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Optimization of Welding Variables on Mechanical Properties on Stainless Steel 304L Welded By GTAW Welding

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Abstract

In this research work an efforts has been taken to identify the effect of GTAW welding variables such as electrode angle with work surface, flow rate of shielding gas, arc gap and voltage affecting reactive performance variables such as hardness of weldment, tensile strength and toughness by impact test by using factorial design. Arc length is the important variables among all, which has the impact on the tensile, yield strength and elongation of the material and on hardness of the weldment. However, shielding gas has impact on toughness.
Keywords: GTAW welding, welding variables, mechanical properties.

1.1 Introduction

Welding is used in all science and technology fields, such as the electrical, computer, digital a nd petrochemical industries to make a solid and sound joint [1]. In order to produce the sound joint variables of welding plays important role [2-3]. The main fusion welding variables are current, Voltage, and Welding speed which plays important role to produce a good and sound weldment [4-5]. In addition to this there are other minor variables which also have more or less influence on produced weld quality [6]. Current work focused on electrode angle with work surface, gas flow rate, arc gap and voltage and the optimization of GTAW welding variables on mechanical properties on stainless steel weldments produced through GTAW welding process under different set of combined and individual parameters have been made for above said variables. Factorial design is valuable for initial research to identify the relations among different variables and their output [7-8]. Fractional designs for experimentation are represented using the notation L^{k-p}, where L stands for the quantity of levels investigated for each process variables considered for the study, k stands for number of process variables used in the experimentation [3,9,10]. For factorial fractional design L > 2 levels for designs, if the rate is greater than 2 than the efficiency of factorial fractional reduces than the methodology of the surface response [11-12].

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1.2 Experimentation

Stainless steel of 304L grade with the dimensions of 100 mm× 100 mm× 5 mm were taken for the experimentation and the test samples were fabricated from them. Table 1.1 depicted the chemical composition of material and mechanical properties of same are shown in table 1.2 by their weight percentage.

Table 1.1: Chemical composition weldment steel

Element	Cr	Ni	Mn	Mo	Si	C	P	S
Wt. (%)	18.6	8.13	1.54	0.437	0.333	0.0178	0.0268	<0.0050

Table 1.2: Mechanical properties weldment steel

Tensile strength in MPa	Minimum elongation in percentage	Proof Stress 0.2% in MPA	Rockwell Hardness
500 to 6070	45 % minimum	200	RB 92.00 maximum

Square butt joints having 2mm root gap in flat welding position was used to weld the plates by GTAW welding with 1.6 mm electrode diameter of AWS ER304L material.

1.3 Process Variables:

To identify the critical variables on the basis of response parameters different factors and variables are taken and their target value and each variable have two levels as mentioned in Table 1.3. In GTAW welding speed and gap between two plates were kept constant.

Levels for each factor in numbers = 2

Different factors considered in numbers = 4

Fractional factorial design considered for the experimentation = 2 * (4 - 1)

Number of different experimentation conducted = 8 (combination of set) X 2 (repetitions)

Table: 1.3: welding parameters and their limits

Variables	Symbol	Units of variables	Lower Limits	Upper limit
Electrode angle with work surface	S1	θ	60^o	90^o
protective gas flow rate	S2	L/min.	9	15
Welding current	S3	A	110	150
Arc gap	S4	Mm	1.5	2.1

1.4 Result and discussion

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Vicker's hardness, charpy impact test and tensile test were conducted for all the samples to make any conclusion. Table 1.4 shows the responses obtained from the different test results.

Table: 1.4: welding variables, Limits and their responses.

Sr no	**Actual variable**				**Response**											
	S1	**S2**	**S3**	**S4**	**Tensile strength**		**Yield strength**		**Elongation**		**Tensile strength**		**Yield strength**		**Elongation**	
					Set1	**Set 2**	**Set 1**	**Set 2**	**Set 1**	**Set 2**	**Set 1**	**Set 2**	**Set 1**	**Set 2**	**Set1**	**Set2**
1	600	9	110	1.5	610.3	624.7	390.6	419.3	36.2	38.1	245.0	248.0	240.0	247.0	110.0	100.0
2	900	9	110	2.1	436.3	550.2	333.0	401.1	32.7	42.2	287.0	261.0	270.0	255.0	120.0	128.0
3	600	15	110	2.1	322.4	322.9	189.6	237.9	12.3	12.5	281.0	308.0	279.0	260.0	280.0	272.0
4	900	15	110	1.5	655.8	550.8	422.7	350.6	65.2	15.5	284.0	240.0	280.0	235.0	130.0	140.0
5	600	9	150	2.1	529.2	436.2	309.9	273.1	34.0	21.2	289.0	239.0	275.0	238.0	120.0	110.0
6	900	9	150	1.5	597.0	476.0	311.4	406.9	42.1	32.0	252.0	249.0	248.0	240.0	130.0	135.0
7	600	15	150	1.5	443.9	550.7	311.4	431.2	22.8	42.0	262.0	245.0	255.0	231.0	200.0	220.0
8	900	15	150	2.1	482.2	555.7	316.0	416.8	38.9	32.0	273.0	248.0	265.0	230.0	120.0	130.0

