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STRENGTH ANALYSIS OF WELDING ELECTRODES ON MILD STEEL WELDING UNDER VARING CONDITION OF ARC WELDING PROCESS PARAMETER

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Arc welding is a type of welding process which uses an electric arc to create heat to melt and join metals. In these we have used mild steel grade 1018 as a base material of cross section 5mm, 8mm & 10mm and welded with different filler materials E6013, E9015, E308L to predict its strength and get comparisons of strength of the welded joint keeping welding current, voltage, heat input rate, welding speed and working temperature constant and left for air, water and sand cooling in normal room temperature for a fixed interval of time and finding the best suitable electrode for welding for a specific thickness of a mild steel grade1018. When the base material is welded, it is tested for its mechanical properties such as tensile strength test. This present experiment shows comparison of various mechanical properties when welded with different weld filler material with different thickness and varying voltages. To get the optimum result for the strength of the joint as today high quality with correct price is preferable for these TAGUCHI method is used to optimize the values of welding parameters in Minitab 2019 for getting best combination values for weld.

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1. INTRODUCTION

Arc welding is a welding process which uses an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents. Arc welding is a fusion welding process which is used to join metals. An electric arc from an AC/DC power supply which creates an intense heat of around 6500°F which melts the metal at the join between two work pieces. The arc can be either manually or mechanically guided along the line of the join, while the electrode either simply carries the current or conducts the current and melts into the weld pool at the same time to supply filler metal to the join because the metals react chemically to oxygen and nitrogen in the air when heated to high temperatures by the arc, a protective shielding gas or slag is used to minimize the contact of the molten metal with the air. Once cooled, the molten metals solidify to form a metallurgical bond.

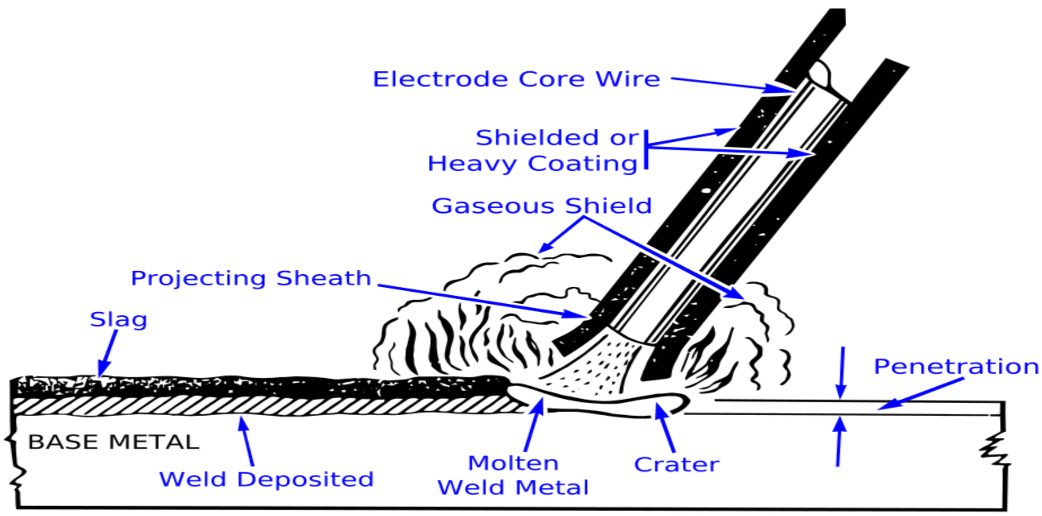

Fig 1 Schematic Drawing of electric arc welding

CONSUMABLE ELECTRODE

The arc process uses a variety of rods which have different strengths & weaknesses which can impact weld quality. The rod is connected to the welding machine and a current is passed through to join work pieces together. In some cases, such as with SMAW, the rods melt to become part of the weld - these are consumable electrodes. In other instances, such as with TIG, the rods to do not melt - these are non-consumable electrodes. Rods are generally coated but the exact type of coating varies. While uncoated rods are available, these are far less common, create more spatter and can make it difficult to control the arc. Coated rods are better to reduce or eliminate contaminating oxides or sulphur. The three types of coating include cellulose, minerals. or a combination of the two. Whether coated or uncoated, the correct rod needs to be selected to create clean, strong welds with the right bead quality.

2. LITERATURE REVIEW

Ajit et. al. 2012 [1] attempted to develop a response surface model to predict tensile strength of inert gas metal arc welded AISI 1040 medium carbon steel joints. The process parameters such as welding voltage, current, wire speed and gas flow rate were studied. The experiments were conducted based on a four-factor, three-level, face centred composite design matrix. The empirical relationship can be used to predict the yield strength of inert gas metal arcwelded AISI 1040 medium carbon steel. Response Surface Methodology (RSM) was applied to optimize the MIG welding process parameters to attain the maximum yield strength of the joint.

