# Study on Effect of Manual Metal Arc Welding Process Parameters on Width of Heat Affected Zone (Haz) For Ms 1005 Steel

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***Abstract:*** *Heat flow in welding is mainly due to heat input by welding source in a limited zone and it subsequent flow into body of work piece by conduction. A limited amount of heat loss is by a way of convection and radiation. Local Heating and cooling of metal shrinkage on solidification and structural change on solidification cause temperature distribution. In the present work, authors have investigated the width of HAZ with various process parameters like heat input & welding speed. In manual metal arc welding (MMAW), selecting appropriate values for process variables is essential in order to control heat-affected zone (HAZ) dimensions and get the required bead size and quality.*

*In this study, the effect of various welding parameters on the weldability of Mild Steel specimens having dimensions 125mm× 75mm× 5 mm welded by manual metal arc welding (MMAW) for single V-Butt joint were investigated. The welding current, arc voltage, welding speed, heat input rate are chosen as welding parameters. The effect of these parameters on the size of Heat affected zone is investigated.*

***Key Words:*** *MMAW, welding speed, heat input, heat affected zone (HAZ).*

## I. Introduction

Manual metal arc welding was first invented in Russia in 1888. It involved a bare metal rod with no flux coating to give a protective gas shield. The development of coated electrodes did not occur until the early 1900s when the Kjellberg process was invented in Sweden and the Quasi-arc method was introduced in the UK [1]. It is worth noting that coated electrodes were slow to be adopted because of their high cost.

However, it was inevitable that as the demand for sound welds grew, manual metal arc became synonymous with coated electrodes. When an arc is struck between the metal rod (electrode) and the work piece, both the rod and work piece surface melt to form a weld pool. Simultaneous melting of the flux coating on the rod will form gas and slag which protects the weld pool from the surrounding atmosphere. The slag will solidify and cool and must be chipped off the weld bead once the weld run is complete (or before the next weld pass is deposited).[2]

Welding is an efficient and economical method for joining of metals. Welding has made significant impact on the large number of industry by raising their operational efficiency, productivity & service life the plant and relevant equipment. Welding is one of the most common fabrication techniques which is extensively used to obtained good quality weld joints for various structural components. The present trend in the fabrication industries is to automate welding processes to obtained high production rate.

Arc welding, which is heat-type welding, is one of the most important manufacturing operations for the joining of structural elements for a wide range of applications, including guide way for trains, ships, bridges, building structures, automobiles, and nuclear reactors, to name a few. It requires a continuous supply of either direct or alternating electric current, which create an electric arc to generate enough heat to melt the metal and form a weld.

The arc welding process is a remarkably complex operation involving extremely high temperatures, which produces severe distortions and high levels of residual stresses. These extreme phenomena tend to reduce the strength of a structure, which becomes vulnerable to fracture, buckling, corrosion and other type of failures.

Hardness is very important mechanical property of material but during welding high heating and rapid cooling influence the hardness of the weld as well as the Heat affected zone (HAZ). Also the optimum hardness of weld and heat affected zone (HAZ) at minimal heat input rate for 60˚ and 70˚ bevel angle weldments have been investigated.[3]

A mathematical models was developed to Study the effects of process variables and heat input on the heat affected zone (HAZ) of submerged arc welds in structural steel pipes.[4]

High deposition rate welding process which can produced a smooth bead with deep penetration at a faster travel speed also welding input parameters plays a very significant role in determining the quality of the weld joint have been investigated.[5] .

A numerical model of fluid flow and temperature field in GMAW was established according to the new mode of arc heat flux distribution. By using a numerical simulation technique, the effects of welding heat input on microstructure and hardness in HAZ of HQ130 steel were studied[6].

The effect of welding parameters on the size of the heat affected zone (HAZ) and its relative size as compared to the weld bead of submerged arc welding. It is discovered that the welding parameters influences the size of weld bead and HAZ differently which can be relate to the effect of welding parameters on the various melting efficiencies. This difference in behavior of HAZ and weld bead can be explored to minimize the harmful effect of HAZ in future welds.[7]

In this study, the effect of various welding parameters on the weld ability of Mild Steel specimens having dimensions 125mm× 75mm× 5 mm welded by manual metal arc welding (MMAW) for single V-Butt joint were investigated. The welding current, arc voltage, welding speed, heat input rate are chosen as welding parameters.
The effect of these parameters on the size of heat affected zone is investigated.

