Influence of Heat Input and PWHT on the Microstructure and Mechanical Properties in Dissimilar (IS2062-EN8) Welded joints

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Abstract

In the research work we evaluated the effect of heat input and PWHT on dissimilar metal joints influencing their mechanical properties and microstructure. Dissimilar metal joints of Mild steel and EN8 are prepared by using MIG welding process. This melting is possible because a sufficient amount of energy transferred per unit time and energy density is supplied to the wire. Tensile strength, impact, hardness was tested and Microstructure was studied. The heat input transferred along the transverse length of the welded joint will affect the entire weldment zone. Across the traverse length the hardness values are used to identify different zones of the welded joint. This heat input is varied with input parameters such as voltage, current and speed of wire. In the present research work heat input is considered as low and high heat input cases. The microstructure and the mechanical properties at different zones of each plate of weldment with low and high heat input cases are analysed with and without post weld heat treatment.

Keywords: Low Heat input, High heat input, Before Heat treatment, After Heat treatment, Base metal, Heat Affected Zone, Welded Zone.

1. Introduction:

In manufacturing industry welding of dissimilar metals often plays a vital role. Applications of welding dissimilar metals and alloys are widely found in automobile machinery, pressure vessels etc. The chemical compositions of the metals make their dissimilarities of the metals. Particularly weldability and other mechanical properties are much affected by the chemical composition of the dissimilar steel alloys. During the manufacturing of structural steels some elements are particularly added to improve the properties, but some inevitable elements may
be present, added from the scrap materials during the production of steel. Individual dissimilar metals properties vary with other alloy dissimilar metals, because of the variation of the alloying elements. Hence welding of dissimilar metals may compose different properties of the metals. In order to improve the performance with minimum cost an appropriate welding procedure is to be identified. D. Gery et al had studied the effect of welding speed, energy input and heat source distribution on Temperature variations in butt joints by MIG welding processes. Their results showed that temperature distribution and variation in the welded plates are sensitive to the heat source distribution, energy input and welding speed [1].

The thermal expansion and contraction during heating and subsequent cooling as well as material plastic deformation at elevated temperatures result in inevitable distortions and residual stresses [2,3] in the joint and the parent metals, which greatly affects the fabrication tolerance and quality. In current industrial practice, welding processes are developed largely based on trial and error experiments incorporating with engineers’ knowledge and experience of previous similar designs. To avoid the damages of high strength; low alloy steels of dissimilar joints are preferred suitable heat input are selected [4]. After that one of the most important notice is edge preparation, i.e. to avoid the welding defects such as lack of penetration, air bubbles formation, under cut and segregation of different chemical compositions due to change the microstructures of base metal, heat effected and welded zones of each metals [5-8]. After that to inspection in the dissimilar welded joints is done by using X-ray test and obtained negative result from the X-ray test. The deposition of filler material in the single V- butt joint of dissimilar joints transferred the non uniform temperature along and perpendicular to the weld axis at each pass of welding torch. So sudden heating and cooling at room temp within the parent metal some disturbance formed at different zones, it affects the quality of dissimilar welded joints [9, 10].

Smith.e [11], Olabi [12], Ahmad [13] et al, it is well known that PWHT effects their mechanical and micro structural properties of the similar weldments. Vera Lucia et al[14]-[15] studied the effect of PWHT on the microstructure of ferrite weld include the tempering of the microstructure, precipitation hardening and depending on the temperature of PWHT, finally mechanical properties will be defined by the magnitude of each possible effect of the PWHT. A. A1. Mazrouee et al [16] present this result on the role of PWHT of such micro structural variations on inhomogeneous scaling across the weldment of the Cr-Mo steels. Generally fabrication of high pressure vessels require a PWHT processes, The reason is to relive the internal disturbances within the weldments as a result to improve the mechanical and micro structural properties. Some of the authors concentrated on pre-post weld heat treatment of similar and dissimilar joints.

However there is no enough work on the influence of low heat high heat inputs and PWHT on mechanical Micro structure of dissimilar welded joints. The proposed research work is concentrated on investigating the influence of heat input and PWHT on the microstructure and mechanical properties in a dissimilar (IS2062-EN8) welded joint.

