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The use of Taguchi method to analyze the effect of welding parameters on weldment

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Abstract:- Purpose of this paper to use the Taguchi method and what are the effect of welding parameters on weldment and analysis different test on it. The objective of this paper is to analyze voltage transients associated with MIG 400 welding of IS 5986 Fe410 MS for various plate thicknesses (8 mm, 10 mm & 14 mm) with 100% CO2 as the shielding gas and the relation between these transients and observation is used to analyze the depth of penetration and weld bead geometry. The weld bead geometry plays an important role in determining the mechanical properties of a weld joint. Its geometric parameters such as bead width, reinforcement height, and depth of penetration depends on the process parameters, such as thickness of material, gas flow rate, arc voltage, travel speed. Therefore, it is important to set up proper welding parameters to produce a good weld bead.

Keywords:- ***MIG** 400; Bead geometry; Shape relationships; Mini Tab 15 and Voltage transients.*

I. INTRODUCTION

A review of the available literature reveals many studies relating to the fundamental physical and chemical properties of IS 5986 Fe410 mild steel (MS) [1-4]. Due to its excellent mechanical properties, and the ease with which it may be formed and welded, IS 5986 Fe410 MS is widely used throughout the chemical and automotive industries, nuclear power plants, aircrafts, conveyers, bridges, health care facilities etc. The joining of these parts is often achieved by welding, and consequently, the favourable welding characteristics of IS 5986 Fe410 MS play an important role in its selection as the material of choice. It is recognized that IS 5986 Fe410 MS can be successfully welded using a variety of techniques, including Gas Metal Arc Welding (GMAW), Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW), Flux Cored Arc Welding (FCAW) and Plasma Arc Welding (PAW) [5-6]. With the increase of automation in arc welding, the selection of welding procedure must be more specific to ensure that adequate bead quality is obtained [7-8]. Several researchers have attempted to investigate the effects of various process variables on the weld bead geometry. Also the mechanical strength of welds is influenced by the compositions of the metal and to greater extent by the weld bead geometry and shape relationships and in turn the weld bead geometry is influenced by the direct and indirect welding parameters. The study of weld bead geometry and shape relationships is important as these dimensions and ratios decide to a great extent, the load bearing capacity of weldment. This includes the study of penetration (p), bead width (w), height of reinforcement/crown height (h), ratio of bead width to penetration (w/p) also known as weld penetration shape factor (WPSF) and ratio of bead width to reinforcement height (w/h) also known as weld reinforcement form factor (WRFF) [9]. All these terms are depicted in Figure 1.

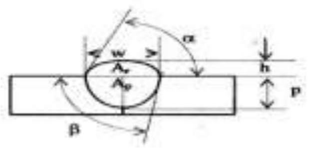
WPSF(w/p)	Weld penetration shape Factor	W	Weld bead width
WRFF(w/h)	Weld reinforcement form factor	P	Weld bead penetration
		h	Weld bead height
		Ap	Area of penetration
		Ar	Areaof reinforcement
		α	Angle of convexity
		β	Angle of entry
		At	Ap + Ar =Total weld bead Area

Fig. 1 Weld bead geometry and shape relationships

The Taguchi method [10, 11] is a systematic application of design and analysis of experiments for the purpose of designing and improving product quality. In recent years, the Taguchi method has become a powerful tool for improving productivity during research and development so that high quality products can be produced quickly and at low cost. However, the original Taguchi method is designed to optimize a single quality characteristic. Furthermore, optimization of multiple quality characteristics is much more complicated than optimization of a single quality characteristic [12, 13]. Improving one particular quality characteristic would possibly lead to serious degradation of the other critical quality characteristics. When the results have a conflict between multiple quality characteristics, it is necessary to rely on the subjective experiences of engineers to attain a compromise [14]. As a result, uncertainty will be increased during the decision-making process. Antony [15] has demonstrated an alternative approach for tackling such optimization problem using Taguchi quality loss function analysis by taking an example of electronic assembly problem. He has found considerable improvement in multiple quality characteristics, in comparison to single quality characteristics.