A. Mohamadizadeh et. al.2019, [2] researched on developing a novel methodology for modeling the link between nugget size and strength, as well as resistance spot welding (RSW) parameters and expulsion, in commercial hot-stamping Usibor® 1500 and Ductibor® 500. The RSW process was simulated for more than 250 different sets of welding time, current, and electrode force, resulting in the creation of 3D processing maps for both materials. The predictions were evaluated by measurements, and 3D nonlinear regression methods were used to explain the variations in strength as the function of welding parameters. A substantial amount of effort was devoted to taking the effect of expulsion into the numerical models so that the shear-tension strength of the spot welds would be predictable based on the occurrence and extent of expulsion during RSW. The results indicated that the occurrence of expulsion may decrease the strength of the spot weld up to 10kN (2248 lbf) in Usibor (45%) and leads to 4 kN (899 lbf) strength loss (23%) in Ductibor. The models can estimate the strength of the spot weld with ± 1 kN (224 lbf) error.

Anil et. al. 2017 [3] reviewed on process carried out by joining two similar and dissimilar metals.MIG welding is one of the most widely used processes in industry. The MIG welding parameters are the most importantfactors affecting the quality, productivity and cost of welding.We studied input parameters of welding such aswelding current, arc voltage, welding speed, root gap and output parameter are hardness, tensile strength, impactenergy, and microstructure.This review is based on optimization techniques and analysis tools used by researchersto optimize the parameters.In this research paper a review has been presented on MIG welding. The previousliterature has been discussed along with the future aspects included in the field of MIG welding.

Andrej 2012 [4] reviewed in domains of production engineering where he faced very small batch production as it is the case in the production of heavy hydro energy equipment. In this domain manual welding is one of the most time consuming operations. Monitoring of the welding process isessential from the point of work organization as well as from the point of process control. In this paper a novel concept of data acquisition and recording of welding parameters to the welding diary is presented. Several considerations on signal acquisition, sampling rate, processing,data aggregation, wireless information transfer, and presentation are discussed. Implementation of the concept is discussed on laboratory and industrial examples.

A. S. Haselhuhn et. al.2020, [5] researched in a traditional resistance spot welding (RSW) process in combination with a GM patented Multi-Ring Domed (MRD) electrode was used to join two types of aluminum alloys, AA5754-O and AA6022-T4, to interstitial-free low carbon steel (LCS). Parallel studies were carried out for AA5754-LCS and AA6022-LCS resistance spot welds to investigate the effects of aluminum contact resistance on the weld profile, interfacial microstructure, defect distribution, and coach peel performance. The results indicated AA5754-O develops a higher contact resistance when exposed to atmospheric conditions. This resulted in a degradation of the RSW process due to increased internal expulsion of the molten aluminum nugget and concurrent reduction in aluminum nugget size that contributed to a loss in joint mechanical performance. By contrast, AA6022-T4 exhibited a lower contact resistance, which minimized internal expulsion and promoted the retention of larger aluminum nuggets. The larger AA6022 weld nuggets exhibited improved mechanical performance in comparison to the smaller 5754 nuggets.

3. OBJECTIVE OF WORK

The main objective of present work is to predict weld strength of the various filler material with various thickness of work piece with various parameters of voltages i.e. impact test of electric arc welded 1018 grade mild steel and finding the best for a specific thickness. The objectives which are going to perform in this thesis are:

1. Select the parameters for electric arc welding to join the work piece.
2. Design the experiment according to the parameters and their level selected.
3. Perform electric arc weld on two similar mild steel as per the generation of design of experiment.
4. Measure the strength of charpy test of weld joints.
5. Apply TAGUCHI METHOD to optimize the welding parameters

4.1 Electric Arc Welding Tool

An electrode is an electric conductor used to make contact with a non-metallic part of a circuit. The word was coined by William Whewell at the request of the scientist Michael Faraday from two Greek words: electron, meaning amber and hodos, meaning a way.

Fig 2 specimen of working electrode

Chemical Composition

The following table shows the chemical compositions:

Table 1 chemical compositions of electrode E6013

ELEMENTS	CONTENTS (%)
Carbon	.08
Manganese	.45
Silicon	.18
Phosphorus	.012
Sulfur	.009

Table 2 chemical compositions of electrode E308L

ELEMENTS	CONTENTS (%)
Carbon	.04
Manganese	2.1
Silicon	.90
Phosphorus	.04
Sulfur	.03
Nickel	10
Chromium	20
Molybdenum	.75

Table 3 chemical compositions of electrode E9015

ELEMENTS	CONTENTS (%)
Carbon	.1
Manganese	.69
Silicon	.3
Phosphorus	.01
Sulfur	.009
Nickel	.75
Chromium	9.3
Molybdenum	.98

4.2 DESIGN OF EXPERIMENT

DOE is a systematic way to approach for an investigation of a system. A series of structure designed in which planned changes are made to the input variables of a system. The effects of these changes on a pre-defined output are then solved. DOE is an important formal way of maximizing information gained while minimizing resources required. It has more to offer than 'one change at a time' experimental methods, because it allows a judgment on the significance to the output of input variables which is acting alone, as well as input variables acting in combination with each another. DOE is a team oriented and a variety of backgrounds (e.g. design, manufacturing, statistics etc.) should be involved when identifying factors and levels and developing the matrix because this is the most skilled part. Moreover, as this tool is used to answer specific questions, the team should have a clear understanding of the difference between control factor and noise factors. It is very important to get the most information from each experiment which is performed.

