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Analysis of Weld Bead and Hardness during MIG Welding of Mild Steel

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Abstract: The present investigation on MIG welding machine performed on bright Mild Steel is conducted to establish the influence of welding current, welding voltage and weld speed on hardness and surface quality. The experimental results concluded that hardness is mainly influenced by welding voltage followed by welding current and least by welding speed. In the case of surface quality assessed by SEM, it was found that each parameter has great influence on the quality of surface produced.
Keywords: MIG, Mild Steel, Hardness, Surface Quality

I. INTRODUCTION

Metal-inert gas welding (MIG) is a process of joining metals by melting with the heat generated by arc established between a continuously fed filler wire electrode through the wire reel and the metal workpiece. The molten weld puddle and the arc zone are shielded by inert gases medium of argon or helium or carbon dioxide. Metal inert gas (MIG) is also known as Gas Metal Arc Welding (GMAW) and this method is the most common technique used for mild steels and a smooth metal transfer is observed with low spatter loss and good weld penetrations can be achieved by a stable arc.

Considering the shielding gases, argon, helium or carbon dioxide and their mixtures are used for ferrous and nonferrous metals as well as stainless and alloy steels. Although comparing the arc energies for argon arc, this energy is less uniformly dispersed as compared to helium arc as the lower heat conductivity of argon gas. Hence as a result of this phenomenon, argon arc plasma generally has a very high energy core and it is observed that an outer mantle of lesser thermal energy is seen and by this, a stable, axial transfer of metal droplets through argon arc plasma can be achieved.

Researches were performed earlier in order to assess the performance of MIG welding. Works were carried out on various metals so as to find the optimum MIG welding conditions.

K. Abbasi [1] in their study found that when speed is taken as variable parameters, penetration depth increases with increase in speed upto an optimum value of 1450 mm/min, beyond that speed penetration starts decreasing. These researchers also found that when the heat input is considered, the depth of penetration will increase with heat input till 109 J/min. Beyond this value, the penetration depth will decrease. Patil et al. [2] during the investigation while finding the effect of welding current, welding voltage, welding on the ultimate tensile strength (UTS) of AISI 1030 mild steel material during welding process used Taguchi method for designing the experiments and analysis of variance was employed for studying the welding characteristics of material and optimize the welding parameters.

Chandresh N. Patel et al. [3] in the study of design of experiment methods adopted the grey relational analysis (GRA) optimization technique, where the input parameters for MIG welding selected were welding current, wire diameter and wire feed rate and the performance measure was hardness. Another investigation carried by Ajit Hooda et al. [4], they developed a RSM model for predicting tensile strength of inert gas metal MIG welded AISI 1040 medium carbon steel. Welding voltage, current, and wire speed and gas flow rate were chosen as the parameters of the machine. RSM methodology was applied for optimizing the MIG welding process parameters so as to attain the maximum yield strength of the joint. S.Utkarsh et al. [5] in their investigation studied the influence of input parameter such as welding current, welding voltage, gas flow rate in l/min and welding speed in m/min so as to study the Ultimate Tensile Strength(UTS) of st-37 low alloy steel material in MIG Welding (GMAW). Experiments were carried out by using L9 orthogonal array. Sudesh Verma et al. [6] investigated the optimization of input parameters of metal inert gas welding by using Taguchi Method of experiment design for bead width and bead height. They found that each parameter has influence on the output parameters.

Srivani Valluru et al [7] in their investigation reveals that Weld Area Hardness is much higher than parent metal hardness and less than Heat affected zone Hardness. Sindiri Mahesh and Velamala.Appalaraju [8] through their experimentations concluded that with increase in the levels of the selected parameters for MIG welding of AISI 1050, the strength of welded joint is enhanced and all the selected parameters have impact on the strength of the joint. Rakesh Kumar and Satish Kumar [9] through their research found that the highest tensile strength was achieved at 180 A current, 35 V voltage and 4 mm root gap while the maximum hardness was observed at a welding current of 180 ampere, arc voltage of 40 volt and root gap of 3mm.

II. EXPERIMENTAL DETAILS

1) *Work piece:* The material used for welding is Bright Mild Steel with specification of 25mm×25mm×4mm.
2) *Machine:* ESAB MIGMATIC MIG welding machine available at Punjab Body Builders, Sarojini Nagar, Lucknow.

The present investigation is performed by varying welding current, welding speed and welding voltage so as to analyze the hardness and surface quality of weld produced.