1.4.1 Analysis of variance for tensile load

The best possible combination of variables for the higher value of tensile strength are 90^0 of electrode angle to work surface, 150A of welding current, 9 L/min. of flow of protective gas and 1.5 mm of arc gap, and for. Large to the better has been considered for noise in main plot for tensile strength. Figure 1.1 depicts that ANOVA for joining strength of steel plates and it is evident from the same figure that for tensile strength the arc gap is found to be the most significant factor.

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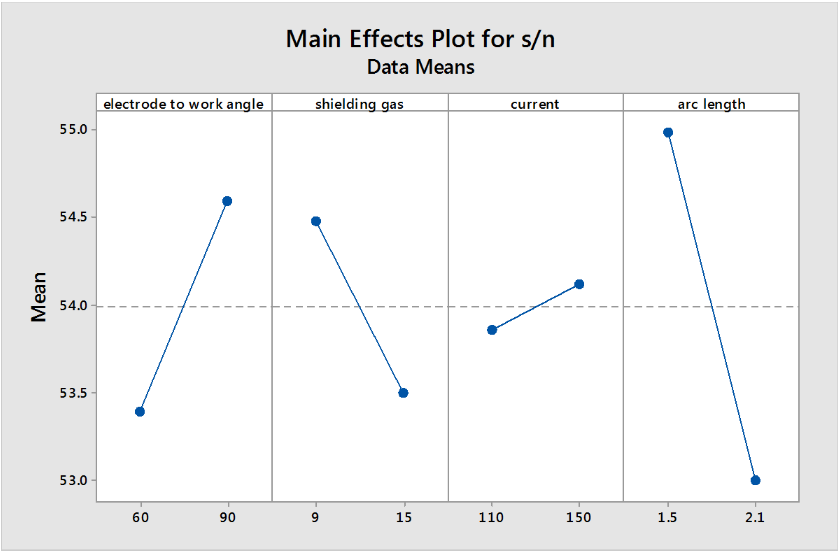

Figure 1.1: Tensile strength key outcomes diagram for S / N ration

1.4.2 Analysis of variance for yield load

The best possible combination of variables for the higher value of yield strength are 90^0 of electrode angle to work surface, 150A of welding current, 9 L/min. of flow of protective gas and 1.5 mm of arc gap, and for. Large to the better has been considered for noise in main plot for tensile strength. Figure 1.2 depicts that ANOVA for joining strength of steel plates and it is evident from the same figure that for tensile strength the arc gap is found to be the most significant factor.

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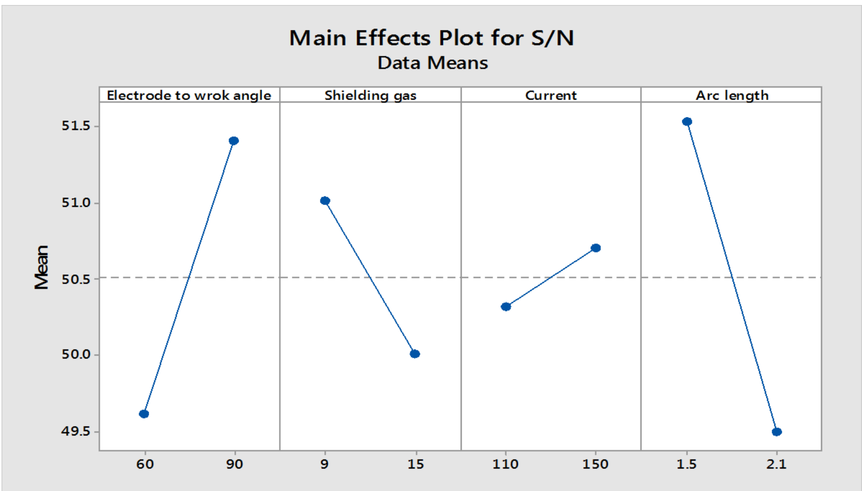

Figure 1.2: Yield strength key outcomes diagram for S / N ration

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1.4.3 ANOVA for elongation

The best possible combination of variables for the higher value of elongation of weld material are 90^0 of electrode angle to work surface, 150A of welding current, 9 L/min. of flow of protective gas and 1.5 mm of arc gap, and for. Large to the better has been considered for noise in main plot for tensile strength. Figure 1.3 depicts that ANOVA for weld elongation of steel plates and it is evident from the same figure that for elongation of weld material the arc gap is found to be the most significant factor.

