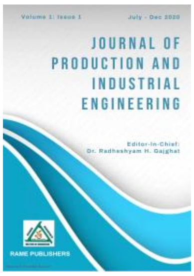

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Process Parameter Optimization of Sheet Metal Arc Welding of AISI 1020 Mild Steel

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Abstract - **Sheet Metal Arc welding is also known as Manual Metal Arc welding (SMAW/MMAW), is an advance arc welding process become a popular choice when a high level of weld quality or considerable precision welding is required. However, the serious issues of SMAW welding process are its moderate welding rate and restricted to lower thickness material in single pass. In this work, autogenously SMAW welding has been performed on 12 mm diameter AISI 1020 mild steel rod without utilizing any filler material. The full perforation welding has been tested for a variety of welding current and scanning speed. In addition, activated flux was used to enhance welding depth. The geometry of the weld globules and the tensile strength of the weld were investigated after the welding had kept up a different gap between the soldering rods. It can be shown that a proper gap is maintained, which provides strength for the entire penetration welding of rod.**

***Index terms* -** Sheet Metal Arc welding, activated flux, Current, Voltage, Tensile test, Hardness test and A - SMA welding process

I. INTRODUCTION

The SMAW is a manual arc welding system which uses a flow-covered, consumable electrode for mounting the welding known as the manual arc welding (MMA or MMAW). Electric flux is used as a direct current from the soldering power supply for making the electric arc to be fitted between the electrode and the metals. The workpiece and the electrode constitute a meltspool of fluid metal (seld pool) cooling into a joint. As the weld is laid, the electrode flow coating disintegrates, releasing fumes which act as a protective gas and supplying a layer of slaughter that both protect the sold area from air pollution. Due to its adaptability, its equipment and simplicity of operation, protected metal arc welding is one of the world's first and most famous welding processes. Othesis dominates other welding processes in the repair and maintenance industry, while SMAW continues to play a key role in building and manufacture of heavy steel structures, although flux-core arc welding is very popular. This method can be used to soften aluminum, nickel and copper composites. This is used primarily for iron and steel soiling (including rust steel). DOE or optimization technology for mechanical property process parameters and weld penetration, weld bead geometry, are investigated in numerous ways. I found that few studies on IS7887GR-7M Mild stones have been carried out so we need to study this material. For parametric optimization, we like to use experiment design. For the shielded metal arc process of welding, the main control parameters include a welding current, arc voltage, soldering speed, type of electrode and electrode diameter. They influence the quality of the suddenness in terms of mechanical properties and percussive geometry. The value

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of the penetration depth increases by changing the welding parameters, and the grain limit varies.

A. In three ways, SMAW can be done

i. *Semi-automatic soldering* **-** only electrodes wire feeding is controlled by the devices. Welding gun movement is manually controlled. This could be referred to as hand welding.

ii. *Machine welding* **-** uses a weapon associated with a certain manipulator (not hand-held). An operator must set and change controls to move the manipulator on a continuous basis.

iii. *Automatic welding* – Uses equipment that welds with a welder or operator without the constant adjustment of controls. Automatic sensor devices control the correct alignment of the weapon in a weld joint on certain equipment.

A. Working principle of SMAW welding

This process produces heat through an electric arc from a base metal to a consumable electrode. This process is now known as manual metal arc welding as electrode movement. Physically controlled. It is generally used to deposit welding metal because the liquid welding metal can be easily deposited ideal where it is needed and no separate shielding is required. This process is generally used to weld metals that are almost less susceptible to environmental gases. You can use both AC and DC for this process. The steady current DC power source is constantly utilized with a wide range of electrode (basic, rutile and cellulosic) regardless of base metal (ferrous and non-ferrous). However, AC can be unsatisfactory for particular types of electrodes and base materials. Consequently, AC ought to be utilized considering maker's recommendations for the electrode application. In case of DC welding, heat freed at anode is commonly more prominent than the arc column and cathode side. The measure of heat created at the anode and cathode may differ obviously relying on the flux composition of coating, base metal, polarity and the nature of arc plasma. In case of DC welding, polarity decides the dissemination of the heat created at the cathode and anode and accordingly the electrode melting rate and the base metal penetration are influenced. Heat generated by a welding arc (J) = Arc voltage (V) X Arc current (A) X Welding time (s). When Arc moves at speed S (mm/min), net thermal input is determined as: Hnet= VI (60)/(S x 1000) kJ/mm.