Fig. 1: MIG welded specimens

Table I: Showing Parameters Used For Experimentation On Mig Welding Machine

S.No.	Parameters	Units	Level 1	Level 2	Level 3
1	Welding Current	A	180	230	280
2	Weld Speed	mm/sec	200	300	400
3	Welding Voltage	V	22	24	26

Table III: Showing Experimental Values Of Hardness

Exp. No	Welding Current	Weld Speed	Welding Voltage	Rockwell Hardness HRC
1	180	200	22	60.5
2	180	300	24	62
3	180	400	26	61
4	230	200	24	62
5	230	300	26	59.7
6	230	400	22	62
7	280	200	26	58
8	280	300	22	61
9	280	400	24	60

III. RESULTS AND DISCUSSION

A. *Influence of Parameters on Hardness*

The following table III shows the analysis of variance for hardness of welded specimens. The result shows that the contribution of welding voltage is most and is 40.57%. It is clear from the table that welding voltage is the most influencing parameter for hardness with a contribution of 40.57%. Similar effect is seen in the research of Rajesh [9], where welding voltage was the most dominating parameter for hardness.

The second most dominating factor found for harness of the welded joint is welding current with a contribution of 33.47%. Weld speed is the least influencing parameter for hardness with a contribution of 8.83%.

Table IIIII: Anova Table Of Hardness Of Welded Specimens

Source	DOF	SS	Adj MS	F Value	Contribution
Welding Current	2	4.709	2.354	1.95	33.47%
Weld Speed	2	1.242	0.621	0.52	8.83%
Welding Voltage	2	5.709	2.854	2.37	40.57%
Error	2	2.409	1.204		17.13%
Total	8	14.069			100%

Figure 2(a) shows main effect plot for hardness. It depicts that the Hardness initially have negligible influence with both welding current and welding voltage but with further increase in their levels, hardness tends to decrease. Both these parameters have major influence on Hardness. Moreover, with increase in weld speed, initially hardness increase at a faster pace but with further increase in weld speed the hardness increases at a slower pace. Similar to the condition observed by Rajesh [9], here also the hardness follow the same trend and it first increase with increase in voltage and further it get decreased.

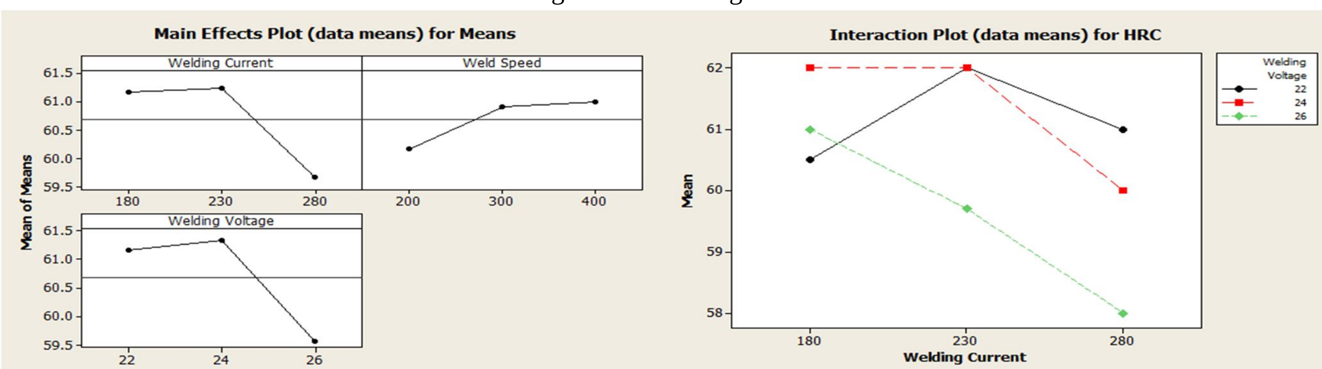

Fig. 2: (a) Main effect plot for Hardness; (b) Interaction plot for Hardness with parameters

The above figure 2(b) shows the interaction of hardness with MIG welding parameters. The plot elucidates that the Hardness decreases with welding current at lower level of welding voltage. With increase in welding voltage level, the hardness obtained is higher but it decreases with increase in welding current. At higher level of welding voltage, initially the hardness obtained is low but with increase in welding current it first increases and then tends to decrease.

B. Discussion on Surface Quality

The below scanning electron microscopy image in figure 3(a) shows the quality of weld obtained at 180 Ampere welding current, 200 mm/sec weld speed and 22 V welding voltage. Image shows the uneven surface at the joint of weld. Few small porous spots are also visible beneath the weld bead near the area where beads of the double 'V' joint weld meet. The porosity is due to some air disturbed the delivery of shielding gas. The MIG welding gun is laid at such an angle that it spreads the gas flow out and actually sucks in the atmosphere from the back side, opposite the nozzle direction.

