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Experimental Study on Effects of Process Parameters on HAZ of Plain Carbon Steel Using GMAW

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Abstract

This paper evaluates the effects varying current, voltage and number of passes on mechanical properties of HAZ. The remaining welding parameters torch angle, welding speed, groove angle, wire feed rate, stick-out distance, shielding gas pressure etc were kept constant. In the present work plain carbon steel plate having composition C 0.29%, Fe 98.594, Si 0.175%, Mn 0.50%, P 0.032%, S 0.37%, Cr 0.14%, Al 0.016%, Cu 0.096%, Ni 0.040%, Mo 0.010%, V 0.005% using gas metal arc welding (GMAW) have been investigated. Carbondioxide is taken as shielding gas. The parameters are varied one by one in turn and effects on mechanical properties and microstructure of heat affected zone have been investigated. It was found that with increase in current hardness also increases and increase in voltage depth of penetration increases. Hardness from weldbead centre decrease gradually with distance but increase at a distance of about 4mm from weldbead centre and then decrease gradually with distance this change in hardness is due to rapid cooling of that region of weldment by atmospheric air contact. With increase in no of passes there is reduction in hardness and increase in impact strength and increasing current result in reducing tensile strength and % elongation. Grain size is enlarged with decreasing current and also with increasing no. passes. It is found experimentally in the present work that using a higher valve of voltage for better penetration and lower of current for higher tensile strength is necessary. Also found best combination of current, voltage and number of passes is current130 Ampere, voltage 24 volt and number of passes are 2.

1. Introduction to HAZ

A lot of work has been done in welding of different materials using different types of welding technique and varying welding parameters. Effects on the properties of weldment, base metal and HAZ have been studied with varying parameters. But there is only little work on plain carbon steels. As we know plain carbon steel is mainly used for general purposes. So it is necessary to find best welding parameters for such materials. A heat affected zone (HAZ) of a weld is that part of the welded joint which has been heated to a temperature up to solidus of the parent material resulting in varying degree of influence on microstructure as a consequence of heating and cooling cycle. The temperature distribution around a metallic arc butt weld the leading edge of the temperature pattern is compressed, because the arc is continually moving cold metal and the trailing edge becomes extended because the arc leaves preheated metal in its wake [R.K Jain].Depending upon the peak temperature reached the HAZ in steels can be sub-divided into the following zones.

Starting from the weld metal side:

(i). Under Bead Zone i.e., that part of HAZ which is heated to beyond the critical temperature of grain growth and extend up to the fusion boundary zone,

(ii). Grain Growth Zone, beyond 1150^{0}C to peritectic temperature.

(iii). Grain Refined Zone, 950 to 1150^{0}C, i.e., beyond A_3 up to grain refined temperature range,

(iv). Partially Transformed Zone, 750 to 950^{0}C, i.e., between A_1 and A_3 temperature.

(v). Zone of Spherodized Carbides, 550 to 750^{0}C, i.e., below A_1,

(vi). Zone of Unchanged Base Material, up to 550^{0}C.

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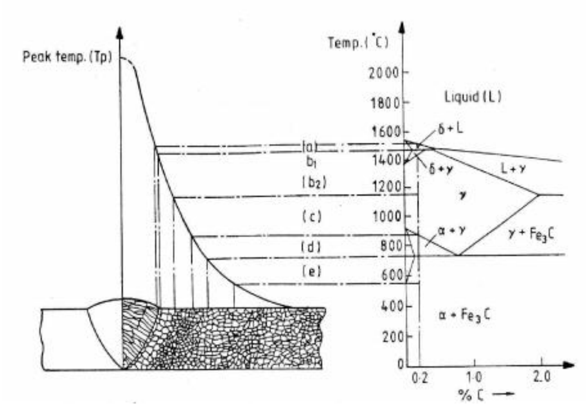

Fig. 1: Sub-divisions of HAZ for plain carbon steel welds and their corresponding temperature ranges on an iron-carbon equilibrium diagram.

