An Analytical Approach towards the Interactive Behavior of the Confounded Parameters of Submerged Arc Welding Process for Mild Steel Plates

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ABSTRACT

This paper deals with the Study of the Interactions of the Confounded Parameters of Submerged Arc Welding Process for Welding Mild Steel Plates of Higher thicknesses. Here the thickness of the plate is more than 10 mm. This experimental study was conducted at the workshop of Indian School of Mines, (Dhanbad). For this study MEMCO semiautomatic welding equipment with constant voltage rectifier was used. Specifications are as below:

- Input voltage supply- 380/440 volts
- Welding speed Trolley-30 to 1200 mm/min
- 3 Phase,50/60 Hz cycle, Air cooled
- Wire feed speed-100 to 8000 mm per minute.
- Output current 600 amps
- Wire diameter -2 to 5 mm
- Duty cycle 100%
- Open circuit voltage 56 Volts, 35 Kva
- Flux hopper capacity 12.5 kg
- Deposition rate- 4 to 6 kg/hr
- Wire flux ratio-1: 1
- Flux used: ADOR Auto melt GrII AWS/SFA 5.17(Granular flux)
- Test Piece: 190mm X 90mm X 12mm
- Weld position flat
- Electrode positive and perpendicular to the plate.

The SAW process has been chosen for this application because of the complex set of variables involved in the process. Submerged arc welding (SAW) is a high quality, very high deposition rate welding process commonly used to join plate. SAW is usually operated as a fully mechanized or automatic process, but it can be semi-automatic also Submerged arc welding provides a purer and cleaner high volume weld which is also faster than traditional welding methods. The SAW process is much more critical because of its application in welding critical parts, equipments and machinery which have huge economic and social implications. Welding parameters: current, arc voltage and travel speed all affect bead shape, depth of penetration and chemical composition of the deposited weld metal. Because the operator cannot see the weld pool, greater reliance must be placed on parameter settings.

In this study the parameters among current, arc voltage, and travel speed were varied and then the readings for penetration, bead width, metal deposition rate and time were taken. Welding parameters were noted during actual welding to determine the fluctuations. The same procedure is repeated many times to achieve more accurate results. On the bases of these readings graphs were plotted between the parameters to study the interactions of the parameters with each other. The main objective being to identify the main input factors, to determine the interactions amongst the input factors and finally to establish the optimum settings for the input factors the response output being weld bead parameters.

Keywords - SAW, Confounded Parameters, Bead Parameters.

INTRODUCTION

Submerged arc welding (SAW) is a high quality, very high deposition rate welding process commonly used to join plate. Here an arc is formed between a continuously-fed wire electrode and the work piece, and the weld is formed by the arc melting the work piece and the wire. The arc is completely submerged under a blanket of granular, fusible flux which adequately shields the arc from atmospheric contamination.

During welding the intense heat of the arc simultaneously melts the tip of the bare wire electrode and a part of the flux. The electrode tip and the welding zone are always surrounded and protected by molten flux, while all of them are covered by the top layer of unfused flux. As the arc progresses along the joint, the molten metal settles down while the lighter molten flux rises from the puddle in the form of slag.

The weld metal, having a higher melting point solidifies first while the slag above it takes some more time to freeze. The solidified slag continues to protect the weld metal while it is still hot, and is capable of reacting with the atmospheric oxygen and nitrogen. After the weld has solidified; the unfused flux is removed manually or by a vacuum pick up system, to be screened and reused.

In SAW, a shielding gas is not required as the layer of flux generates the gases and slag to protect the weld pool and hot weld metal from contamination. Flux plays an additional role in adding alloying elements to the weld pool The process can be fully automatic or semi-automatic.

In fully automatic welding, the flux is fed mechanically to the joint ahead of the arc, the wire is fed automatically to the welding head, and the arc length is automatically controlled and the transverse of the arc or the work piece is also mechanized.

In semi-automatic version, the wire feed and the arc length are automatic, while the welder moves the welding gun, usually equipped with a flux feeding device, along the joint at a controlled rate of travel. Flux may also be applied in advance of the welding operation or ahead of the arc from a hopper run along the joint.

The submerged-arc welding (SAW) process is popular because of its ability to match the chemistry and physical properties of the base material. This ability allows a multitude of possible weld-wire and flux combinations. These combinations can be easily sorted and matched to specific applications.