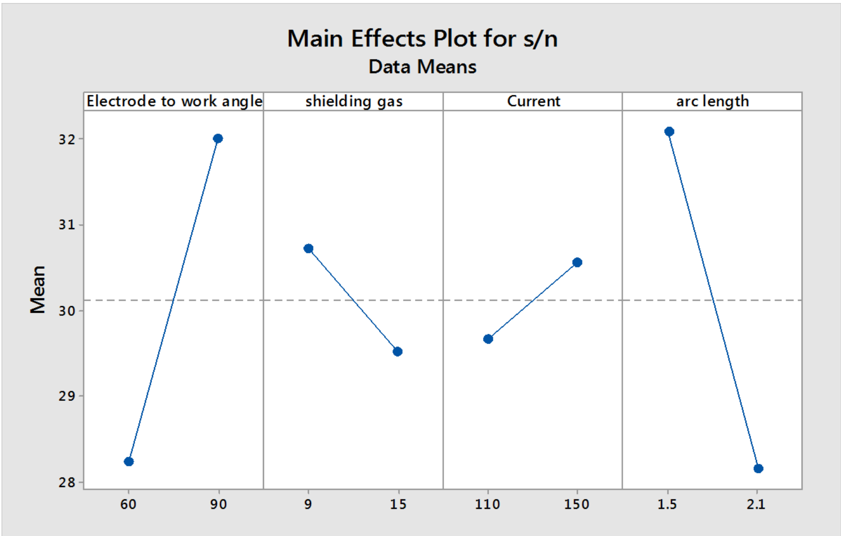

Figure 1.3: Elongation key outcomes diagram for S / N ration

1.4.4 ANOVA for Micro hardness on weld bead

It is observed from the figure 1.4 that with increase in electrode angle wrt work surface varies linearly to hardness of weld bead. Similar trend has also been observed for hardness of heat affected area by other parameters like arc length, and shielding gas. So, one can conclude that arc gap is the highly significant variable for weld bead's hardness. The best possible combination of variables for the higher value of hardness are 90^0 of electrode angle to work surface, 110A of welding current, 15 L/min. of flow of protective gas and 2.1 mm of arc gap, and for. Large to the better has been considered for noise in main plot for hardness of weld bead.

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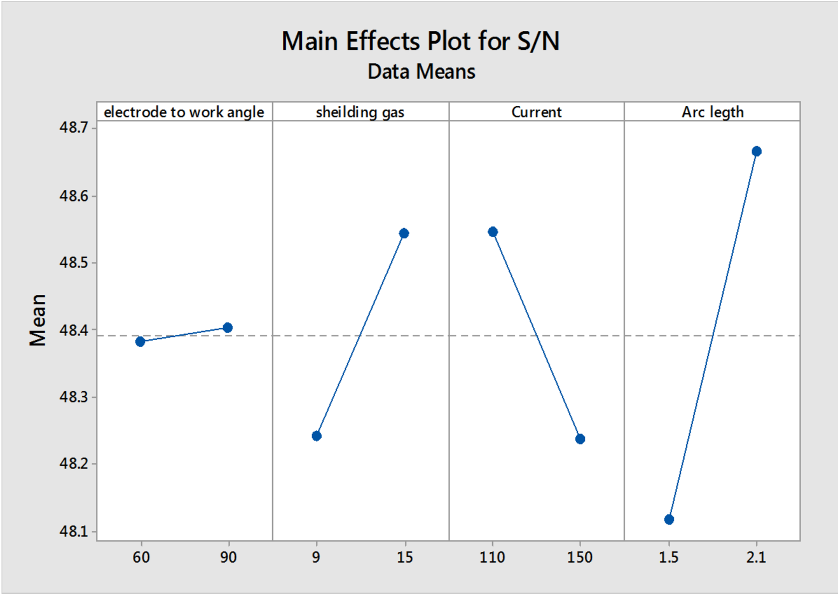

Figure 1.4: Micro hardness of WB key outcomes diagram for S / N ration

1.4.5 ANOVA for Microhardness on HAZ

It is observed from the figure 1.5 that with increase in electrode angle wrt work surface varies linearly to hardness of heat affected area. Similar trend has also been observed for hardness of heat affected area by other parameters like arc length, and shielding gas. So, one can conclude that arc gap is the highly significant variable for heat affected area's hardness. The best possible combination of variables for the higher value of hardness are 90^0 of electrode angle to work surface, 110A of welding current, 15 L/min. of flow of protective gas and 2.1 mm of arc gap, and for. Large to the better has been considered for noise in main plot for hardness of heat affected area.