The design of experiment by means of Taguchi method which is selected to identify the best set of parameters among the effective factors by cutting down a number of experiments. The steps to complete an effective designed experiment are:

1. Factor selection
2. Selection of orthogonal array and factor levels
3. Conduct tests described by trials in orthogonal arrays
4. Analyse and interpret results of the experimental trials.

Factor selection

In electric arc welding there are a number of possible factors that produce significant effects on strength which are voltage, working temperature, current, cooling medium, holding time, welding speed, depth of weld etc. In this experiment, the factors taken are voltage, cooling medium and cooling time.

Selection of orthogonal array and factor levels

In an L9 orthogonal array three levels of each factor are conducted where the selection of the array is because of its suitability for two factors with three Levels. The L9 orthogonal array is shown in Table.4 The levels and factors suggested are all shown in Table 4

Table 4 L9 Orthogonal array

Trail no.	Voltage(v)	Cooling time(min)	Cooling medium
1	1	1	1
2	2	2	2
3	3	3	3
4	1	1	2
5	2	2	3
6	3	3	1
7	1	1	3
8	2	2	1
9	3	3	2

Table 5 control factors and levels for factors

Factors	Levels		
	1	2	3
Voltage(v)	80	120	160
Cooling Time (min)	10	15	20
Cooling medium	Air	Water	Sand

Conduct tests described by trials in orthogonal arrays

The tests are conducted on charpy machine according to the sets of control factors obtained from trials of orthogonal array. The control factors and levels of control factors according to orthogonal array are shown in Table 6.

Table 6 Response of electrode E6013 (5mm)

Voltage(v)	Cooling time(min)	Cooling medium	RESPONSE
80	10	Air	32
80	15	Water	26
80	20	Sand	29
120	10	air	34
120	15	water	25
120	25	sand	28
160	10	air	22
160	15	Water	27
160	20	sand	29

Table 7 Response of electrode E9015 (5mm)

Voltage(v)	Cooling time(min)	Cooling medium	Response
80	10	Air	25
80	15	Water	26
80	20	Sand	34
120	10	air	22
120	15	water	38
120	25	sand	28
160	10	air	29
160	15	Water	24
160	20	sand	30

Table 8 Response of electrode E308L (5mm)

Voltage(v)	Cooling time(min)	Cooling medium	Response
80	10	Air	32
80	15	Water	26
80	20	Sand	29
120	10	air	34
120	15	water	25
120	25	sand	28
160	10	air	22
160	15	Water	27
160	20	sand	29

Table 9 Response of electrode E6013 (8mm)

Voltage(v)	Cooling time(min)	RESPONSE
80	10	30
80	15	45
80	20	38
120	10	24
120	15	23
120	25	28
160	10	27
160	15	25
160	20	20

Table 10 Response of electrode E9015 (8mm)

Voltage(v)	Cooling time(min)	response
80	10	28
80	15	35
80	20	28
120	10	34
120	15	26
120	25	33
160	10	38
160	15	24
160	20	27

Table 11 Response of electrode E308L (8mm)

Voltage(v)	Cooling time(min)	response
80	10	28
80	15	27
80	20	25
120	10	32
120	15	28
120	25	27
160	10	26
160	15	34
160	20	28

Table 12 Response of electrode E6013 (10mm)

Voltage(v)	Cooling time(min)	RESPONSE
80	10	44
80	15	38
80	20	28
120	10	36
120	15	21
120	25	22
160	10	42
160	15	51
160	20	38

Table 13 Response of electrode E9015 (10mm)

Voltage(v)	Cooling time(min)	response
80	10	34
80	15	38
80	20	28
120	10	29
120	15	24
120	25	34
160	10	27
160	15	28
160	20	31

Table 14 Response of electrode E308L (10mm)

Voltage(v)	Cooling time(min)	response
80	10	28
80	15	35
80	20	34
120	10	25
120	15	32
120	25	38
160	10	25
160	15	27
160	20	35

Analyze and interpret results of the experimental trials

Table 15 S/N ratio of electrode E9015 (5mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	25	27.9588
2	80	15	26	28.2995
3	80	20	34	30.6296
4	120	10	22	26.8485
5	120	15	38	31.5957
6	120	20	28	28.9432
7	160	10	29	29.2480
8	160	15	24	27.6042
9	160	20	30	29.5424