## II. Experimental Procedure

### 2.1 Material

The material used for manual metal arc welding (MMAW) is SAE 1005 mild steel.
The entire specimens were machined into the dimensions of 125mm long x 75mm x 04mm thick.
The details composition (weight %) of specimens is shown in Table 1. This metal had very good welding characteristics and could be welded by all of the common welding techniques.
The typical Thermal and Mechanical properties of carbon steels at room temperature (25°C) are shown in Table 2

**Table 1 The Chemical Composition of the used steel (SAE 1005) (weight %) of specimens [9,10]**

| Sample Identity | C | Si | Mn | P | S | Cr | Mo | Ni | Al | C | Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wt% | 0.035 | 0.024 | 0.104 | 0.0062 | 0.0033 | 0.007 | 0.0047 | 0.0102 | 0.039 | 0.004 | 0.0026 |

**Table 2 Thermal and Mechanical properties of Steel SAE1005 [9, 10]**

| **Property** | **Value** | **Unit** |
|---|---|---|
| Conductivity | 42 | W/mk |
| Specific Heat | 481 | J/Kg-K |
| Density | 7872 | Kg/m |
| Poisson's Ratio | 0.27-0.30 | |
| Elastic Modulus | 190 to 210 | GPa |

### 2.2 Welding Tools

This sections provides the important specifications of the tool used in the welding process

#### 2.2.1 Welding Machine

Welding machine used for welding is a general purpose welding machine (Usha Welding Machine ® C/O). The Technical Specifications of Welding Machine are as stated in Table 3

Fig. 1 Welding Machine

**Table: 3 Technical specification of welding machine**

| Welding Machine Model | Welding Range (mA) | Striking voltage (V) | Duty range | Welding voltage(kVA) | Primary voltage(V) | Primary current (Amp) |
|---|---|---|---|---|---|---|
| EAD 25 | 50 to 250 | 65 | 60% | 32 | 220-440 | 30 to 20 |

#### 2.2.2 Welding rod

Welding rod is an electrode used to weld the metal. The Technical Specifications of Welding rods are as stated in Table 4

Fig. 2 Welding electrode/rod

**Table: 4 Technical specification of welding rod/electrode**

| Material | Diameter | Length | AWS/SFA | IS |
|---|---|---|---|---|
| MS | 3.15mm | 350 mm | 5.1m, E6013 | 8142004-ER4211X |

### 2.3 Sample Preparation

The Choice of sample for a microscopic study is very important. In the manual welding process the speed of welding varies along the length. Therefore a sample is taken from the middle section of the welded plate where the welder's speed of welding is assumed to be constant. In the present experimentation SAE1005 M.S sheet was selected. Six sample plates of dimensions (12.5x7.5x0.5) cm3 were cut from the sheet. All the six plates of mild steel were welded on their surfaces lengthwise by varying the parameters. Each sample is tested for varying welding speed, current & voltage which is shown in table 5. Heat input has been calculatd & shown before each sample in table no.5. The photographic views of the welded plates are shown in Fig.4.

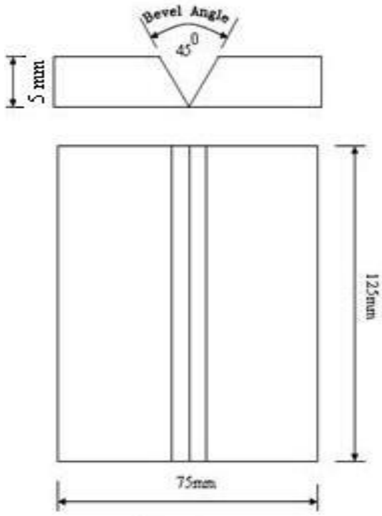


Fig. 3

Front side of welded material Back side of welded material
Fig. 4 Welded Specimens

**Table 5 Process parameters used in the experimentation.**

| S. No. | Welding voltage(V) | Welding current(A) | Arc time(sec) | Welding speed (mm/min) | Heat Input** (J/mm) |
|---|---|---|---|---|---|
| **1** | 30 | **150** | **43** | **174.42** | **1547.98** |
| **2** | 30 | **150** | **36.9** | **203.25** | **1328.41** |
| **3** | 30 | **150** | **27.15** | **276.24** | **977.37** |
| **4** | 30 | **200** | **47.8** | **156.90** | **2294.34** |
| **5** | 30 | **200** | **41.2** | **182.03** | **1977.69** |
| **6** | 30 | **200** | **36.2** | **207.18** | **1737.61** |

