# Investigating the effect of Process Parameters in Shielded Metal Arc welding (SMAW) for Joining Stainless Steel 304 L and Mild steel

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***Abstract:*** In this work, emphasis is given on investigating the influence of process parameters in Shielded Metal arc welding process for joining dissimilar metals like Stainless Steel 304 L and Mild Steel which are extensively used in fabrication industries for manufacturing the ships and boiler accessories such as Air preheater, economizer , Feed water heater and Deaeriator tanks .Welding current, Welding speed, Electrode angle, root gap are taken as input process parameters while Metal Deposition rate, Welding strength and Weld bead geometry are considered as output parameters. Taguchi L9 array is used for conducting the experimental trial and result obtained are analyzed by using Taguchi method. The main effect plots are used to decide the operating range of process variables which are required in next part of the research. Form the analysis , the significant operating ranges are Welding Current (80-120 Ampere), Welding speed ( 5-8 mm/s), Root gap ( 1-1.5 mm) and Electrode angle ( 30 -90 degree).

***Keywords:*** Dissimilar metals, Metal Deposition rate, shielded metal arc welding, Taguchi Method, Welding strength

## 1. INTRODUCTION

Shielded (Manual) metal arc welding is very offenly used primary manufacturing method in various Fabrication industries due to its simplicity and handy equipment. To survive in global competitive world, fabrication industries are using various dissimilar metals to trade off between the quality and cost. The dissimilar metal welding is commonly used in Power Industries, Oil and refineries, Automobile Industries [1-5]. But welding dissimilar metals by any fusion welding process is tough task because of their different Metallurgical and Mechanical properties. There is a carbon transfer from higher Carbon containing alloy to the relatively lower carbon alloy steels, resulting in differences in thermal residual stresses across the different regions of weldment. [1,2,6]. The dissimilar metals commonly used in many industries are stainless steel 304 L is having a good resistance to wear and corrosion and mild steel which is having good tensile and impact strength with availability at low cost [1,8]. While welding stainless steel 304L with mild steel by using shielded metal arc welding, the most commonly used coated electrodes are ER 309L , ER 2209, AWS:E3081-16, AWS: 6013[5,8]. In this work emphasis is given on obtaining the robust shielded metal arc welding process for joining dissimilar metals stainless 304L and Mild Steel which is having good bead geometry, Maximum Welding strength, and minimum Metal deposition rate with joint free from all type of welding defects. Process variables that are considered in this analysis are Welding current (Amperes), Welding speed (mm/sec), Electrode angle (Degree) and root gap. By using Minitab15 software's, Taguchi Method-main effect plot, the significant operating range of factors will be defined to obtain the optimum output parameters in the next step of research.

## 2. Experimental Set Up

Experimentation work is carried out at Prabhu Vaishnav Industries; engaged in manufacturing the Boiler accessories like superheater, Economiser, Airpreheater, Feed water heater. Stainless steel 304 L and Mild Steel 3 mm thick sheet are sheared in size of 100 mm x50 mm x3 mm and ER 309L coated electrode of 3.15 mm diameter is used to join the dissimilar metals. Chemical composition of both metals are shown in Table1

**Table 1 Chemical Composition of Stainless Steel 304L and Mild steel**

| Material | C | Si | S | P | Cr | Ni | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| SS 304 L | 0.03 | 1.00 | 0.003 | 0.045 | 18.00 | 8.000 | 2.00 | Balance |
| Mild steel | 0.18 | 0.11 | 0.100 | - | 0.020 | 0.016 | 0.39 | Balance |

Experimental runs are conducted by using Taguchi L9 orthogonal array by considering 4 factors and 3 Levels as: Welding Current (80A, 120A, 160A), Welding Speed (5mm/s,8mm/s,13mm/s), Electrode angle ( $30^0$ , $60^0$ , $90^0$), Root gap (1mm,1.5mm,2mm), as shown in Table 2.

**Table 2 Taguchi L9 array for conducting experimental runs (Design Matrix)**

| Trial Number | Welding Current | Welding Speed | Electrode Angle | Root Gap |
|---|---|---|---|---|
| 1 | 80 | 5 | 30 | 1.0 |
| 2 | 80 | 8 | 60 | 1.5 |
| 3 | 80 | 13 | 90 | 2.0 |
| 4 | 120 | 5 | 90 | 1.5 |
| 5 | 120 | 8 | 30 | 2.0 |
| 6 | 120 | 13 | 60 | 1.0 |
| 7 | 160 | 5 | 60 | 2.0 |
| 8 | 160 | 8 | 90 | 1.0 |
| 9 | 160 | 13 | 30 | 1.5 |

The plates of Stainless Steel 304L and Mild steel are welded by using double butt joint with the help of, ARC200 Dc inverter welding machine as shown in figure 1.