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 3

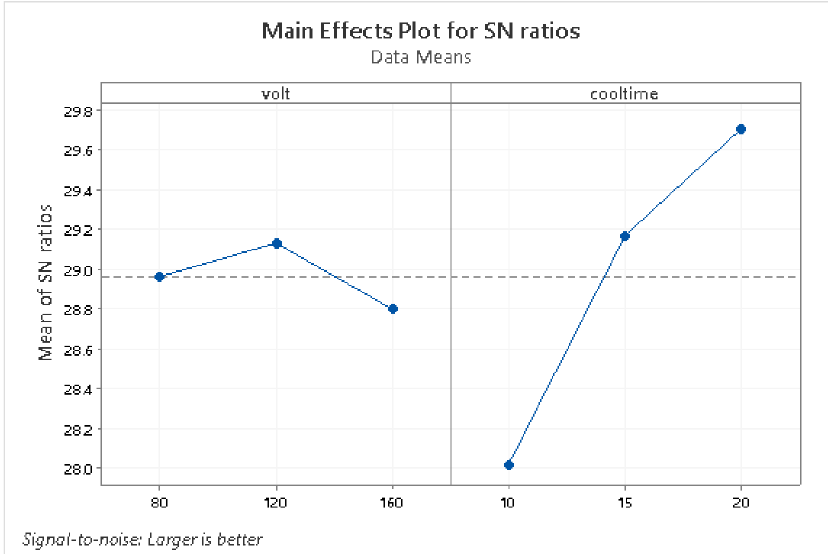

Fig 3: main effects plot for S/N ratios for electrode E9015 (5mm)

Table 16 S/N ratio of electrode E6013 (5mm)

TRIAL	VOLTAGE	COOLING TIME	Cooling medium	RESPONSE
1	80	10	32	30.1030
2	80	15	26	28.2995
3	80	20	29	29.2480
4	120	10	34	30.6296
5	120	15	25	27.9588
6	120	20	28	28.9432
7	160	10	22	26.8485
8	160	15	27	28.6273
9	160	20	29	29.2480

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 4

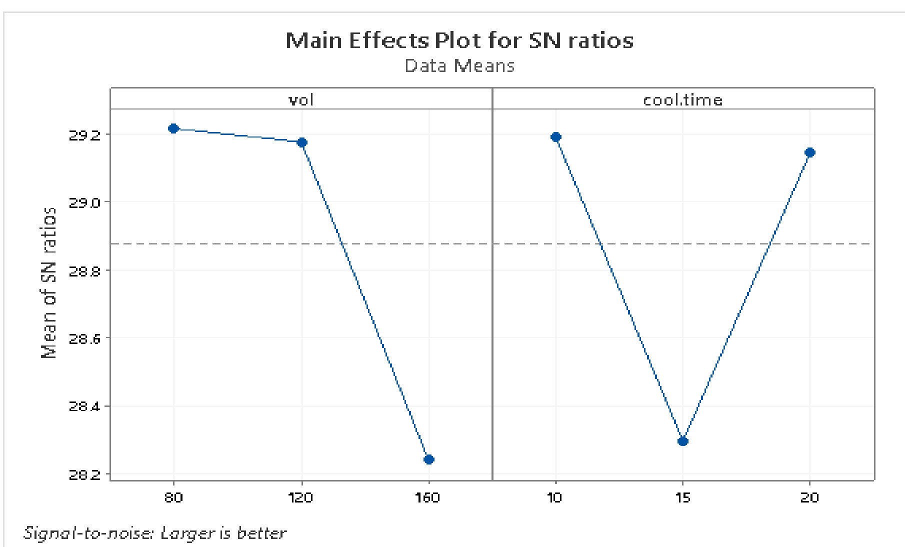

Fig 4 main effects plot for S/N ratios for electrode E6013 (5mm)

Table 17 S/N ratio of electrode E308L (5mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	32	30.1030
2	80	15	26	28.2995
3	80	20	29	29.2480
4	120	10	34	30.6296
5	120	15	25	27.9588
6	120	20	28	28.9432
7	160	10	22	26.8485
8	160	15	27	28.6273
9	160	20	29	29.2480