**Welding speed (v):** Welding Speed is defined as the rate of travel of the electrode along the seam or the rate of travel of the work under the electrode along the seam. Weld travel Speed = Travel of electrode/arc time, mm/min.[1]
****Heat input rate (Q):** Heat input is a relative measure of the energy transferred per unit length of weld. Heat input is typically calculated as the ratio of the power (i.e., voltagex current) to the velocity of the heat source (i.e., the arc) as follows -

**Heat input rate or arc energy = V×I×60 /v joules per mm**
Where, V= arc voltage in volts, I = welding current in ampere,v = speed of welding in mm/min.[1]

## III. 3. Result & Discussion

### 3.1microstructure of Weld Metal:-

To study the metallurgical structure of the base metal, weld zone as well as heat affected zone (HAZ) with different heat inputs of all the samples have been cleaned by zero grade emery paper. All the samples were dipped in 2% nital agent & finally dried by using air blower. The microstructure of base metal, weld zone as well as heat affected zone(HAZ) of all the samples have been carried out by optical microscope having 400X zoom. The metallurgical structure of base metal, weld & HAZ of all the samples are shown in figure. 5,6,7,8,9,10

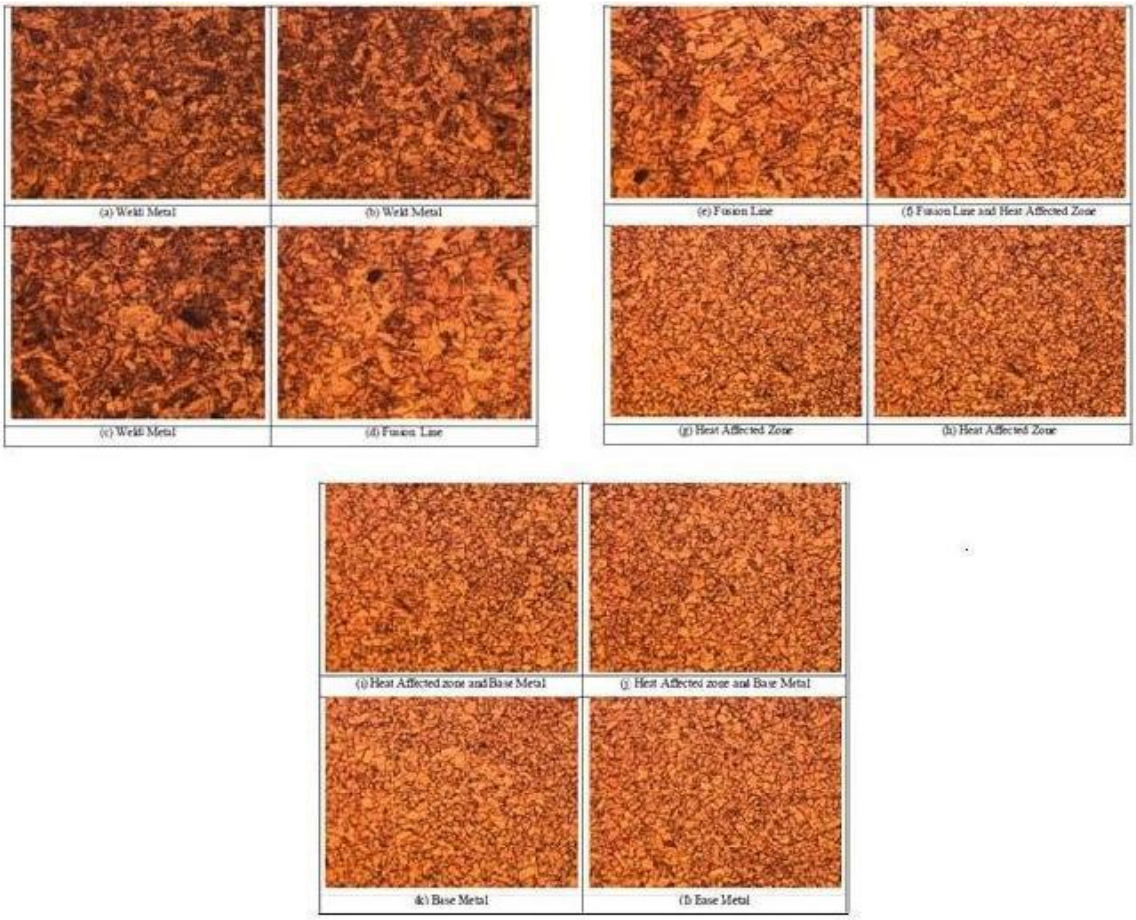


**Figure : 5 Microstructure with heat input = 1547.98J/mm**

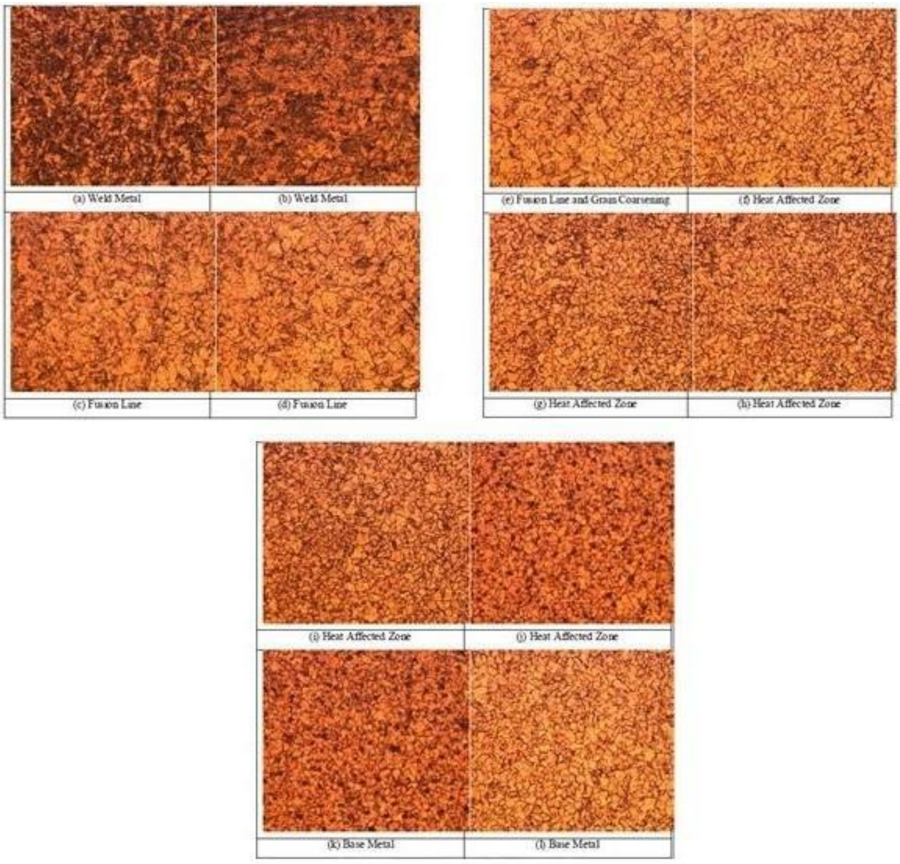


**Figure : 6 Microstructure with heat input = 1547.98J/mm**

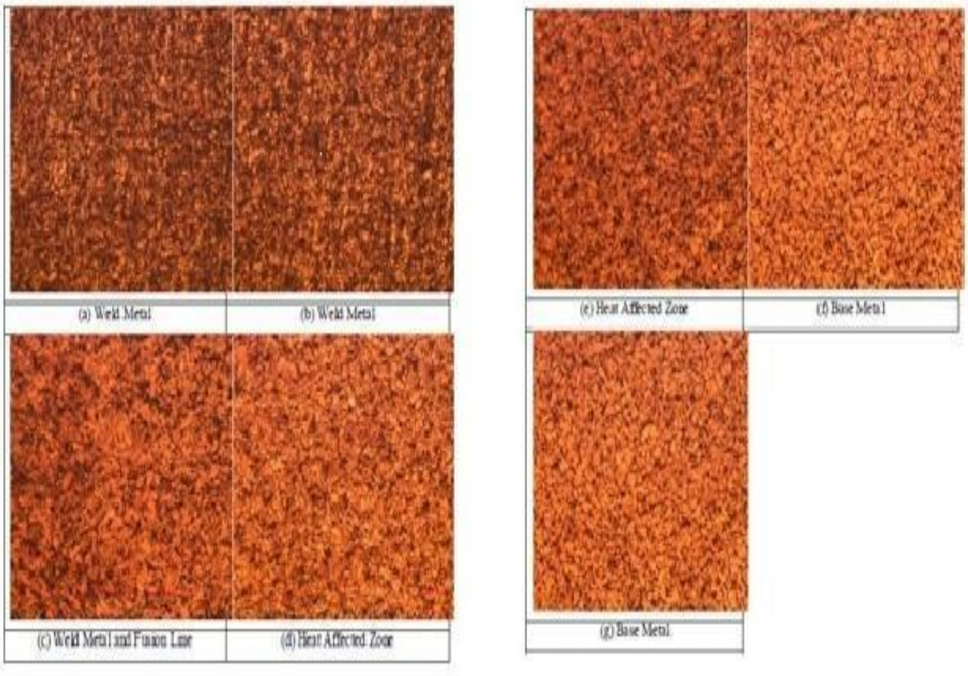


Figure : 7 Microstructure with heat input = 977.37 J/mm

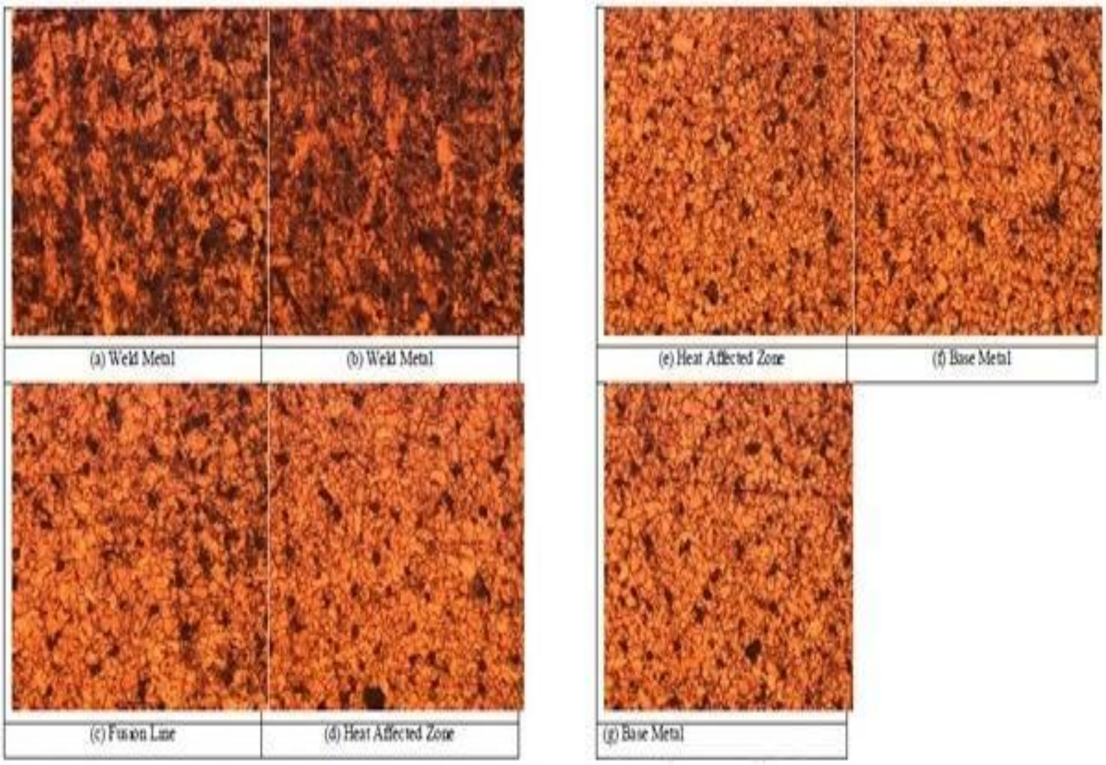


Figure : 8 Microstructure with heat input = 2294.37 J/mm

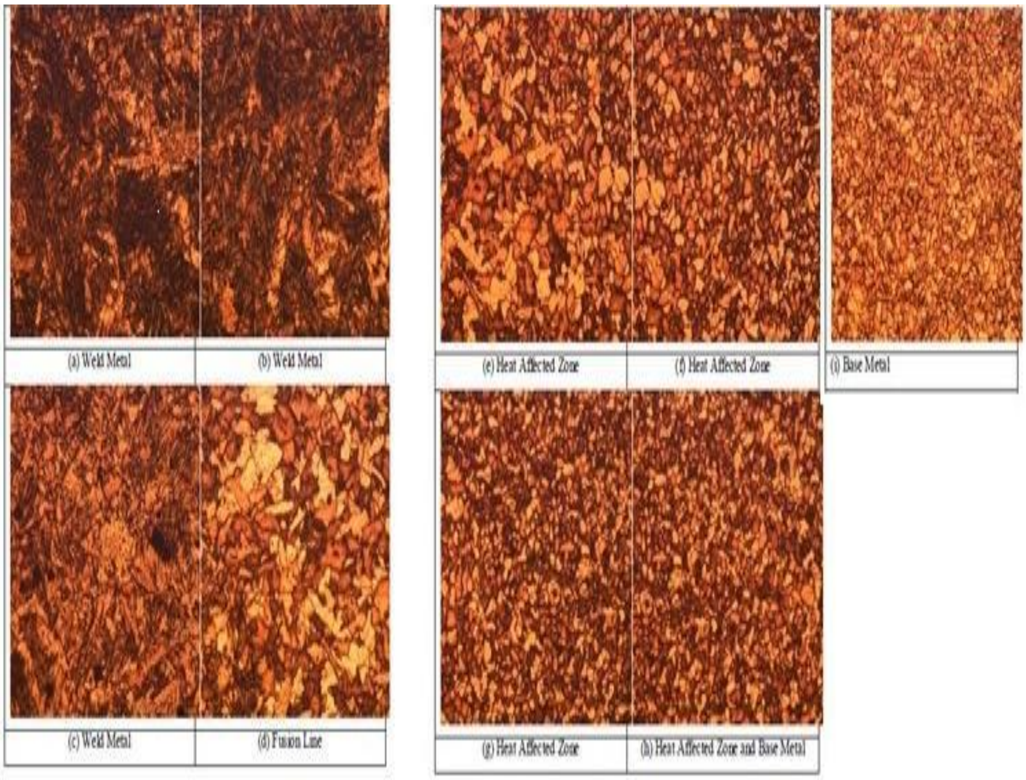


Figure : 9 Microstructure with heat input =1977.41 J/mm

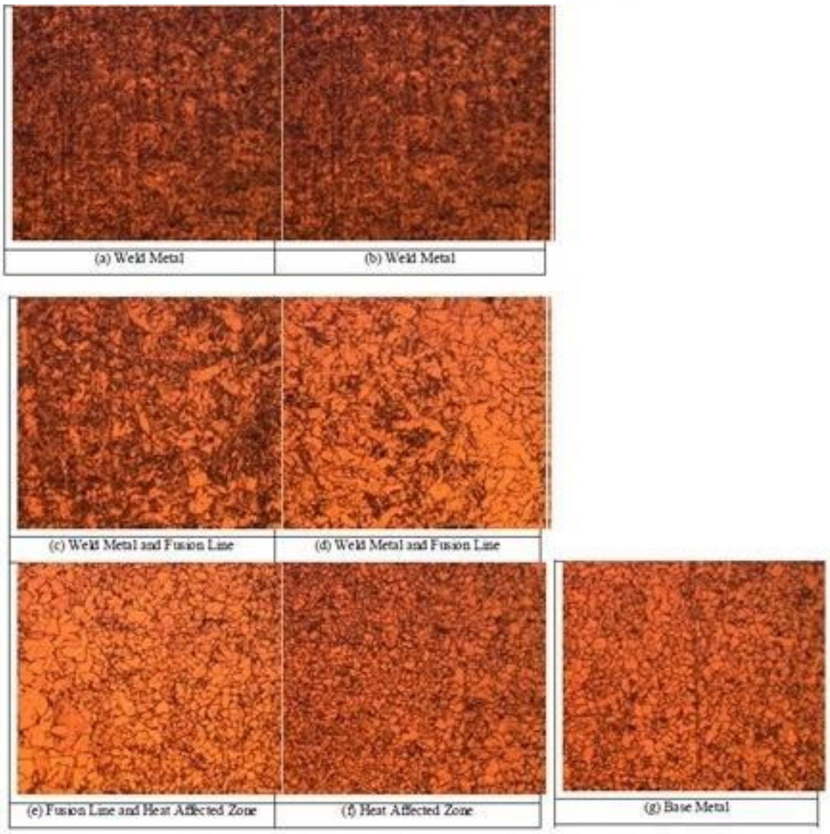