2. Literature review

Oldand et al [1] in their experiments have investigated that with increase in heat input the hardness increases and tensile strength, ductility reduces of high strength steels. Makighi et al [2] have studied the effect of welding current and heat input on the metallic crystal and hardness in the deposited metal and heat affected zone of mild steel welds. The hardness increases with increasing current. P. K. Ghosh et al [5] observed that the use of pulsed current with controlled parameters can improve the characteristics of the weld joint with respect to its distortion and stresses, especially in the case of suitable narrow groove welds. Influence of the concerned functions on the weld characteristics studied are appropriately correlated and discussed. CO_2 laser beam (LB) welding done on 7075-T6 aluminum alloy sheets at two different welding speeds and compared it with gas tungsten arc (GTA) welding. The mechanical and microstructure characteristics of the welds are evaluated using tensile tests, hardness tests, optical microscopy and energy dispersive X-ray spectroscopy (EDS). Results indicate that both the hardness and tensile strength of LB welds are higher than those of GTA welds [6].

The size and number of defects increase markedly with the welding current. The welding speed affects the character of the defects. Cracks and ripple cavities are formed at low speeds while centre cavities and their cracked versions and undercuts and humps arise due to high speeds[7].

In the weld joint of AH36 TMCP steel the resistance to crack initiation and growth is found to increase from the base metal toward the weld metal as the contents of fine acicular ferrite becomes larger. The variation is, however, rather small and may be practically overlooked. The fracture toughness is found lowest in the heat affected zone near the fusion line where coarse bainite grains are found[8]. D. D. Harwing et al. [9] they evaluates the arc behavior and melting rate in the variable polarity (VP) gas metal arc welding (GMAW) process. The basic welding variables like groove angle and joint geometry can be used to determine the effect on mechanical properties for tension and compression loading of butt-joint-welded armor steel [10].A sensitivity analysis was performed that showed travel speed is the most influential input parameter when predicting weld geometries. This is to be expected for any given welding setup due to the influence of the travel speed on the heat input [11]. K. Poorhaydari et al [12] investigates the cooling rates estimated by Rosenthal's thick- and thin-plate solutions can be modified by a weighting factor to account for intermediate values of plate thickness. C. S. Pathak and A. D. Saharabudhe [13] Analysis of Thermal Cycle during Multipass Arc Welding Convection and radiation heat loss from the plate surface during multipass gas tungsten arc welding (GTAW) plays a very important role in deciding peak temperature. X. R. Li et al [14] conveniently monitor weld penetration and acquire the needed feedback for weld penetration control, welding parameters and conditions affecting weld penetration were analyzed and specific variables subject to variation and fluctuation were identified. Experiments were conducted to see what parameters affect the weld penetration and what their significances. K. Morita et al [15] study that the measurement of the actual toughness level and the formulation of the relationship between HAZ toughness and chemical compositions, were examined. As for the HAZ toughness measurement, both multilayer weld joints and single-layer weld joints were used .Gooch & Ginn [16] Have examined the effect of varying welding procedures on HAZ toughness of 12%Cr austentic-ferritic steels. Gowrishankar et al [17] have experimentally found the effect of number of passes on the structure and properties of AISI type 316L stainless steel weld prepared by submerged arc welding. They used welded specimens prepared by 5, 9 and

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13 passes to test hardness, tensile strength, ductility, toughness of welds and examine their microstructure. They derived following conclusions from their experimentation. An increase in the number of passes during welding results in an increase in minimum 8 ferrite content in the root region of the weld. Increasing the number of passes increases hardness and tensile strength of welds. Ductility and impact properties of the weld metal decrease with an increase in number of passes during welding. For hardness measuring hardness Rockwell testing machine has easy reading as compared to Vicker test but have large indenter as compared to Vicker [18]. Voigit and Loper [19] have found poor weldability for ductile cast iron due primarily to the formation of high carbon content martensite and massive iron carbide in the heat-affected zone and partial fusion zone, respectively. Even after post weld annealing, a fine distribution of secondary graphite particles in the heat- affected zone can prevent the weldment from attaining base metal toughness and ductility. Notch position on the HAZ with an angle of 22.30 degree gives best result for impact strength of HAZ [20]. The fatigue crack propagation in friction stir welded 2024-T351 aluminum is due to residual stresses and there is variation in HAZ properties [21]. The hardness of heat affected zone depends on the grain size smaller the grain size more will be hardness of the material. The final microstructure of a section of a HAZ depends upon several factors including composition, grain size, peak temperature attained, heating and cooling rates, etc. Although it is often said that the HAZ of a weldment is its heat treated part, but there is considerable difference between welding and heat treating of, say steels.