II. PROJECT DESIGN AND IMPLEMENTATION

In this section it is necessary to present in details assumptions and course of own researches to such an extent that a reader could repeat those works if he was going to confirm achieved results. In short papers those information should be given in as short a version as possible.

A. Experimental Verification

All the weldments in this study were carried out using MIG 400 welding machine. Welding gun was placed perpendicularly to mild steel IS 5986 Fe410 plates. In the welding experiments, a 308L filler wire with a 1.2 mm diameter was used. All experiments were carried out with contact tip to work distance (CTWD) of 20 mm, using pure CO_2 as shielding gas at a three different flow rate i.e. 8 lit/min,10 lit/min & 11 lit/min. A direct current power source was used to perform the bead on plate welds by means of MIG 400 process. ‘Bead on plate’ technique was employed for depositing the weld beads on mild steel plate of thickness 8, 10 & 14 mm using semi mechanized welding station.

B. Design of Approach

The project involves the use of particular software such as MINITAB-15, D-PLOTER and base metal dimensions are 190mm×65mm. According to the Taguchi method there is 9 combination and table design is in L9 orthogonal array with factorial design 3 for four parameters (Thickness of material, gas flow rate, arc Voltage, Travel speed).

Table I: L9 Orthogonal Array

Experiments	Factor 1	Factor 2	Factor 3	Factor 4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	1	3	2	1

Table III: Selection of Parameters Levels

Factors	Level 1	Level 2	Level 3
A:Arc voltage(v)	32	42	45
T:Welding speed(mm/sec)	1	2	3
G : Gas flow rate(lit/min)	8	10	11
TH:Thickness of material(mm)	8	10	14

Table IIIII: Experimental Layout

Exp. No.	A (V)	WS (mm/sec)	G (lit/min)	TH (mm)
1	32	1	8	8
2	32	2	10	10
3	32	3	11	14
4	42	1	10	14
5	42	2	11	8
6	42	3	8	10
7	45	1	11	10
8	45	2	8	14
9	32	3	10	8

III. TESTING OF WELDMENTT

Macrostructural Test- The weld bead samples are cut from each weld bead at 15 mm intervals, with the first sample being located at 15 mm behind the trailing edge of the crater end to eliminate the end effects. The transverse faces of the specimens were further prepared for study of weld bead geometry. Specimens were polished with various grades of emery papers, starting with 150, 180, 320, 400, 800, 1200 and SIA Sianor B 1600. Water was used as coolant.

Finally the specimens were etched with mixture of three parts of HCl and one part of HNO3. All the test specimens were washed off with water to reveal the geometry of the weld bead. Several critical parameters, such as bead penetration, bead width & bead heights were measured by projecting it on the micro profilometer.

Chemical Equation:

$$HNO_3\,(aq) + 3\,HCl\,(aq) \longrightarrow NOCl\,(g) + Cl_2\,(g) + 2\,H_2O\,(l)$$

Aqua Regia

From macrostructural test it can be observed that the surface of the welded plate is clean and good. The weld zone, if free from cracks for all the experimental runs is considered for profile measurement. Spatter and discontinuities are also not observed in the welded sample. This is confirmed that not only based on the visual inspection and also by liquid penetration test. The experimental results for the weld bead profiles are presented in Table 4.

IV. RESULT AND ANALYSIS

Table IVV: Experimental Results

EXP. NO.	DEPTH OF PENETRATION (mm)	WIDTH (mm)	REFORCEMENT HIGHT (mm)
1.	0.2	4.8	3.66
2.	0.4	5.6	3.95
3.	1.5	7.05	4.55
4.	2.4	6.1	4.22
5.	0.6	6.62	5.63
6.	1.2	7.2	5.77
7.	0.7	5.7	4.78
8.	1.0	6.4	4.9
9.	0.9	5.55	5.2

In that section it is necessary to present achieved results of own researches in details e.g. researches or calculations illustrating them in details and legibly by pictures, diagrams, photos eg. metallographical ones, results, calculations, tables etc. and giving in details casual and result relations between stated facts confirming or excluding data known from the literature. That section should have a character of a scientific discussion, although in order to do that the separate section can be created and in the given one only the information about achieved results of researches can be included. In short papers you should rather limit yourself to a discussion.