Fig. 3: (a) SEM image of sample 1; (b) SEM image of sample 3

The above figure 3(b) shows SEM image of specimen 3 shows the quality of weld obtained at 180 Ampere welding current, 400 mm/sec weld speed and 26 V welding voltage. Uneven surface of the weld is seen in the image. Appropriate weld joint is obtained at the present set of experiment. None of the flaws are visible on the surface of the weld and a good weld joint is obtained.
The figure 4(a) shows scanning electron microscopy image of sample 7 image shows the quality of weld obtained at 280 Ampere welding current, 200 mm/sec weld speed and 26 V welding voltage. More dispersed porous spots are observed with the present of experiment and porosity is due to combination of high level of current and voltage. The porous spots are smaller in size as compared to those observed in other set of experiments.

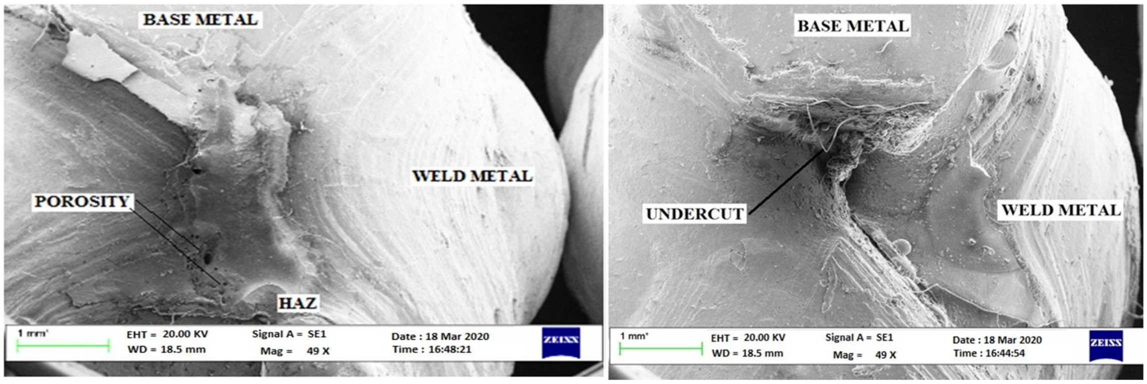

Fig. 4: (a) SEM image of sample 7; (b) SEM image of sample 9

The above figure 4(b) shows SEM image of sample 9 elucidates the structure of weld bead making joint between two MS plates. It is clear from the figure that the base metal is washed away due to the intense heat generated by the welding temperature and is visible in form of undercut. The cause for undercut is high speed of welding (400mm/sec) and excessive heat generation during welding.

IV. CONCLUSIONS

The present experimental investigation describes the optimization of MIG welding parameters on Mild Steel using L9 orthogonal array of Taguchi method. Factors like welding Current, welding voltage and weld speed were considered and their interactions were found for better hardness and better surface quality. Following conclusions are made as per the investigation:

A. Hardness initially has negligible influence with both welding current and welding voltage but with further increase in their levels, hardness tends to decrease.
B. With increase in weld speed, initially hardness increase at a faster pace but with further increase in weld speed the hardness increases at a slower pace.
C. Hardness first increases then get decrease with welding voltage [9]. Here also the same trend is observed.
D. Welding voltage is the most influencing parameter for hardness with a contribution of 40.57%.
E. Welding Voltage is the most dominating factor for hardness [9]. Here also we achieved the same outcome.
F. The second most dominating factor found for harness of the welded joint is welding current with a contribution of 33.47%.
G. Weld speed is the least influencing parameter for hardness with a contribution of 8.83%.
H. The porosity at lower level is due to some air disturbed the delivery of shielding gas. The MIG welding gun is laid at such an angle that it spreads the gas flow out and actually sucks in the atmosphere from the back side, opposite the nozzle direction.
I. At 180 Ampere welding current, 400 mm/sec weld speed and 26 V welding voltage. Uneven surface of the weld is seen but none of the flaws are visible on the surface of the weld and a good weld joint is obtained.
J. At 230 Ampere welding current, 300 mm/sec weld speed and 26 V welding voltage, large porous spots are observed due to some air disturbed the delivery of shielding gas. A 5° to 15° angle, perpendicular to the joint, is an acceptable angle for forehand or backhand methods with MIG welding.
K. At 280 Ampere welding current, 200 mm/sec weld speed and 26 V welding voltage, more dispersed porous spots are observed and porosity is due to combination of high level of current and voltage.
L. At higher level of MIG welding parameters, the base metal is washed away due to the intense heat generated by the welding temperature and is visible in form of undercut. The cause for undercut is high speed of welding (400mm/sec) and excessive heat generation during welding.

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