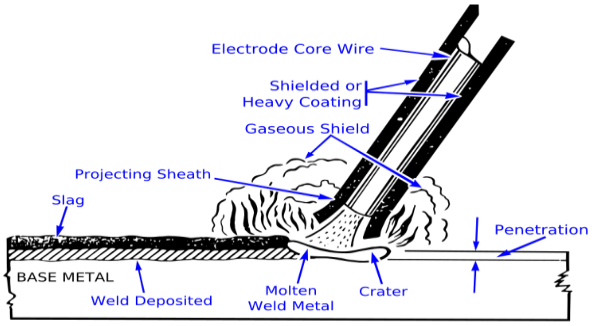

Figure 1: Shielded Metal Arc Welding (SMAW)

Protective surroundings must be provided by shielding in SMA so that molten soil metal is not contaminated by atmospheric gases present in and around the sounding arc. This protection comes from different approaches during different arc welding processes. For protected metal arc welding, a covering of the slag formed over the surface of the soldering pool/metal and inactive gasses is ensured by the flow/coverage thermal decay on the anode (Fig. 1). Nevertheless, more than two have relatively high impacts on the protection of the sold metal. Few fluxes (such as cellulosic coating) produce large amounts of inactive sold gas for protection, while several streams form a large amount of scratch to cover the weld pool. The inactive shielding of the soil pool by SMAW gas is not found to be extremely convincing, as two reasons are firstly because gas created by the thermal decomposition of the coating matter does not really provide an adequate cover for the arc and the welding pool. Secondly, arc movements constantly and arc gaps fluctuating when welding reduce further the shielding gas's efficiency. SMAW weld joints are thus regularly contaminated and not clean to create critical joints for possible use. As a result, weld joints of reactive metals such as Al, Mg, Ti, Cr or stainless steel are not usually suggested. Through welding procedures such as GTAW, GMAW and so on, these reactivating metal systems are commonly welded, giving the welding pool greater protection against at movables.

B. SMAW welding applications

SMAW might be operated in semiautomatic, machine, or automatic modes. By selecting the appropriate shielding gas, electrode, and welding factors, all commercially significant suitable metals, such as carbon steel, high-strength, low-alloy steel, and stainless steel, aluminium, copper, titanium, and nickel alloys, may be welded in all locations using this procedure.

C. Problem Statement

i. To study the various process parameter of SMAW.

ii. Find optimum values of process parameters from various sets of process parameter using DOE and experimentally.

D. Objectives

i. Determination of the optimum SMAW process parameters.

ii. The impact of each process parameter on the SMAW.

iii. Using design of experiment, determine the optimum values of process parameters.

In the context of the present work, the literature review conducted for optimizing sheet metal arc welding is presented.

The pulsed metal inert gas welding process parameters are optimized by a grey-based Taguchi method. Numerous quality parameters are consolidated by gray relational grade or grade into one integrated quality parameter. The welding process parameters considered in this study include pulse voltage, background voltage, pulse frequency, pulsation factor, wire feeding rates and flow rate. The quality parameters are pulleys strength, perforation geometry, shrinkage, angular distortion, and deposition efficiency. Variations were analyzed for the effect of each process parameter on the quality parameters. The pulsed voltage is considered the most important process parameter when the tensile strength is determined to be of a larger weight. Tests with optimized parameter settings, obtained from the analysis, support the results [1].

A two-tier design matrix is developed using (RSM) to plan, implement and develop a mathematical model. As a base metal is used for experiment [SA-516 (Gr-70)]. Graphical effects on bead geometry and shape factors are presented as fundamental and interactive factors for process variables. The results of the test show that speed and voltage play a key role in determining the welding bead dimensions [2].

The mechanical characteristics of AA 5456 aluminum alloy welds can be improved by the process of pulsed tungsten inert gas (TIG). Taguchi method is used to optimize AA 5456 AA aluminum alloy welds for pulsated TIG welding process parameters to increase mechanical properties. Models of regression have been developed. Variance analysis was used to verify the appropriateness of the models developed. The effects of planning on mechanical characteristics were also studied and mechanical properties were improved. All welds microstructures have been examined and linked to mechanical properties [3].