A. Analysis of Result

- **Effects of process parameters on penetration**- The graphs of welding speed vs. penetration were drawn using Table 3 and Table 4. In 32 V, 42 V & 45 V constant arc voltages for 8 mm, 10 mm and 14 mm plate thickness respectively as shown in Fig. 2. The depth of penetration increases with increasing welding speed up to 3 mm/sec. The graph of gas flow rate vs. penetration was drawn using Table 3 and Table 4. With 32 V, 42 V and 45 V constant arc voltage and gas flow rate of 8 lit/min, 10 lit/min and 11 lit/min values for 8 mm, 10 mm and 14 mm plate thickness respectively as shown in Fig. 3. The depth of penetration increases with increasing gas flow rate up to 11 lit/min.

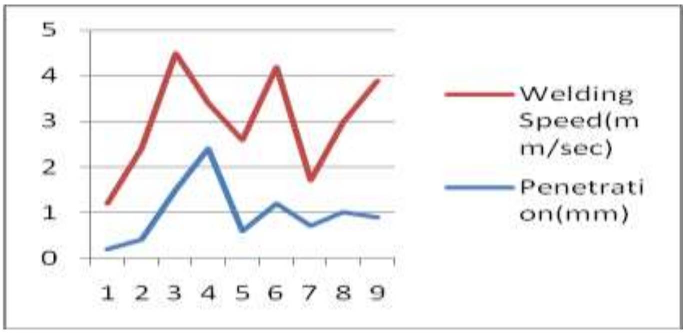


Fig. 2 Penetration vs. Welding speed for all plate thickness

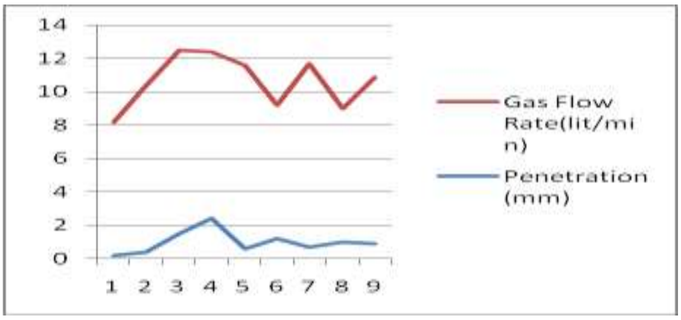


Fig. 3 Penetration vs. Gas flow rate for all plate thickness

- **Effects of process parameters on weld bead width-** Weld bead width increased from 4.8 mm to 6.62 mm, 5.6 mm to 7.2 mm, 6.1 mm to 7.05 mm, for 8 mm, 10 mm and 14 mm plate thickness respectively when gas flow rate was increased from 8 lit/min to 11 lit/min as shown in Fig. 4.
  Weld bead width decreased from 6.62 mm to 4.8 mm, 7.2 mm to 5.6 mm and 7.05 mm to 6.1 mm for 8 mm, 10 mm and 14 mm plate thickness respectively when welding speed was increased from 1mm/sec to 3 mm/sec as shown in Fig. 5.