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 5

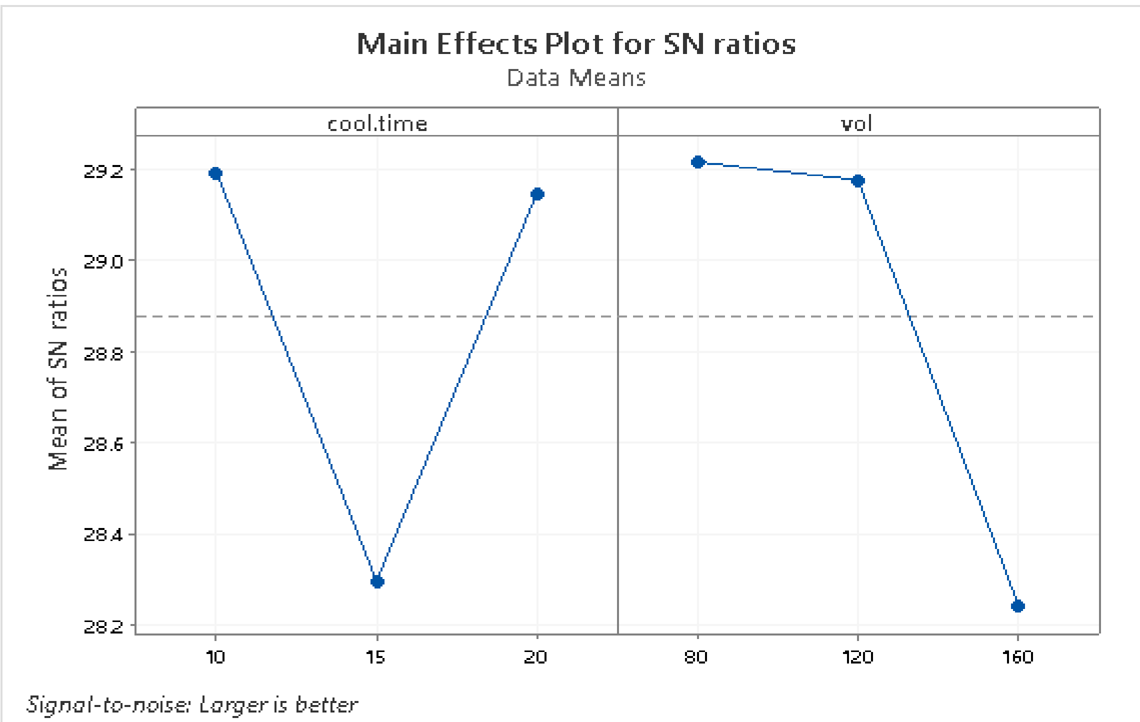

Fig 5 main effects plot for S/N ratios for electrode E308L (5mm)

Table 18 S/N ratio of electrode E9015 (8mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	28	28.9432
2	80	15	35	30.8814
3	80	20	28	28.9432
4	120	10	34	30.6296
5	120	15	26	28.2995
6	120	20	33	30.3703
7	160	10	38	31.5957
8	160	15	24	27.6042
9	160	20	27	28.6273

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 6

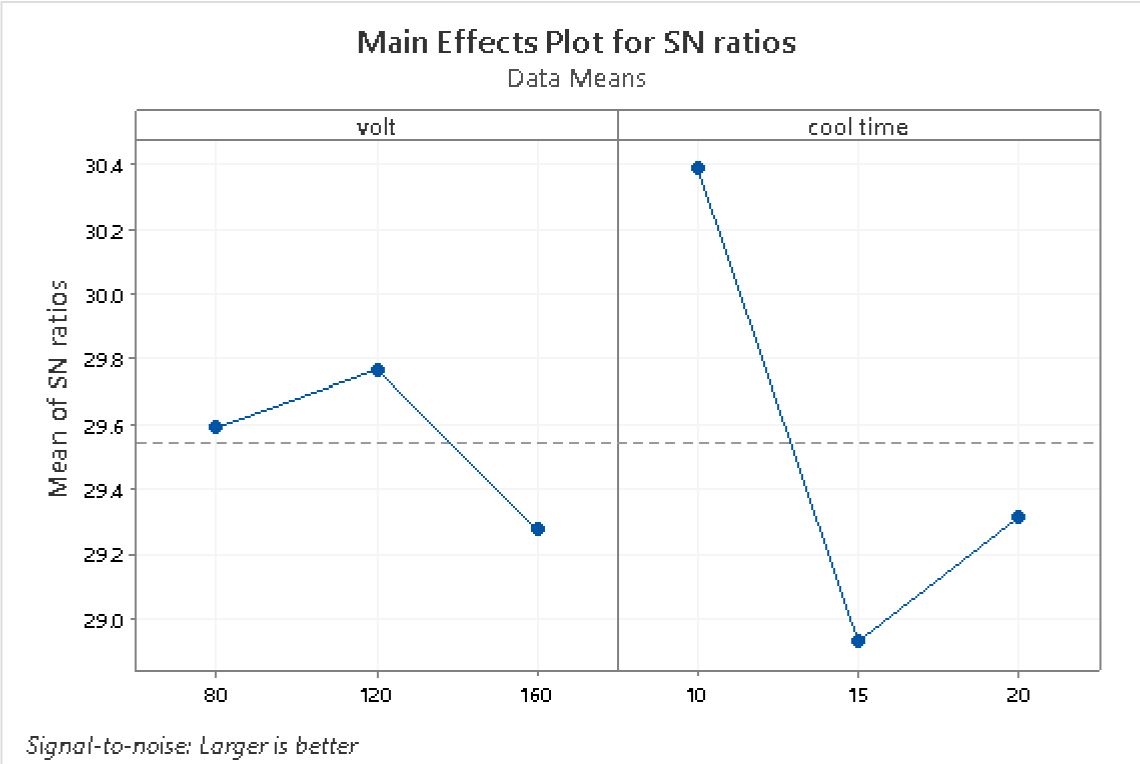

Fig 6 main effects plot for S/N ratios for electrode E9015 (8mm)

Table 19 S/N ratio of electrode E6013 (8mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	30	29.5424
2	80	15	45	33.0643
3	80	20	38	31.5957
4	120	10	24	27.6042
5	120	15	23	27.2346
6	120	20	28	28.9432
7	160	10	27	28.6273
8	160	15	25	27.9588
9	160	20	20	26.0206