P Lazzarin et.al.,[13] has discussed about the notch stress intensity applied to fatigue life prediction of welded joints. They have emphasized on crack initiation life in relation to the welded toe geometry. The other parameters related to welding like voltage current, diameter of the electrode are not considered & their interactions are not studied. Bechet et.al., [1] carried out investigation on wear behavior of bulldozer rollers welded using a SAW process. They considered only wear as a yield of SAW where the other yields like strength of welds, heat affected zones, and deposition rate are to be critically investigated. Trindade et.al., [14] argued about the influence of zirconium on microstructure and toughness of low alloy steel weld metals. He stressed on microstructure and toughness as the weld parameter in comparison to the other yield like material deposition rate, heat affected zone and longitudinal strength of the weld. Gunaraj et al, [9] argued about the prediction and control of weld bead geometry and shape relationships in submerged arc welding of pipes. He stresses on the weld bead geometry, and shape relationships. Kanjilal et al, [11] discusses about the combined effect of the flux and welding parameters on chemical composition and Mechanical properties of submerged arc weld metal. He stresses on the rotatable mixture designs, heat input, electrochemical reaction etc. Jerzy et al, [5] investigated the influence of welding heat input on submerged arc welded duplex steel joints imperfections. He stresses on the welding heat input, butt joints defects and radiographic test. Tuek et al,[15] studied about the weld cost saving accomplished by replacing single wire submerged arc welding with triple wire welding. Sterjovski et al, [16] argued about the evaluation of cross weld properties of quenched and tempered pressure vessel steel before and after PWHT (Post weld heat treatment). He stresses on PWHT and residual stresses. Kim et al, [4] discusses about the prediction of welding parameters for pipeline welding using an intelligent system. In his study he mainly stresses on pipeline welding based on one database and a finite element method (FEM) model, and on two back-propagation (BP) neural network models and a corrective neural network (CNN) model was developed and validated.

Zhao et al, [10] investigated about the numerical simulation of the dynamic characteristics of weld pool geometry with step changes of welding parameters. Under his study he developed a three-dimensional numerical model to investigate the dynamic characteristics of the weld pool geometry when the welding current and welding speed undergo a step-change. Menaka et al, [7] argued about the estimating bead width and depth of penetration during welding by infrared thermal imaging. The study highlights the estimation of bead width and depth of penetration during Tungsten Inert Gas (TIG) welding using infrared thermal imaging.

After going through the books and reference material and holding detailed discussions with the welding shop personnel operators and instructors the possible factors affecting the weld joint was arrived at. The above figure gives the detailed list of factors under various heads.

The output variable was decided based on the guidelines in the reference material. The bead parameters were considered for measuring the response output.

Three output parameters considered are:

1. P-Penetration(mm)
2. H- Reinforcement height(mm)
3. W-Width(mm)

Sample Preparation for the Experiment

Now the first thing for conducting the experiment was to prepare the sample for experiment. For this purpose a long mild steel piece was selected and was brought to the welding shop for cutting it to the required dimensions and shape. The mild steel piece was having thickness more than 10mm. Now here with the help of oxy-acetylene flame it was cut in the desired length. After cutting it into pieces it was left for cooling. After few hours of cooling the pieces were welded in pairs so that they remain together during the experiment. This was done with the help of welding. These samples were having a V-groove over which submerged arc welding was to be done.

Now the initial weight of each sample was taken and noted. Also the Submerged Welding Machine was started. Flux was filled in the machine so that there may be no problem in between the experiment. The machine was fully automatic. Now the welding was done on each sample. The welding parameters travel speed, current, voltage were varied each time. Total time taken during the welding was noted and weight after each welding was also taken.

CONDUCTING THE EXPERIMENT

This experimental study was conducted at ISM workshop (Dhanbad). For this study MEMCO semiautomatic welding equipment with constant voltage rectifier was used.

The welding parameters were noted during actual welding to determine the fluctuations if any. The slag was removed and the job as allowed to cool down. The values of the reinforcement height, and width were taken using vernier caliper of least count 0.02mm. And metal deposition rate was also calculated with the help of stop watch and weighing machine. Finally the readings obtained are tabulated as below:

With the help of the above data graphs were plotted between the welding parameters to study the interactions among them.