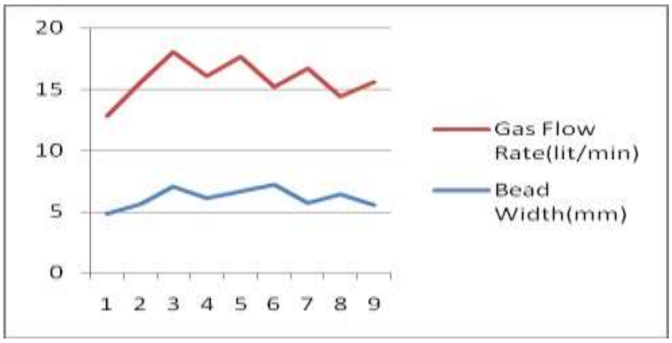


Fig. 4 Bead width vs. Gas flow rate for all plate thickness

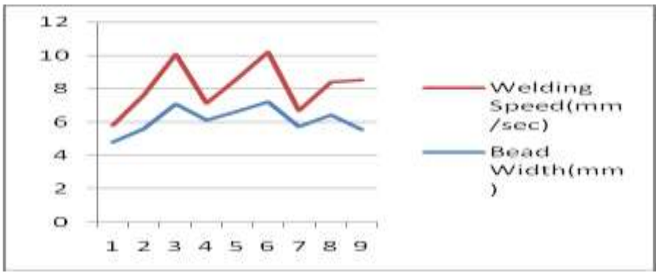


Fig. 5 Bead width vs. welding speed for all plate thickness

- **Effects of process parameters on reinforcement height-** Reinforcement height increases from 3.66 mm to 5.63 mm, 3.95 mm to 5.77 mm and 4.22 mm to 4.9 mm for 8 mm, 10 mm and 14 mm plate thickness respectively when

gas flow rate was increased from 8 lit/min to 11 lit/min as shown in Fig. 6.
The reinforcement height decreased from 5.63 mm to 3.66 mm, 5.77 mm to 3.95 mm and 4.9 mm to 4.22 mm for 8 mm, 10 mm and 14 mm plate thickness respectively when welding speed was increased from 1mm/sec to 3 mm/sec as shown in Fig. 7. This could be due to the fact that weld pool size is affected by cooling rate, which can decrease by increasing the current or by decreasing the travel speed. Details are shown in Table 3 and Table 4.

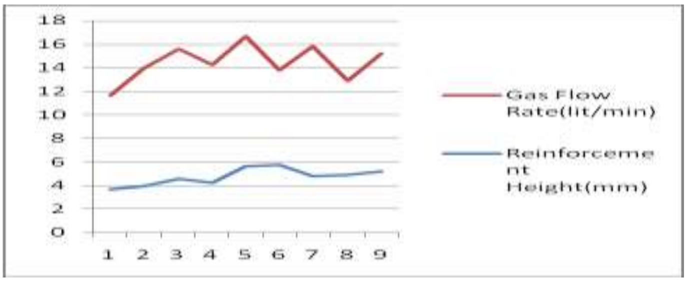


Fig. 6 **Reinforcement height vs. Gas flow rate for all plate thickness**

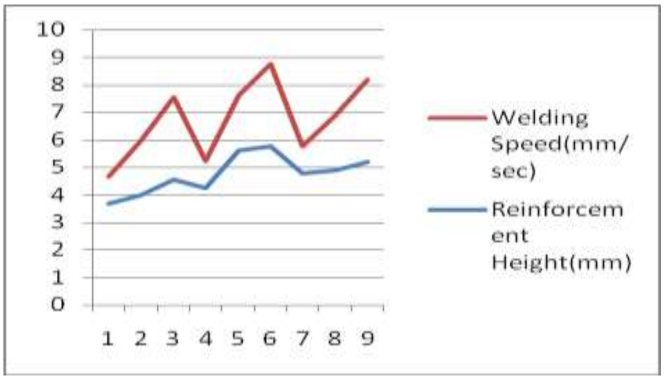


Fig. 7 Reinforcement height vs. welding speed for all plate thickness

V. CONCLUSIONS

Following conclusion was drawn from this analysis:

1. The depth of penetration increases with increasing welding speed up to 3 mm/sec point which was the optimum value to obtain maximum penetration, because it begins to decrease after this point again linearly. The depth of penetration increases with increasing gas flow rate up to 11 lit/min point which was the optimum value to obtain maximum penetration, because it begins to decrease after this point again linearly.
2. Weld bead width increases when gas flow rate increases from 8 lit/min to 11 lit/min. Bead width increases when current is increasing from low level to high level. But, weld bead width decreases when welding speed increases from 1 mm/sec to 3 mm/sec.
3. Reinforcement height increases when gas flow rate increases from 8 lit/min to 11 lit/min. Reinforcement height also increases when current was increased from low level to high level. Reinforcement height decreased when welding speed is increases from 1 mm/sec to 3 mm/sec.

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