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 7

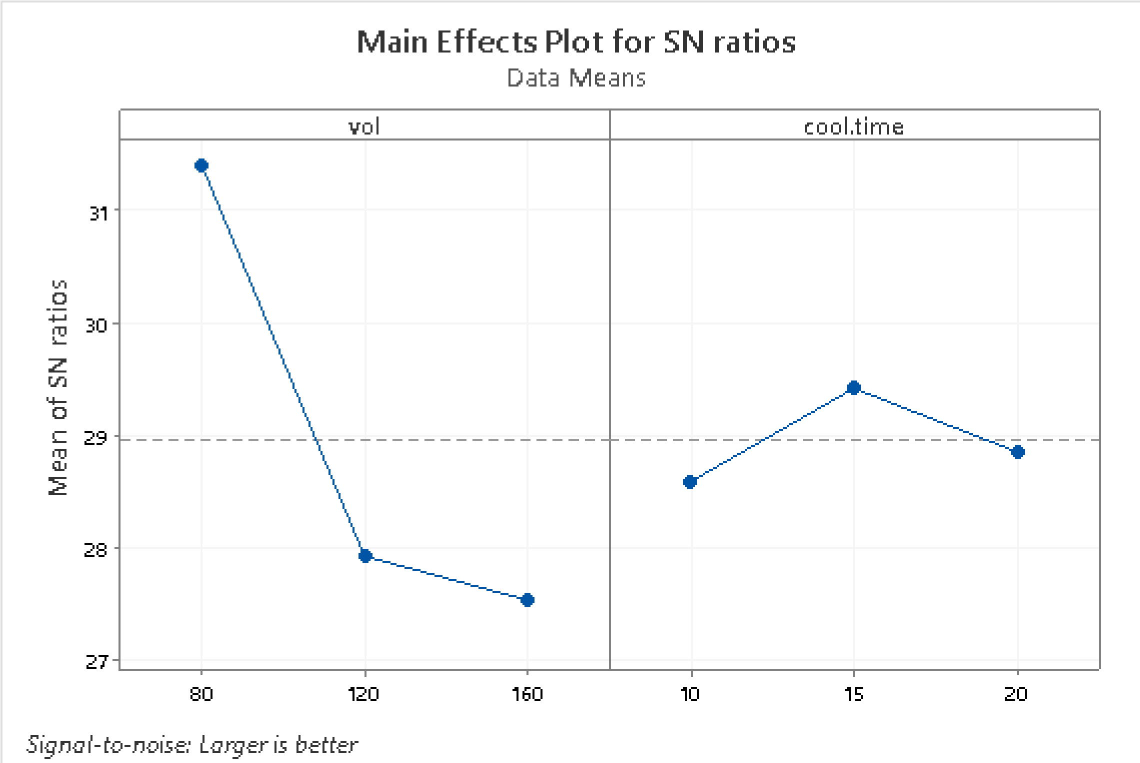

Fig 7 main effects plot for S/N ratios for electrode E6013 (8mm)

Table 20 S/N ratio of electrode E308L (8mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	28	28.9432
2	80	15	27	28.6273
3	80	20	25	27.9588
4	120	10	32	30.1030
5	120	15	28	28.9432
6	120	20	27	28.6273
7	160	10	26	28.2995
8	160	15	34	30.6296
9	160	20	28	28.9432