EXPERIMENTAL SETUP

This experimental study was conducted at Indian School of Mines workshop (Dhanbad). For this study MEMCO semiautomatic welding equipment with constant voltage rectifier was used. The welding parameters were noted during actual welding to determine the fluctuations if any. The slag was removed and the job as allowed to cool down. The values of the reinforcement height, and width were taken using vernier caliper of least count of 0.02mm and metal deposition rate was also calculated with the help of stop watch and weighing machine. Finally the readings obtained are tabulated as below:

CONCLUSION

Effect of Travel Speed (B) On Bead Parameters

Travel speed has a negative effect on all the three bead parameters.

An increase in travel speed substantially reduces the heat input resulting in lower burn off rate. This reduced burn off rate decreases the metal deposition at the weld joint thereby lowering all the three bead parameters i.e. penetration, reinforcement height and the width.

Effect of Current (E) On Bead Parameters

It is seen that the penetration increases with increase in the current, the reinforcement height also increases marginally with an increase in the current but the width decreases i.e. it has a negative effect. The increase in current results in decreasing arc length as well as prevents the spreading of the arc cone; which results in higher melting temperature at the tip and parent material, resulting in deeper penetration at the cost of bead width. The decrease in bead width helps in marginally increasing the reinforcement height.

Effect of Voltage (V) On Bead Parameters

It is generally observed that as the arc voltage increases, the weld bead becomes wider and flatter and the penetration decreases.

The effects of changing voltage are explained as follows :

1 **Increasing the voltage**

Produces a flatter and wider bead.

Increases flux consumption.

Helps bridge up the gap when fit up is poor.

Increases the pick up of the alloy from the flux: this can be used to advantage to raise the alloy content of the weld when welding is performed with alloy or hard surfacing fluxes.

2 **Excessively high voltage.**

Produces poor slag removal in groove welds.

Produces a hat shaped bead that is subject to cracking

Increases undercut on fillet welds.

3 **Lowering the voltage**

Produces a stiffer arc needed for getting penetration in a deep groove and to resist arc blow on high speed work

4 **An excessively low voltage**

Produces a high, narrow bead with poor slag removal.

Future Direction of Work

Often the first results are just learning experiences. This dissertation study has been an earnest effort to understand the submerged arc welding process and to identify the major factors which affect the welding process as well as to determine the interactions among the various factors and the optimum settings for the factors. Although the best combination arrived at the higher limits of current and wire feed rate and lower limits of travel speed and stick out provides a good sub optimal solution but this study can be extended further to optimize the solution further.

Response outputs can be expanded to include parameters such as tensile strength, shear strength, hardness and porosity of weld joint.

Non linear programming or any other search heuristics or algorithm can be used to further improve the solution by using the sub optimal solution as the input values.

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Sl. No.	Travel Speed	Voltage (in volts)	Current (in amphere)	Reinforcement Height (mm)	Bead Width (mm)	Metal Deposition Rate (gm/sec)
1	25	25	300	3.2	13.0	0.810
2	28	26	320	2.0	12.5	0.909
3	24	28	280	2.6	13.0	0.759
4	27	24	300	3.5	13.6	0.550
5	20	20	400	5.0	11.7	1.500

Table 1 :

Travel Speed (cm/min)	Metal Deposition Rate (gm/sec)	Bead Width (mm)	Reinforcement Height (mm)
20	1.5	11.7	5.0
24	0.759	13.0	2.6
25	0.81	13.0	3.2
27	0.55	13.6	3.5
28	0.909	12.5	2.6

Table 2 : Effect of Travel Speed on welding Parameters

Current (Amphere)	Metal Deposition Rate (gm/sec)	Bead Width (mm)	Reinforcement Height (mm)
280	0.759	13.0	2.6
300	0.55	13.0	3.2
300	0.81	13.6	3.5
320	0.909	12.5	2.0
400	1.5	11.7	5.0

Table 3 :

Voltage (volts)	Metal Deposition Rate (gm/sec)	Bead Width (mm)	Reinforcement Height (mm)
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24	0.759	13.0	2.6
25	0.81	13.0	3.2
27	0.55	13.6	3.5
28	0.909	12.5	2.0

Table 4 :