Near the fusion boundary of a weld, where difficulties such as grain coarsening and under bead cracking often arise, the peak temperature can reach up to 1400^{0}C or even higher. In the heat treating of steels, on the other hand the maximum temperature involved is usually around 950-1050^{0}C.With increase in heat input the finer grain size formed and reduces with no of passes [22,26]. Carbondioxide give good result shielding gas for plain carbon steel and spattering is influenced by arc voltage. The spatter losses are small at low voltage as 24. Shielding gas affects the finishing of the weld [23, 24]. Change in groove angle result in metal deposing and reinforcement at 30 degree for thin plate up to 8-10mm single V groove and double V groove for thicker plates [25]. A slower cooling rate causes widening of HAZ, i.e., larger volume of metal affected due to heat. In the case of low carbon steel weldment their crystallization is accomplished within a relatively narrow temperature range, at the rate dependent on the method of welding and application of arcs linear energy.

3. Experimental Procedure

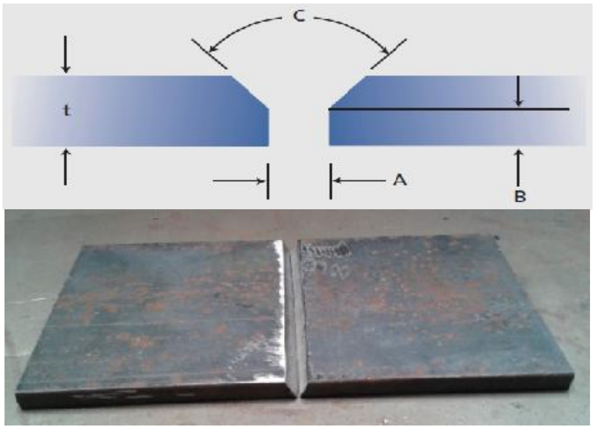
The objectives of this investigation were as follows:

To study the effect of varying process parameters **current, voltage and number of passes** on the following mechanical properties and heat affected zone of the material

- The hardness of HAZ
- Tensile strength of the test specimen
- The microstructure of HAZ
- Impact strength

Preparation of Specimens

Mild steel flats of thickness 6mm, 8mm were cut into pieces of dimensions of 90 mm. x 100 mm. Surfaces of the all samples were cleaned mechanically and finished for a single V-edge of 6o degree as shown in Fig. The angle c is taken as 60˚, root gap A be 1-1.5mm and land B is taken as 1.5-2mm,



Single “V” Joint

Fig. 3.1(a & b Edge Preparations)

The specimens were cut from the welded joint as shown in the Fig. and finished for standard dimension for mechanical and microstructure testing. The samples were cut 10mm from each side as the probability of defects is more in that area.

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4. Result and discussion

Effect of Voltage on penetration:-

By visual observations it was found that with increase in voltage there is also increase in penetration.

Effect of Voltage on hardness:-

As we can see from the graph between distance from the weld centre and hardness at voltage 20V, 22V and 24V there is nearly constant variation of hardness but suddenly the parent metal next to weld metal i.e. HAZ there is increase in hardness because there is a thermal gradient between welding heat and atmospheric temperature due to this sudden quenching by air there is formation of martensitic structure in HAZ causing increase in hardness. As we can see there is increase in HAZ hardness with decrease in voltage.

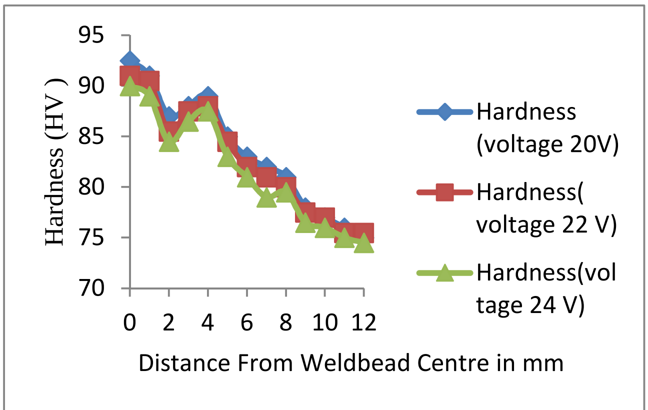

Fig.4.1: Effect of voltage variation with hardness

Effect of Current on hardness:-

Specimens were welded at varying Currents by keeping other conditions contant.

As we can see from the graph with increase in welding current there is also increase in hardness of heat affected zone.