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 8

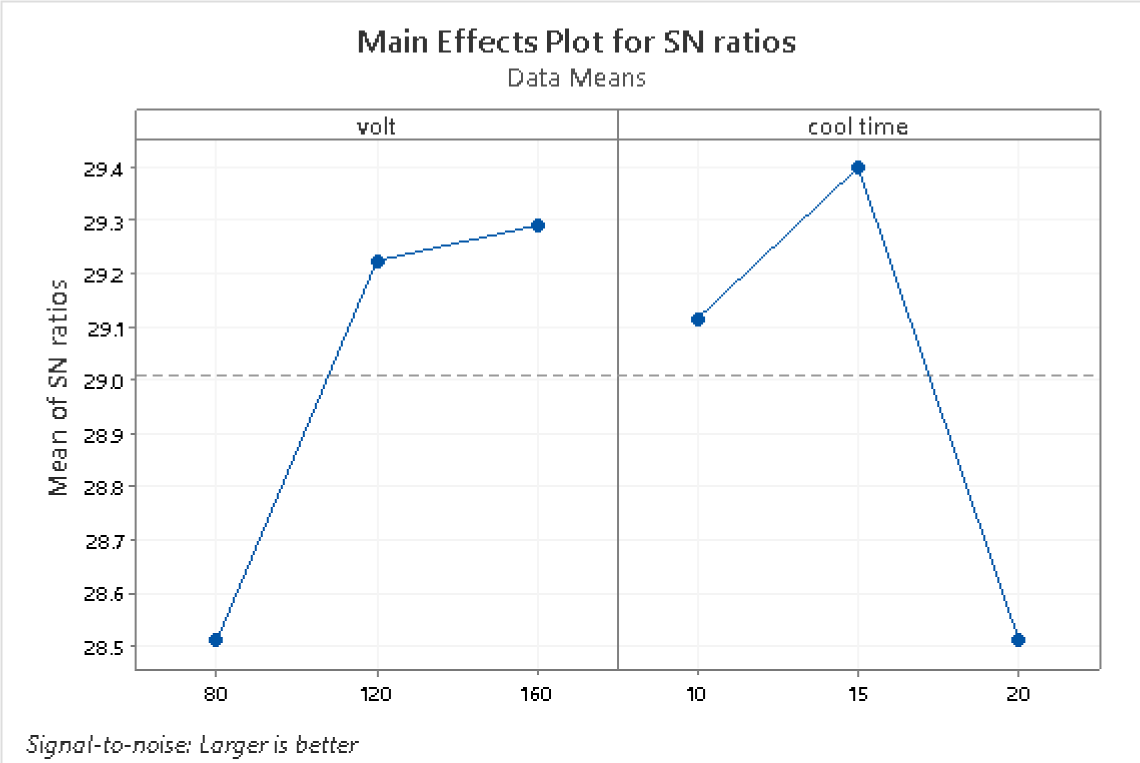

Fig 8 main effects plot for S/N ratios for electrode E308L (8mm)

Table 21 S/N ratio of electrode E9015 (10mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	34	30.6296
2	80	15	38	31.5957
3	80	20	28	28.9432
4	120	10	29	29.2480
5	120	15	24	27.6042
6	120	20	34	30.6296
7	160	10	27	28.6273
8	160	15	28	28.9432
9	160	20	31	29.8272

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 9

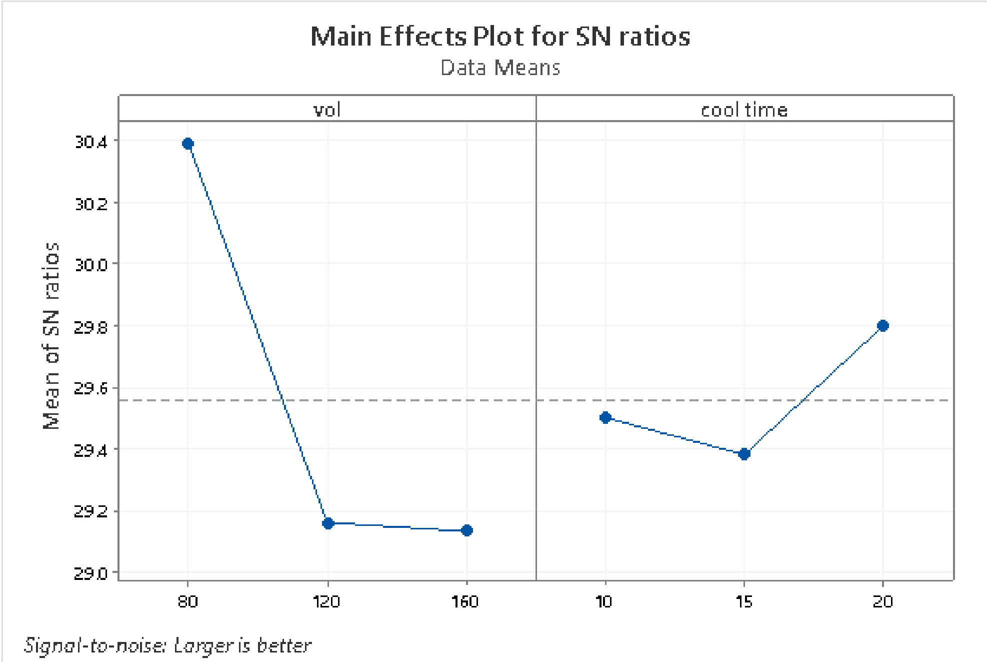

Fig 9 main effects plot for S/N ratios for electrode E9015 (10mm)

5.

Table 22 S/N ratio of electrode E6013 (10mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	44	32.8691
2	80	15	38	31.5957
3	80	20	28	28.9432
4	120	10	36	31.1261
5	120	15	21	26.4444
6	120	20	22	26.8485
7	160	10	42	32.4650
8	160	15	51	34.1514
9	160	20	38	31.5957