### Nomenclature

| Symbol | Description |
|--------|-------------|
| V      | Voltage (26, 30 volts) |
| C      | Current (16, 18 amp) |
| S      | Welding Speed (3.310m/sec) |

### 2. Experimental Procedure:

**2.1 Welding Procedure:** Firstly, the materials which are of the size (250mm x 100mm x 10mm thick) were taken as shown in Fig No: 1. Edge Preparation was done for welding as Single V butt joint. Edge bevelling was performed on
Universal milling machine by fixing the plates in the Machine vise, then milling is done using T-max 80 φ cutter with speed of 450 rpm. After Edge preparation we have selected the combinations of material pair. We considered 10mm thickness of plate, before doing Welding preheating (120°C) was performed using oxyacetylene flame. This would prevent the moisture in the metal, help in distortion control and crack minimization. Here we used the MIG (Metal Inert Gas) Welding with Copper Coated Mild Steel with diameter 1.2mm as filler metal. Copper coating on Mild steel is preferred since current conduct easily and to prevent rust. The chemical properties of base metals and copper coated mild steel as shown in table: 1. Anti spatter spray is applied on the plates for easy clean up after a flux core MIG welder. Co2 is used as the inert gas. Welding is done for 5 passes with respect to average voltage, current, inert gas flow and wire feed rate. Thermocouples are clamped at multiple spots; it gave us the temperature distribution. This helped us to locate different zones of weldment viz. base metal, heat affected zone and welded zone. Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and interpass temperature, it influences the effect of mechanical properties and metallurgical structure of the weld and the HAZ. The heat input equation is as follows

\[
\text{Heat input} = \frac{(V \times A \times 60)}{(S \times 1000)} \times \text{efficiency} \quad \text{(For MIG, efficiency = 0.9)}
\]

\[
= \frac{(26 \times 160 \times 60)}{(3.295 \times 1000)} \times 0.9 = 1.136 \text{ (kJ/mm)}
\]

| S.No | Name of Material     | Composition in % of Weight | Hardness of material (N/mm²) | Breaking Strength(N/mm²) | Notch Impact strength (J/mm²) |
|------|----------------------|-----------------------------|-----------------------------|--------------------------|------------------------------|
|      |                      | C  | Mn  | Si  | Cr  | S   | P   | Mg  |                      |                            |                              |
| 1.   | Mild steel IS-2062   | 0.22 | 1.5 | 0.40 | -   | 0.045 | 0.045 | -   | 1451.630               | 616.466                     | 0.4950                        |
| 2.   | EN-8                 | 0.4 | 0.8 | 0.2 | -   | 0.06 | 0.06 | -   | 1866.758               | 737.236                     | 0.2830                        |
| 3.   | Copper Coated Mild Steel | 0.1 | 1.86 | 0.73 | 0.2 | 0.30 | 0.03 | -   |                            |                            |                              |

Table No: 1 Chemical composition of Base metals and filler wire.

After doing MIG welding back up plate is removed. Dye Penetrant (DP) test was conducted in order to find out weld defects. Pre clean before the test was done in order to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Penetrant was applied, and allowed in “dwell time” to soak into any flaws. Developer was then applied and it draws the penetrant from defects out onto the surface to form a visible indication. Next tempering Heat treatment was conducted for the specimens.

2.2 Metallographic:

After the different heat input weldments we have to select test specimens from each dissimilar joint. Test specimens are polished by using different grades of emery papers and smooth grinding machine as per AWS standards of optical microscope. Here 4% of natal etchant is used in soaking and cooling time 2hr at 600°C-200°C is used to observe different zones in each dissimilar joint and are captured with an optical microscope coupled with
image analyzing software. Fractured area of microstructure study was done using SEM for different zones of weldment. These are performed before Heat treatment and after Heat treatment. Specimens for microstructure study are obtained as per the ASM standard procedure.

2.3 Tensile, impact and hardness Test:
For conducting Mechanical tests i.e. tensile test, hardness test and impact test firstly we have prepared the test pieces as per the requirement i.e. while preparing tensile test and conducting tensile test have measured initial length and the diameter of the test piece and noted valves and then test piece is mounted on the testing machine and then apply load and after sometime test piece is elongated and necking is formed and then loading process continues until fracture. This test is conducted for test pieces before PWHT and After PWHT processes.