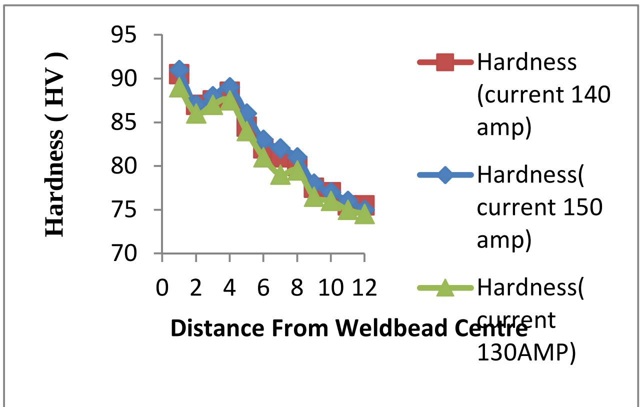

Fig.4.2: Effect of current on hardness

Effect of current variation on tensile strength:- The effect of variation of tensile strength with weld bead at centre is as given in Fig.5.15 It can be seen from the graph that there is decrease in ultimate tensile strength with increasing current.It is also found that reduction in % elongation with increasing current

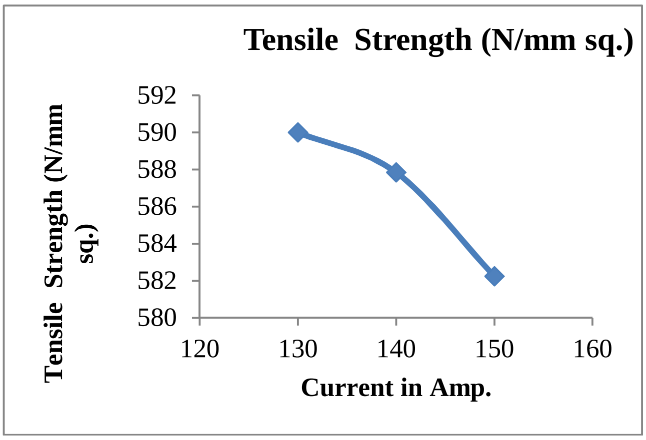

Fig.4.3: Effect of current variation on tensile strength

Effect of varying number of passes on hardness:-

Specimens of 8mm were welded for one, two and three passes keeping other conditions constraint. From the graph we can say that there is decrease in hardness of HAZ with increase in number of pass. It is also due to the fact that the previous pass performed preheats the work material so the temperature gradient between work and ambient temperature gets reduced.

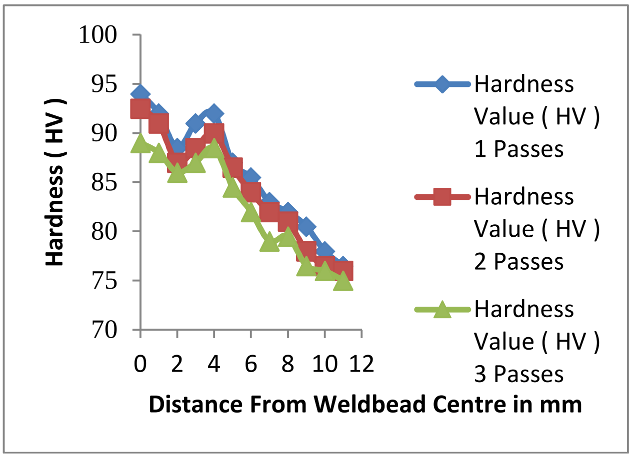

Fig.4.4:Variation of hardness with number of passes

The specimen was welded by making single V grooves. As we can see from the experimentation that for 8 mm thick plate there is also decrease in hardness of HAZ it is also satisfied by its microstructure.

5. Conclusions

By visual inspection it was observed that for increase in voltage there is increase in penetration and there is slight increase in HAZ hardness with respect to increase in Current .So it may be concluded that using higher voltage of 24V better penetration can be obtained. Also the increase penetration has forced to perform rest of multiple pass welding with 24 V and 130Amp current. So 24V and 130Amp current is recommended for welding the specimens. With increase in current from 130Amp to 150Amp there is increase in hardness of HAZ and decrease in ultimate tensile strength was observed and that's why with weld at centre of the specimen the work piece gets fractured from the HAZ With increase in number of pass (from 1 to 3 for 8mm specimen) hardness value of HAZ of welded joints decreases considerably. For increase in number of passes from 1 pass to 3 pass there is increase in impact strength.

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