**Figure 1 Plate joining fixture and Welding Machine ARC200 DC**

After joining the plates, output variables are measured and recorded in Table 3. Metal deposition rate (gm) is measured by taking weights of plates before welding and after welding. Difference in weights of plate will give metal deposition rate in grams. Welding strength (MPa) is measured by using universal testing machine (40 KN Capacity) and Bead geometry (Bead height) is measured by using Profile projector machine in mm. value recorded in table 3 are analysed by using Minitab 15 software.

**Table 3 Taguchi L9 array with output variables value recorded**

| Trial Number | Welding Current | Welding Speed | Electrode Angle | Root Gap | Metal deposition rate (gm) | Welding strength (MPa) | Bead Height (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 80 | 5 | 30 | 1 | 5.34 | 416.66 | 5.68 |
| 2 | 80 | 8 | 60 | 1.5 | 3.51 | 413.66 | 4.54 |
| 3 | 80 | 13 | 90 | 2 | 2.03 | 374.66 | 4.26 |
| 4 | 120 | 5 | 90 | 1.5 | 5.39 | 429.33 | 5.30 |
| 5 | 120 | 8 | 30 | 2 | 4.03 | 402.66 | 4.80 |
| 6 | 120 | 13 | 60 | 1 | 2.42 | 417.33 | 5.10 |
| 7 | 160 | 5 | 60 | 2 | 3.55 | 302.66 | 5.42 |
| 8 | 160 | 8 | 90 | 1 | 3.11 | 398.66 | 4.92 |
| 9 | 160 | 13 | 30 | 1.5 | 2.16 | 401.33 | 5.20 |

## 3. Result and Discussion

Table 3 is copied in Minitab 15 software worksheet and Taguchi analysis is done for metal deposition rate as response, by considering Signal to noise ratio as minimum is better. **Figure 2** show effect of input variable (welding current, welding speed, root gap and electrode angle) on Metal deposition rate. Welding speed has maximum effect, followed by welding current and electrode angle, while root gap is having minimum effect on metal deposition rate.

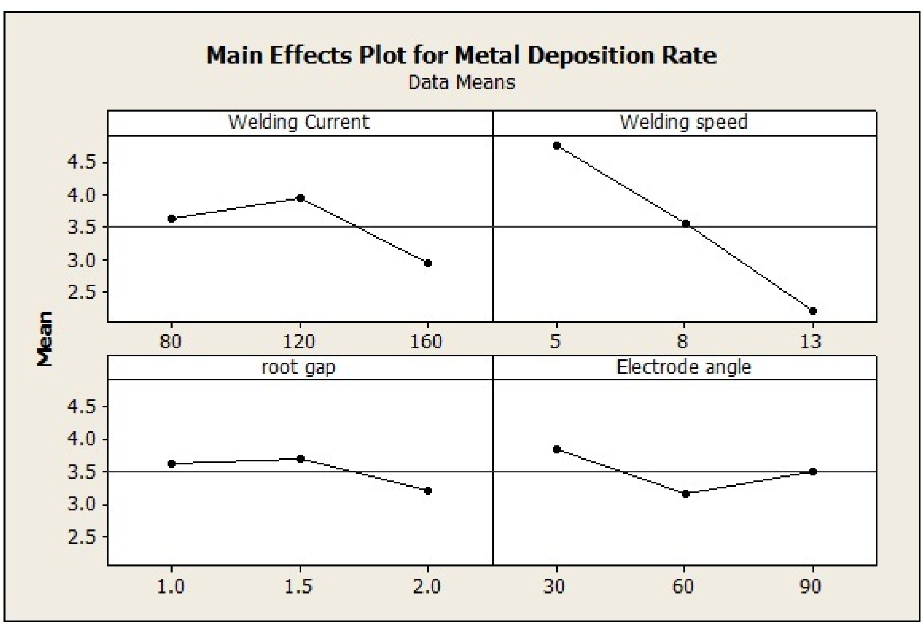


**Figure 2 Main effect plot for Metal Deposition rate**

Similarly, Taguchi analysis is done for Welding strength as response, by considering Signal to noise ratio as maximum is better. **Figure 3** represents the effect of process variables (Welding current, welding speed, root gap and electrode angle) on welding strength.