Figure : 10 Microstructure with heat input =1737.61 J/mm

The microstructure of base metal is shown in Fig. 5 (k) (l), 6 (k) (l), 7 (f) (g), 8 (f) (g), 9 (i), 10 (g). The observation results show that the base metal is consistent with a bainite microstructure and the grain size also indicate that the grain size of the bainite bind is also very small. Because of the small ferrite plate where the original austenite microstructure is refined, a refined bainite microstructure is gained and then the strength and impact toughness of base metal are improved.

The microstructure of the weld zone under different heat inputs are shown in Fig.5 (a) (b) (c), 6 (a) (b), 7 (a) (b) (c), 8 (a) (b), 9(a) (b) (c), 10 (a) (b) (c). The microstructure of the welds under different heat inputs is consistent with acicular ferrite and the plate proeutectoid ferrite along the grain boundary. The impact toughness of the weld depends on the proportion of acicular ferrite and the plate proeutectoid ferrite. The crack is easy to initiate and propagate in proeutectoid ferrite, so when the proportion of proeutectoid ferrite is very high, the toughness of the weld will be deteriorated. The fined acicular ferrite is useful to improve the impact toughness of welds because the crossing distribution grain boundaries can impede the propagation of cracks.

Fig. 6 (e) shows the effect of heat input on the microstructure of coarsened grain zone. The coarsening of original austenite grain and the formation of brittle microstructure are the main cause for the decrease of toughness in coarsened grain zone. It can be seen from Fig. 6 (e) that the original austenite grain size increases with the Increase of heat input. In addition, the size of lath bainite and the proportion of granular bainite in coarse grain zone also increase with the increase of heat input, which results in the decrease of toughness in coarsened grain zone under high heat input.

### 3.2 Effect of Process Parameters on HAZ

The portion of the parent material which has been heated above the critical temperature but has not melted. It is understood that several process control parameters in MAW influence bead geometry, microstructure as well as weld chemistry. Their combined effect is reflected on the mechanical properties of the weld in terms of weld quality as well as joint performance. The study of the various works, review that, the selection of the suitable process parameters are the primary means by which acceptable heat affected zone properties, optimized bead geometry. The increase in amount of heat input increases the width of HAZ. Figure 11 shows the variation of width of HAZ with the change in Heat Input. Figure 12 shows the variation of width of HAZ with the change in Speed of welding