INVESTIGATION PLAN AND ANALYSIS

INPUT FACTORS AND THEIR LEVELS

ISHIKAWA DIAGRAM

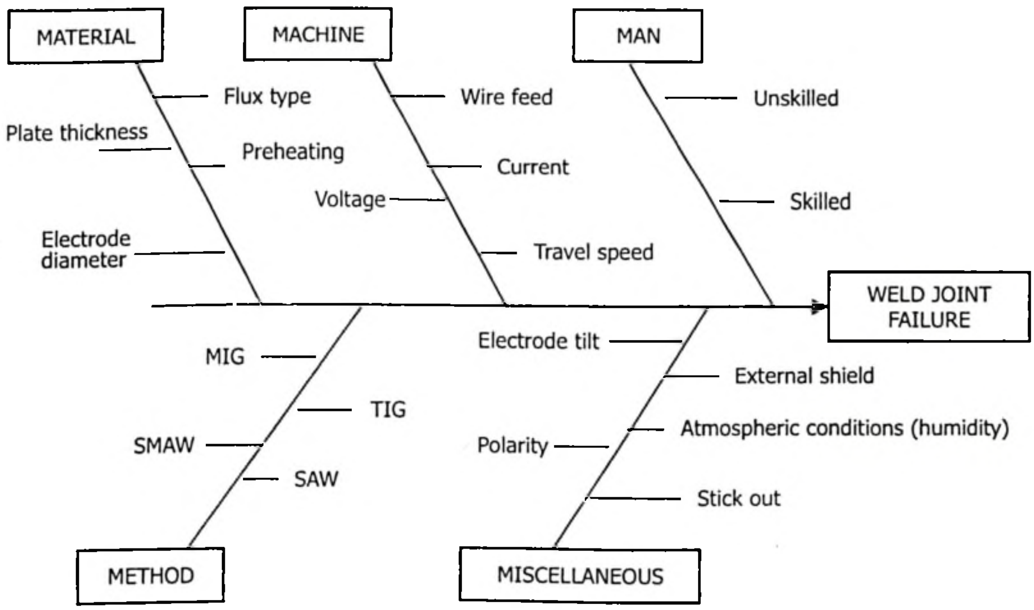


Figure 1

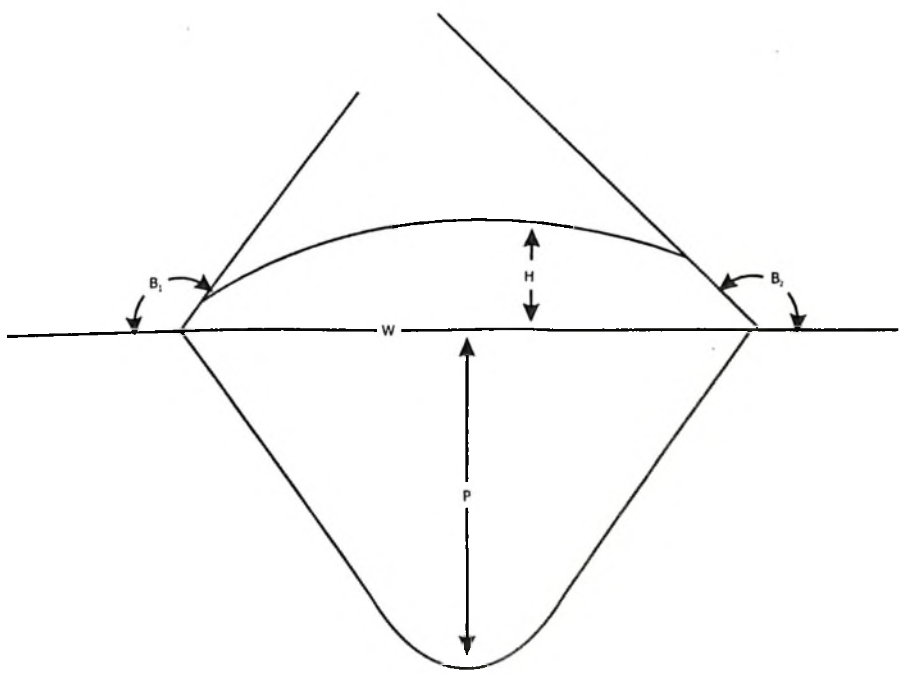
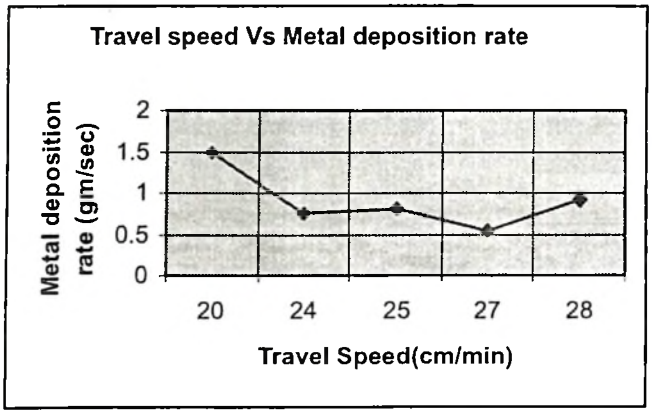
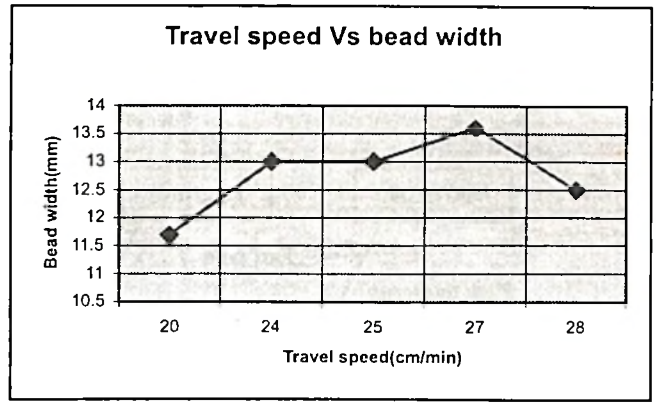