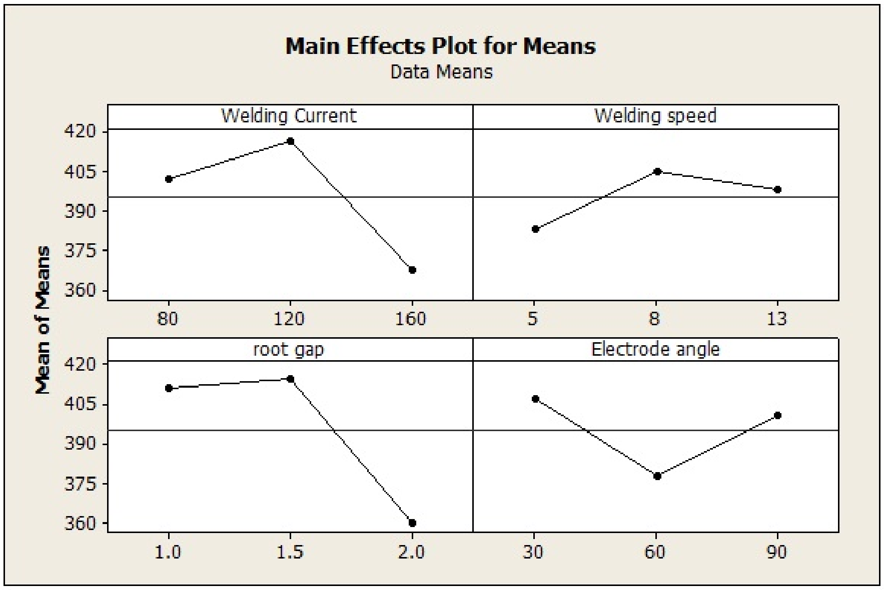


**Figure 3 Main effect plot for Welding Strength**

Welding strength is greatly affected by root gap followed by welding current while electrode angle is having moderate effect followed by welding speed. All factors are significant in deciding the value of Welding strength. Taguchi's Signal to noise ratio is taken as Maximum is better because with higher value of welding strength, joints becomes safer. Similarly Taguchi analysis is done for Weld bead height (mm) as response, by considering Signal to noise ratio as nominal is better.

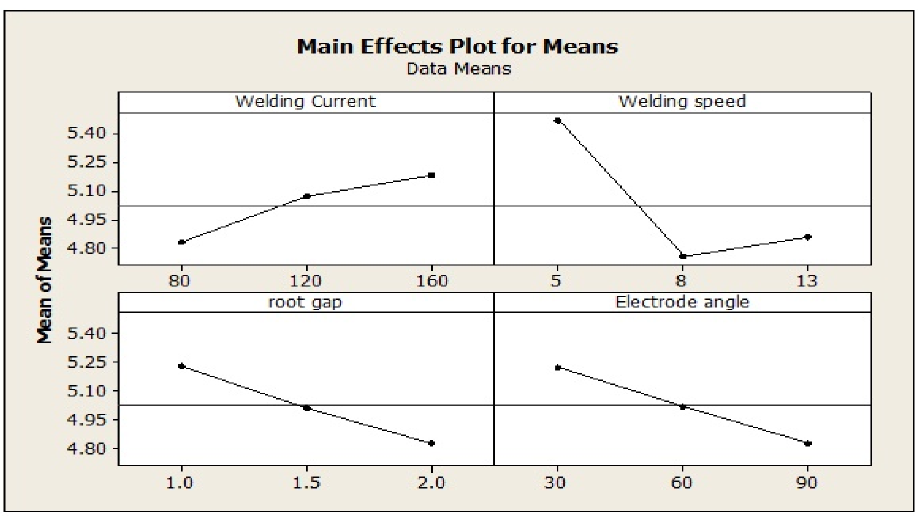


**Figure 4 Main effect plot for Weld bead height**

**Figure 4** represents the effect of process variables on weld bead height. Weld bead height is greatly affected by welding speed followed by welding current, electrode angle and root gap. All factors are significant in deciding the value of weld bead height.

## 4. Conclusion

Following conclusions are drawn by analyzing the result obtained from experimental runs (Pilot run) and data analysis by Taguchi method,

1. With increasing value of welding current above 120 A , there is melting of base metal, resulting in welding defects and decrease in welding strength hence, welding current significant range is 80-120 Ampere.
2. On increasing welding speed above 8mm/s, it is observed that there is decrease in metal deposition rate and welding strength while increase in bead height hence, the significant range of welding speed is 5-8 mm/s.
3. On increasing root gap above 1.5 mm, there is drastic reduction in welding strength while least change in value of metal deposition rate and bead height hence, significant range of root gap is 1-1.5 mm
4. On increasing electrode angle above 60 degree, there is increase in metal deposition rate and welding strength while decrease in bead height, indicating significant changes in all the three responses hence, the significant operating range is 30-90 degree.

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