3. Result Analysis:
3.1 Metallurgical Properties: One of the observations in this study was the heat input increases that corresponding thickened area is also affected. As bottom of the plate is narrow when compared to the top of the plate, Top of the plate is more affected than bottom part of plate. Thermo couples are used to measure the temperature levels so as to study the heat affected zones. Microstructures of weld zone, fusion boundary and HAZ for different heat input combinations are presented in this present work.

| Heat input (After Heat treatment) | Tensile properties | Micro structure details | Location of fracture |
|----------------------------------|--------------------|------------------------|---------------------|
|                                  | Ultimate tensile strength (Mpa) | Percentage of elongation (%) | Dendrite length in WZ(μm) | Interdendrite spacing(μm) |
| Low Heat input                   | 640.12             | 28                     | 106.45              | 8.35                  | Near to B.M |
| High heat input                  | 625.2              | 24                     | 192.67              | 14.67                 | Near to B.M |

Table No: 2 After the PWHT Micro structure details.
Microstructures of different zones are observed by using optical microscopy, where 4% etchant is used in these observations. The grain dendrite length in each plate of the welded zones found on optical microscopy in order to evaluate ferrite in the average valve is tabulated. The dendrite lengths and inter-dendrite spacing for the low and high heat input joints are mentioned in the table.2.

Fig: 2.Micro structures of different zones obtained by optical microscopy
Scanning Electron microscopy (SEM) was used to observe the fractured surface morphologies in and analysed each zone of microphage Fig no: 2. In this % of martensite-Austenite constitutes are found that corresponding to these effect of mechanical properties before and after post weld heat treatment Processes are studied.

In fractured surface of dissimilar welded area some information regarding to maximum length of easy crack propagation is obtained. It means extent of grain growth in these zones depends upon heat input and cooling rate. Particularly in dissimilar metals, When thermochemically treated processed steels are welded some area is formed brittle fracture and ductile fracture are formed in fig: 3, 4.when observed that soften zone, when raised to recrystalline temperatures, will have a change in microstructure to oversaturated baintic-manstensitic, coarsening of austenitic grains take place, resulting in changes in strengthening of this zones when compared with BHT & PWHT processes.

Fig.No: 3.SEM Micrographs of Impact fractured surface of welded part of IS2062, BHT and AHT.

Fig.No: 4.SEM Micrographs of Impact fractured surface of welded part of EN8, BHT and AHT.

3.2 Mechanical Properties: The mechanical properties of the parent material and the welded bead are computed. It can be observed from graphs that the tensile, impact and hardness of dissimilar joints and the weld bead are dependent on the type of heat inputs used and different PWHT shown in Fig no :5.
Figure No: 5. Weldments after the welding, tensile test before PWHT and After PWHT.

Process parameters used for fabricating IS 2062 & EN 8 joint

| S. No | Low heat input | Current (Amps) | Voltage (Volts) | Weld length (mm) | Welding Time (sec) | Welding Speed (mm/sec) | Total heat input length of the weld (kJ/mm) | After Heat treatment Tensile strength (N) | Before heat treatment Tensile strength (N) | % | Before heat treatment Impact strength (N) | After Heat treatment Impact strength (N) | % |
|-------|----------------|----------------|-----------------|------------------|-------------------|----------------------|--------------------------------|---------------------------------|--------------------------------|---|-------------------------------|--------------------------------|---|
| 1     | Low heat input | 160            | 26              | 250              | 75.5              | 3.310                | 1.1311                        | 640.12                          | 625.520                        | 2.34 | 100                           | 130                           | 30 |
| 2     | Low heat input | 160            | 30              | 250              | 75.45             | 3.313                | 1.3039                        | 637.10                          | 625.120                        | 1.91 | 96                            | 125                           | 30.2 |
| 1     | High heat input| 180            | 26              | 250              | 75.3              | 3.317                | 1.2698                        | 627.50                          | 623.025                        | 0.72 | 70                            | 80                            | 14.2 |
| 2     | High heat input| 180            | 30              | 250              | 75.46             | 3.3126               | 1.4712                        | 624.50                          | 621.045                        | 0.56 | 69                            | 79                            | 14.4 |

Table no 3: Tensile results for IS 2062 & IS 45 C8 joint for before and after heat treatment
Varying the heat input typically will affect the material properties and metallurgical structure in the weldments. If the changes in heat input are relatively small, the following table no: 3 shows how the tensile properties are improved in case of low heat input after the post weld heat treatment. After conducting the impact test, It was also observed that the mechanical properties is increased large amounts in case of low heat input and after the PWHT Process as shown in graphs no :1,2.