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 10

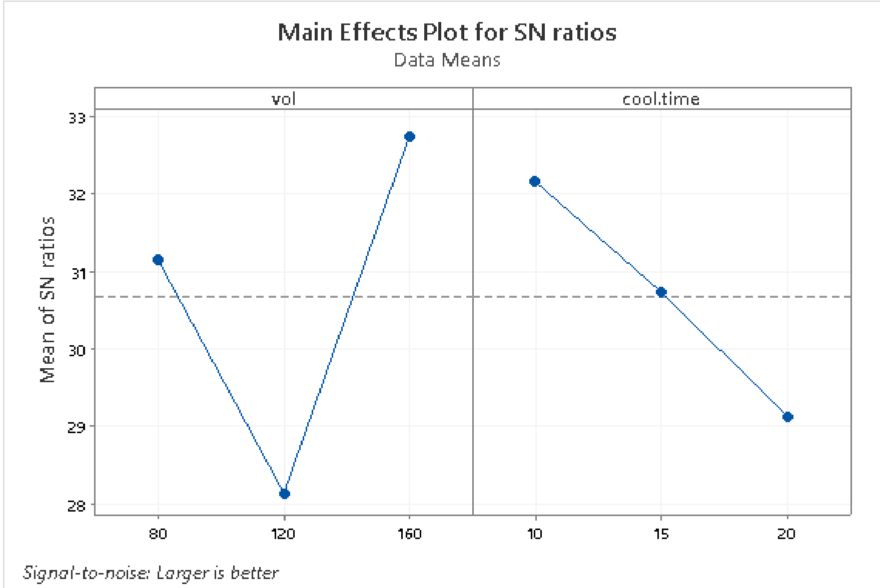

Fig 10 main effects plot for S/N ratios for electrode E6013 (10mm)

Table 23 S/N ratio of electrode E308L (10mm)

TRIAL	VOLTAGE	COOLING TIME	RESPONSE	SNRA1
1	80	10	28	28.9432
2	80	15	35	30.8814
3	80	20	34	30.6296
4	120	10	25	27.9588
5	120	15	32	30.1030
6	120	20	38	31.5957
7	160	10	25	27.9588
8	160	15	27	28.6273
9	160	20	35	30.8814

By using minitab19 software the main effects plot for S/N ratios is obtained and shows in fig 11

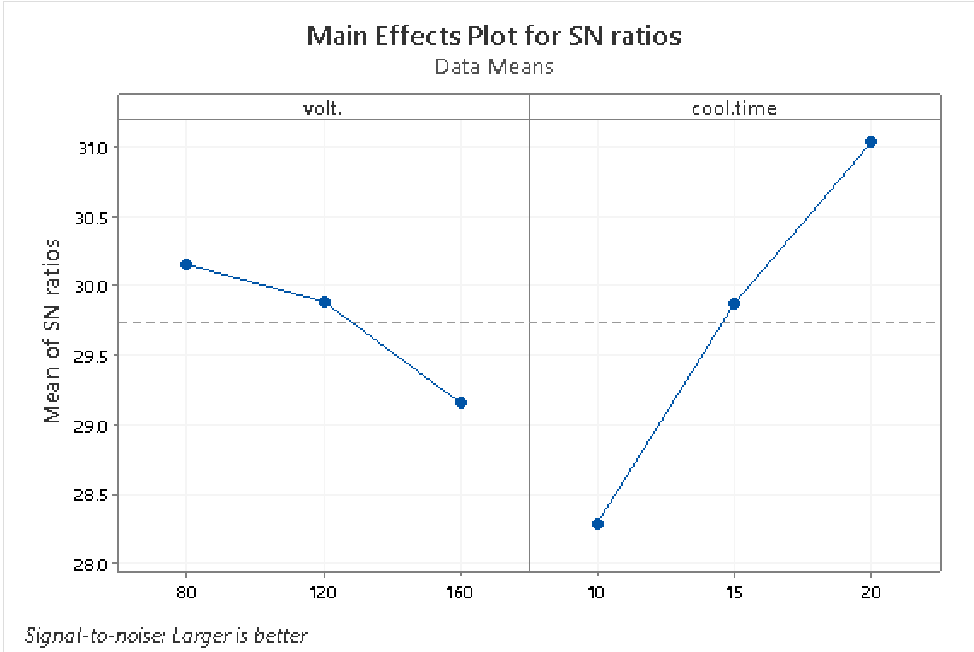

Fig 11 main effects plot for S/N ratios for electrode E308L (10mm)

6. CONCLUSION

In this case the best combination of parameters i.e., voltage and cooling medium with keeping the current constant and found that at 120v and water as a cooling medium for 15 min. and the outcome resulted as 31.5957J and hence best suitable for 5mm thickness.

In this case the best combination of parameters i.e., voltage and cooling medium with keeping the current constant and found that at 80v and sand as a cooling medium for 20 min. and the outcome resulted as 31.5957 J and hence best suitable for 8mm thickness.

In this case the best combination of parameters i.e, voltage and cooling medium with keeping the current constant and found that at 80v and air as a cooling medium for 10 min. and the outcome resulted as 32.8691 J and hence best suitable for 10mm thickness

Finally, we can conclude that for 5mm, 8mm & 10mm thickness mild steel grade 1018 the best possible electrode is E-6013 with various combination of parameters with a maximum welding strength of 31.5957 J & 32.8691 J respectively.

More investigation can be done with different variable; its values at different conditions, and materials. More experimental work has to be done to match the weld quality so that it can act as an original material. Investigate the effect of cooling rate on the process as well as on the resulting weld strength. The combined and main effects of different parameters have been considered in future for finding the more accuracy in welding parameters.

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