and permeability of the metal. The model has been created for heating of the bulk metal in a microwave oven by considering the radio frequency of the microwaves. Shantanu Das et al. (2012) successfully welding bulk metals and dissimilar metals by microwave radiation, by using metal powder particles in the weld zone. they have tried to explain the insight of electromagnetic field penetration into spherical conductive powder particles and its spatial oscillatory distribution.

II. METHODOLOGY

A total of three stages of experiments were carried out on different EN-31 metal pieces to find out the best possible welding methods which could maximize the hardness of welding zone. The stages conducted have been divided into three groups. The first stage of experiments was conducted to study the oxyacetylene gas welding process in detail for the purpose of identifying the hardness of welding zone. In the second stage of experiments, welding of the EN-31 carried out by TIG welding. In the third stage of experiments, an alternative welding technique has been employed for joining of EN-31 i.e. Microwave welding. The oxy-acetylene gas welding process parameters are listed in Table 1:

Table 1: Oxy-Acetylene Welding Process Parameters

Sr. No.	**Process Parameter**	**Type/Value**
1	Type of welding	Oxy-acetylene gas welding
2	Welding technique	Leftward
3	Type of joint	Single ‘U’ butt joint
4	Filler material	Mild steel
5	Diameter of filler rod (mm)	1
6	Flame temperature	3500^0 C

The third stage of experiments was carried out by using microwave welding methods for analyzing hardness of welding zone. A modified 1000W domestic microwave oven was used for microwave heating experiments. The oven was modified so that the magnetron could be operated continuously on reduced power. Test specimens of filled EN-31 plate (125mm x 22mm x 0.6mm) were oriented vertically in the centre of the oven turntable using a block of ceramic foam as support. The welding process parameters which were used in this stage of experiments are shown in Table 3.

The TIG welding process parameters which were used in this stage of experiments are shown in Table 2.

Table 2: TIG Welding Process Parameters Used in Stage – II

Sr. No.	**Process Parameter**	**Type/Value**
1	Type of welding	TIG
2	Welding technique	Leftward
3	Type of joint	Single ‘U’ butt joint
4	Filler material	Mild Steel
5	Diameter of filler rod	2.0 mm
6	Electrode diameter	2.0 mm
7	Flame temperature	3200^0 C

Table 3: Microwave Welding Process Parameters Used in Stage – III

Sr. No.	Process Parameter	Type/Value
1	Type of welding	Microwave welding
2	Type of joint	Single ‘U’ butt joint
3	Filler material	EN-31 powder
4	Width of filler	0.5 mm
5	Bonding material	Epoxy resin
6	Processing time	10 o 14 minutes

III. RESULT AND DISCUSSIONS

In the first stage of experiments, the oxy-acetylene welding process and its parameter were employed for the welding of EN-31 were studied and analyzed. In the second stage of experiments, the welding of EN-31 was carried out by TIG welding process parameters. In the third stage of experiments, EN-31 was welded by Microwave Welding method. Fig. 1 shows the weld bead appearance in different stages of experiments conducted.

Stage-I Stage-II Stage-III

Fig. 1: Weld Bead in Different Stages of Experiments

It can be observed that the width of weld bead in Stage - I was 4.5 to 6.2 mm which was greater than obtained in Stage -II and Stage -III because of left-hand technique and single ‘U’ butt joint was used for welding. In the second stage of experiments, the width of weld bead was 2.5 to 3.7 mm which was less than width of weld bead obtained in Stage -I because TIG welding technique was used. The area covered by oxy-acetylene flame was greater than the area covered by electrode in TIG. In third Stage of experiments, the width of weld bead is 0.5 to 0.8 mm which was less than obtained in Stage -I and Stage -II. The area covered by oxy-acetylene flame and TIG welding was greater than the area covered by Microwave welding.

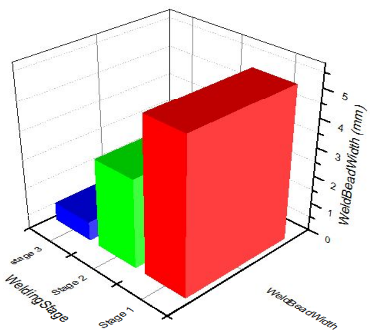

Fig 2: Histogram of Weld Bead Width

Thus it can be concluded that if width of weld bead is less, then amount of volatilization of carbon and other particles will less and this reduces the chances porosity. Hence in Stage -III, the width of weld bead was less as compared to others; therefore the less chance of porosity as compared to oxy-acetylene and TIG welding.