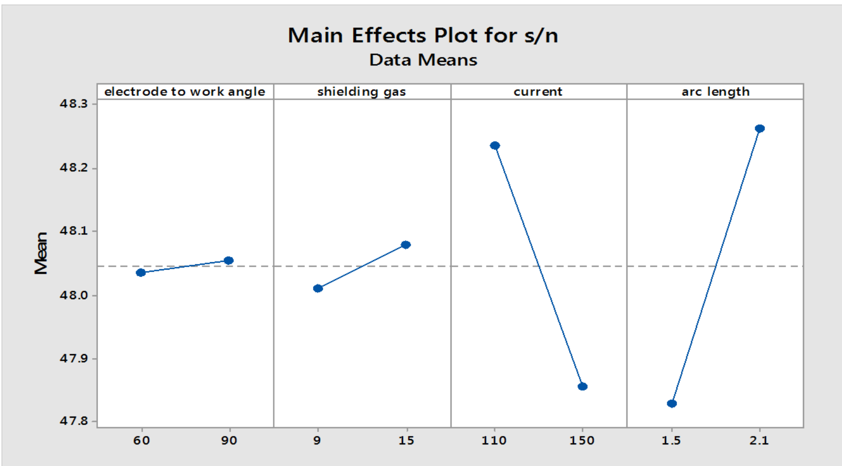

Figure 1.5: Micro hardness of HAZ key outcomes diagram for S / N ration

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1.4.6 ANOVA for Charpy impact test

It is observed from the figure 1.6 that with increase in shielding gas flow rate varies linearly to toughness of weldment. Similar trend has also been observed for toughness of weldment by other parameters like arc length, and shielding gas. So, one can conclude that arc gap is the highly significant variable for toughness. The best possible combination of variables for the higher value of hardness are 60^0 of electrode angle to work surface, 110A of welding current, 15 L/min. of flow of protective gas and 2.1 mm of arc gap, and for. Large to the better has been considered for noise in main plot for toughness of weldment.

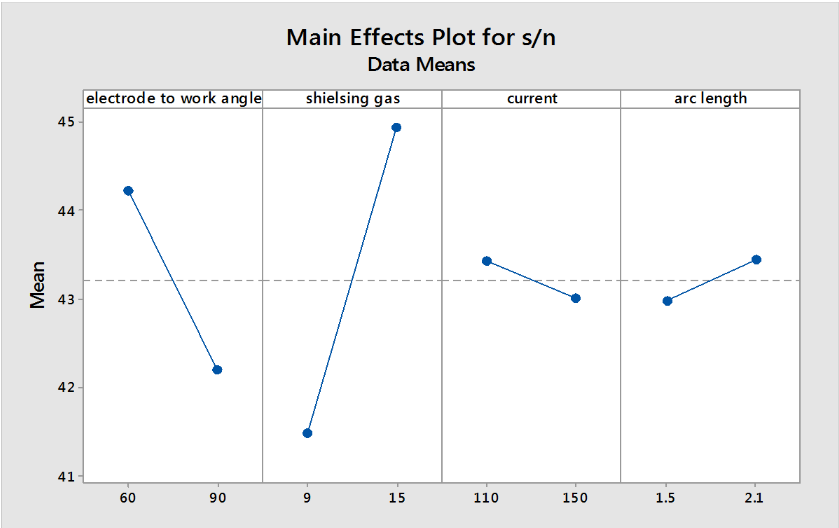

Figure 1.6: Charpy impact test key outcomes diagram for S / N ration

1.5 Conclusion

As we increase electrode to work angle 60 to 90 then our tensile strength increase 2.1%, yield strength increase 3.6%, elongation increase 18.51% and hardness is not affected and toughness decrease 4.96%.

As we increase shielding gas 9L/min to 15L.min then our tensile strength decrease 1.682%, yield strength decrease 1.8%, elongation decrease 12.50%, hardness of WB increase 0.62%, hardness of HAZ increase 0.14% and toughness increase 8.35%.

As we increase current 110A to 150A then our tensile strength increase 0.510%, yield strength increase 0.758%, elongation increase 3.01%, hardness of WB decrease 0.63%, hardness of HAZ decrease 0.71% and toughness decrease 0.97%.

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As we increase arc length 1.5mm to 2.1mm then out tensile strength decrease 3.75%, yield strength decrease 4.12%, elongation decrease 13.99%, hardness of WB increase 1.14%, hardness of HAZ increase 0.90% and toughness increase 1.11%.

From the design of experiment methodology the above observation focuses that for weld strength and hardness the arc length is found to be highly significant factor and for toughness the shielding gas established the significant contribution.

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