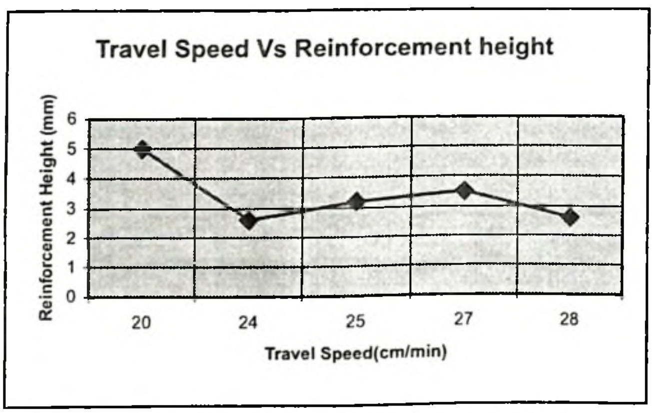
Figure 2 : Weld Bead Profile



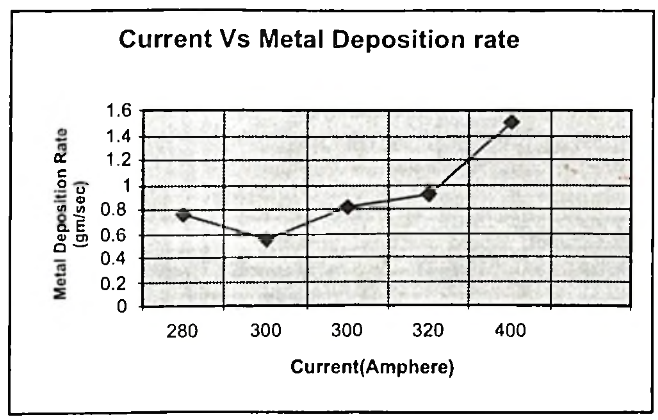
Graph 1 : Effect of Travel Speed on Metal Deposition rate



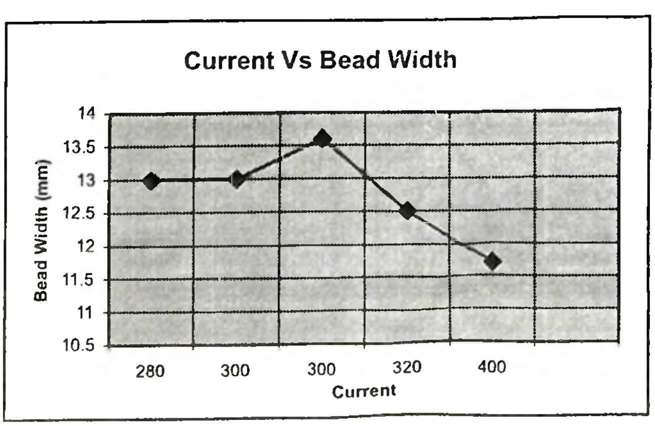
Graph 2 : Effect of Travel Speed on Bead Width