Graph No: 1 Weldments after the welding, tensile test before PWHT and After PWHT. Process parameters used for fabricating IS 2062 & EN 8 joint One of the most important observations is after heat treatment process in which low heat input parameter is used dissimilar joints are very much effective compared to the before heat treatment shown in the graph no:2.so it is suitable for low heat input parameter for this post weld heat treatment.
Graph No: 2Weldments after the welding, impact strength before PWHT and After PWHT. Process parameters used for fabricating IS 2062 & EN 8 joint.

Hardness:

| S.No | Current (amps) | Voltage (volts) | Welding Speed (mm/sec) | B.M (IS 2062) | H.A.Z (IS 2062) | W.Z | H.A.Z (EN 8) | B.M (EN 8) |
|------|----------------|-----------------|------------------------|----------------|-----------------|-----|--------------|------------|
| 1.   | 160            | 26              | 3.31                   | 72             | 78              | 98  | 92           | 82         |
| 2.   | 160            | 30              | 3.31                   | 70             | 76              | 96  | 88           | 81         |
| 3.   | 180            | 26              | 3.31                   | 62             | 66              | 83  | 78           | 72         |
| 4.   | 180            | 30              | 3.31                   | 59             | 64              | 81  | 75           | 68         |

Table no 4: Hardness results for IS 2062 & EN 8 joint for before heat treatment process.

Graph No: 3Weldments after the welding, hardness different zones of IS 2062 & EN 8 joint. The hardness values are taken in the transverse direction in different zones in the weldments before PWHT and After PWHT in table no: 4, 5. particularly the welded zone of the dissimilar joints varies rapidly before PWHT shown in graphs 3, 4. but after PWHT are also measured and the hardness decreases.

| S.No | Current (amps) | Voltage (volts) | Welding Speed (mm/sec) | B.M (IS 2062) | H.A.Z (IS 2062) | W.Z | H.A.Z (EN 8) | B.M (EN 8) |
|------|----------------|-----------------|------------------------|----------------|-----------------|-----|--------------|------------|
| 1.   | 160            | 26              | 3.31                   | 65             | 68              | 88  | 79           | 79         |
| 2.   | 160            | 30              | 3.31                   | 64             | 67              | 86  | 75           | 78         |
| 3.   | 180            | 26              | 3.31                   | 55             | 61              | 78  | 67           | 67         |
| 4.   | 180            | 30              | 3.31                   | 54             | 60              | 77  | 65           | 66         |

Table no 5: Hardness results for IS 2062 & IS 45 C8 joint for after heat treatment (tempering)
Graph No:4Weldments after the welding, hardness before PWHT and After PWHT. Process parameters used for fabricating IS 2062 & EN 8 joint

Conclusions:
From the experimental results it can be concluded that due to slight variation of alloying elements the physical properties of material like IS2062 may not change drastically but considerable change occurs in mechanical properties. When the materials with considerable difference in mechanical properties are joined by arc welding method then the mechanical properties of the weld bead depends a great extent on the type of filler material used, the heat input applied, and the preheating and post heating conditions of the weld bead. In Similar materials, and dissimilar materials, as the Heat input decreases, there is an increase in the tensile strength, impact strength. And also hardness follows an increasing trend in the order of Weld metal, HAZ, base metal for both the inputs. If we compare a joint for any heat input, based on with or without heat treatment, results are much better when the joint is subjected to heat treatment. Based upon the present study it is recommended that heat input should be preferred when welding joints Similar and Dissimilar (IS 2062 & EN 8) joints using MIG process because of the reason that besides giving good tensile strength, impact strength, hardness.

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