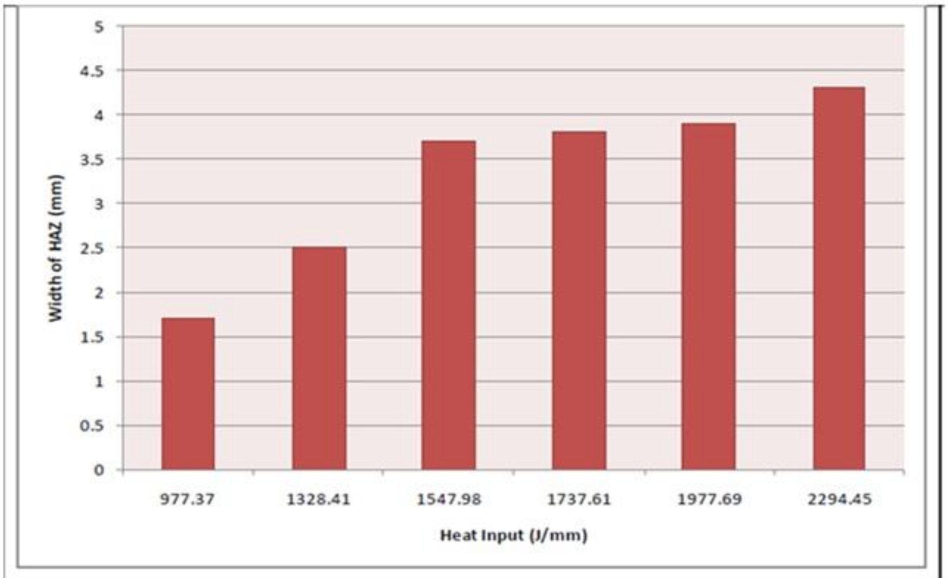


**Fig.11 Direct effect of welding heat input on the width of the HAZ region**

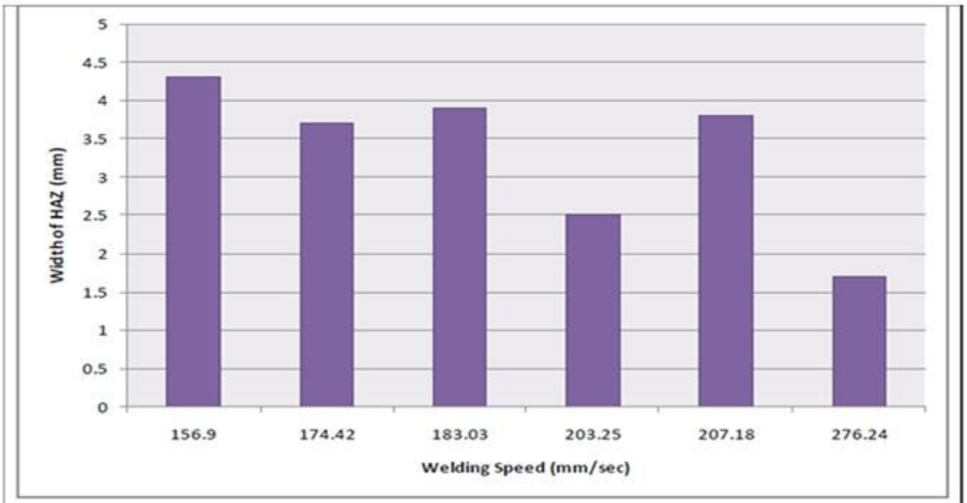


**Fig.12 Direct effect of welding speed on the width of the HAZ region**

In manual metal arc welding (MMAW), selecting appropriate values for process variables is essential in order to control heat-affected zone (HAZ) dimensions and get the required bead size and quality. Effects of process variables on HAZ parameters are shown in Fig 11 and 12.The dimensions of the different HAZ layers increases with the increases in, heat input but decreases with increases in welding speed. Increasing the speed of travel and maintaining constant arc voltage and current will reduce the width of bead and also increase penetration until an optimum speed is reached at which penetration will be maximum. Increasing the speed beyond this optimum will result in decreasing enetration. In the arc welding process increase in welding speed causes: Decrease in the heat input per unit length of the weld. Decrease in the electrode burn off rate. Decrease in the weld reinforcement.
If the welding speed decreases beyond a certain point, the penetration also will decrease due to the pressure of the large amount of weld pool beneath the electrode, which will cushion the arc penetrating force.

## IV. Conclusion

Due to different heat input the microstructure of base metal as shown in Fig. 5 (k) (l), 6 (k) (l), 7 (f) (g), 8 (f) (g), 9 (i), 10 (g). And because of the small ferrite plate where the original austenite microstructure is refined, a refined bainite microstructure is gained and then the strength and impact toughness of base metal are improved.

The coarsening of original austenite grain and the formation of brittle microstructure are the main cause for the decrease of toughness in coarsened grain zone. It can be seen from Fig. 6 (e) that the original austenite grain size increases with the increase of heat input. In addition, the size of lath bainite and the proportion of granular bainite in coarse grain zone also increase with the increase of heat input, which results in the decrease of toughness in coarsened grain zone under high heat input.

Trend of Direct effect of welding heat input and welding speed on width of HAZ as shown in graphs no 11 ,12-

1. Heat input is the most significant factor for controlling width of Heat affected zone (HAZ).and since welding speed increase the width of HAZ decreases, proper control on welding speed is become the important parameter for controlling the HAZ..
2. In manual metal arc welding (MMAW), selecting appropriate values for process variables is essential in order to control heat-affected zone (HAZ) dimensions and get the required bead size and quality.

## V. Scope for Further Work

In the present study authors have consider voltage, current& speed parameter to test HAZ and thereby metals property like microstructure, weld bead & weld quality. The study can be extended by considering other parameters like arc time , weld angle & welding types as a future scope over HAZ & there by effect on metal properties like compressive & tensile strength.

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