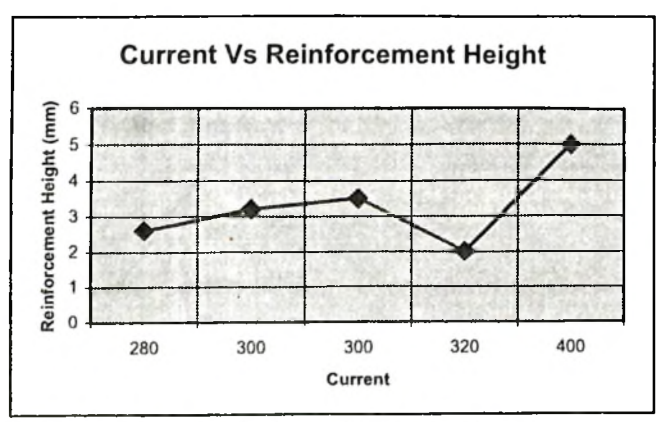
Graph 3 : Effect of Travel Speed on Reinforcement Height



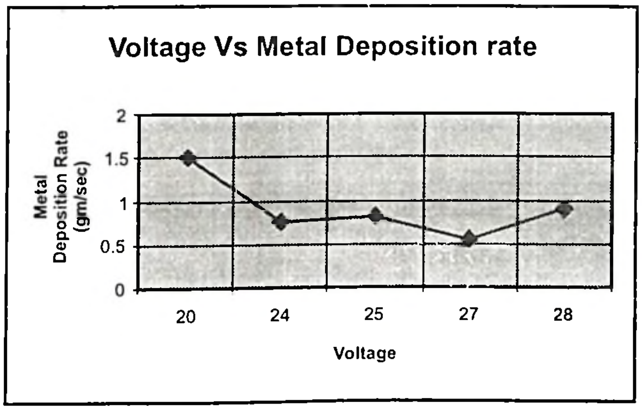
Graph 4 : Effect of Current on Metal deposition rate



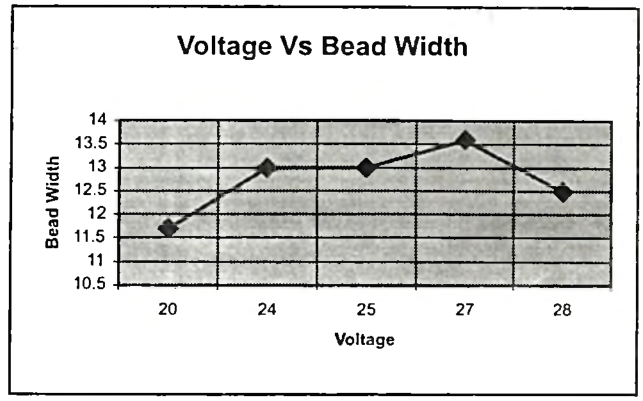
Graph 5 : Effect of Current on Bead Width



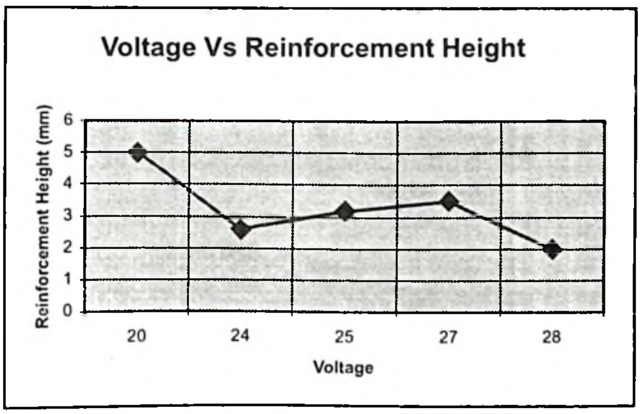
Graph 6 : Effect of Current on Reinforcement Height



Graph 7 : Effect of Voltage on Metal deposition rate



Graph 8 : Effect of Voltage on Bead Width



Graph 9 : Effect of Voltage on Reinforcement Height