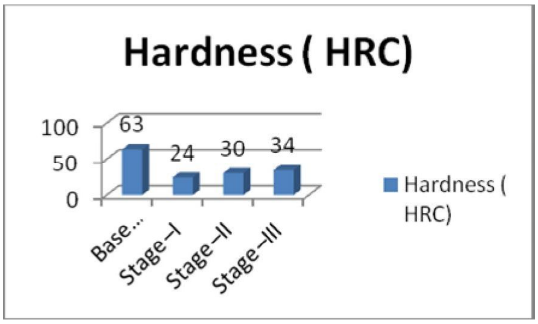

Fig 3: Histogram of Weld Bead Hardness

Thus it can be concluded that the hardness of the joint is more if the weld bead is less. Hence the maximum value of hardness we can get in stage –III. Therefore, the value of hardness of microwave joint is more as compared to oxy-acetylene & TIG welding. The Fig. 4 shows the X- Ray radiography appearance of the weld bead of obtained in first stage of EN-31 component which was carried by oxy-acetylene welding process parameters.

Fig 4: X- Ray radiography appearance of Stage-I

From the X-Ray radiography test of the weld bead in the first stage, the following defects were observed.

(a) Fine and Course scattered porosity – cavities due to entrapped gas.
Radiography appearance – Sharply defined dark shadows of rounded contour.

(b) Incomplete penetration – Lack of fusion in the root of weld or a gap left by the failure of the weld metal to fill the root.
Radiography appearance – Dark continues or intermittent line in the centre of weld.

(c) Slag Inclusions – Solid materials entrapped along weld bead
Radiography appearance – Jagged asymmetrical shapes along the weld joint areas are indicative of slag inclusions.

The Fig. 5 shows the X- Ray radiography appearance of the weld bead of obtained in second stage of EN-31 component which was carried by TIG welding process parameters.

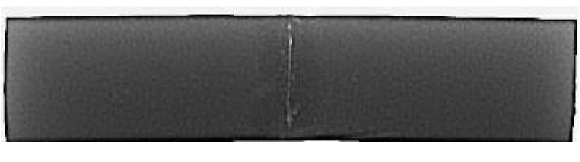

Fig 5: X- Ray radiography appearance of Stage-II

From the X-Ray radiography test of the weld bead in the second stage, the following defects were observed.

(a) Course scattered porosity – cavities due to entrapped gas.
Radiography appearance – Sharply defined dark shadows of rounded contour.

(b) Incomplete penetration – Lack of fusion in the root of weld
Radiography appearance – Dark continues or intermittent line in the centre of weld.

The Fig. 6 shows the X- Ray radiography appearance of the weld bead of obtained in third stage of EN-31 component which was carried by Microwave welding process parameters.

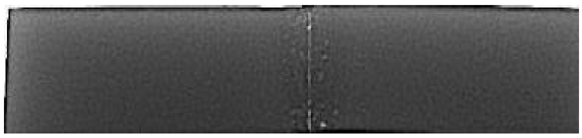

Fig 6: X- Ray radiography appearance of Stage-III

From the X-Ray radiography test of the weld bead in the third stage, the following defects were observed.

(a) Course scattered porosity – cavities due to entrapped gas.
Radiography appearance – Sharply defined dark shadows of rounded contour.

(b) Slag Inclusions – Solid materials entrapped along weld bead.
Radiography appearance – Jagged asymmetrical shapes along the weld joint areas are indicative of slag inclusions.

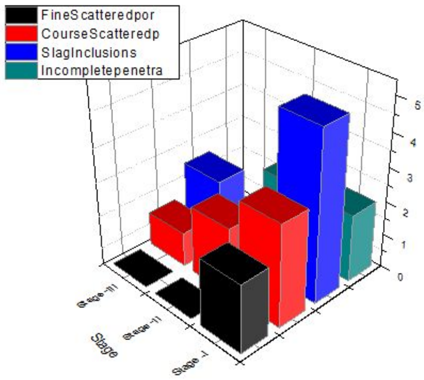

Fig 7: Histogram of Welding Defects

X-ray radiography testing of welded joint revealed that the level of Fine scattered porosity was reduced to negligible value by adopting TIG welding technique and microwave welding technique. However the incomplete penetration was observed during TIG welding component. The level of welding defects is low in Stage-III, Thus it is suggested to use microwave welding rather than oxy-acetylene gas welding and TIG welding in order to minimize the defects.

IV. CONCLUSIONS

- It can be concluded that width of weld bead is less in microwave welding when compare with oxy-acetylene welding and TIG welding, then amount of volatilization of carbon and other particles will less and this reduces the chances porosity.
- The minimum reduction in hardness of weld bead i.e. 34 HRC as compared to base metal hardness i.e. 63 HRC is noted at microwave welding.
- Scattered porosity defects occurred due to volatilization of carbon and ferrous particle during oxy-acetylene welding and TIG welding.
- The level of welding defects is low in Stage-III, Thus it is suggested to use microwave welding rather than oxy-acetylene gas welding and TIG welding in order to minimize the defects.

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