A numerical model has been developed to prevent and optimize the process parameters of friction welding (FW) on the tensile force of aluminum alloy joints (AA6061/AA7075-T6). The ultimate tensile strength from dissimilar frictionally soiled joints can be obtained using a variable FW parameter in process windows. A method was identified for optimizing FW process parameters, maximizing the tensile strength of the various joints and incorporating optimized parameters. In conclusion, energy-dispersive spectroscopic (EDC), electron scan (SEM) microscope and optical microscope were used for the characteristics of the sales zone specimens (OM). [4].

An optimum parameters mix is evaluated so that bead geometry in the submerged arc bead surface welder on mild steel plates acquires acceptable quality characteristics. The SAW procedure was designed for fuse flow/slag consumption in the mixture of fresh flow. Thus, the work tries to use the 'waste for wealth' idea. In addition to optimization, different perforation geometric parameters depending on the process variables were developed for mathematical models. This meant optimizations for maximum quantities of slag-flux mixes that could be used without sacrificing negative effects on pear geometry. The traditional SAW process, which consumes only fresh flux was therefore not implemented. Tests on the basis of the welding current, scratch mix and flux basic index were done, fluctuating as process parameters at four levels. [5].

Welding on mild plates of steel has been completed with full, non-replicated factorial structures to achieve beads weld. After estimating the bead width, depth, and fortification, we have determined additional important percentage parameters of dilution, soil penetration factor, weld strengthening factor, penetration area, reinforcement area and bead cross-sectional total area in view of the straight bead geometry premise. Each data was used for the production of numerical patterns between indicators and reactions. The impacts of the selected process parameters on various reactions are graphically described. The parametric optimization of this welding procedure was finally implemented with dark social research combined with the Taguchi Strategy (with orthogonal array of Taguchi). Confirmatory tests were carried out to verify optimum results.

A study proposes to consolidate the taguchi technique with the artificial neural network in order to develop a model of expectations for a laser cutting CO2 exam. The energy of the moving laser is collective during CO2 laser cutting. The paper creates a basic condition of energy density during the motion of the laser beam and enables it to determine the sliding control factor. In the meantime, the paper shows that only less orthogonal L9 testing is required [6].

The optimization and impact of the welding parameters on the torsional rigidity of the STEEL ST-37 rod welded by the MIG is investigated. The degree of significance of the welding parameters on the torsional rigidity is dictated by utilizing ANOVA. In light of the ANOVA technique, the profoundly compelling parameters on torsional rigidity were found as wire feed rate and welding voltage, though welding voltage was less successful variables. The outcomes show that the welding voltage was about not exactly half times more significant than the principal factor wire feed rate for controlling the torsional rigidity. An optimum parameter combination for the most extreme torsional rigidity was acquired by utilizing the examination of S/N ratio [7].

The optimum value was anticipated utilizing MINITAB 17 software. In view of the examination end are drawn MIG Welding process is fruitful to join Titanium amalgam Based on the S/N proportion investigation and ANOVA, the procedure parameters which altogether influences the Tensile Strength was speed, current and Voltage. Affirmation test did shows that outcomes happening to an ideal level are under the stretch range got at 95% meeting level. The impact of parameters on entrance can be positioned has voltage, Current and speed. Argon gas has protecting gas has been found to work palatable [8].

Manufacturers regularly face the issue to accomplish a decent welded joint with the necessary quality because of control of the info process variables. The primary purpose of this investigation is to identify the best process parameters for producing high-quality welds in MIG welding. To determine the optimal welding current, welding voltage, welding travel speed, and number of welding passes, the Taguchi Method with L9 symmetrical exhibit was used. The examination of the impact of welding parameters on residual stresses and weld hardness was done using factual methods such as analysis of variance (ANOVA) and signal to noise (S/N) ratio. The Taguchi method was used to find the best parametric conditions. To ensure the legitimacy of the results, a confirmatory test was carried out. The study dependant on

S/N ratio and ANOVA discovered that the welding voltage contributes 57.3 percent to the all-out variety saw in residual stresses by executing examination system. The welding current accounts for 26.14 percent of the absolute variation seen in residual stresses. Variable travel speed accounts for 32.28 percent of the total variety saw in hardness [9].

For the current study Gentle steel 1020 was used to study the distinctive parameters of the info process for tensile strength and durability of the welding tests. The L9 orthogonal is the most important parameter that has influenced the tensile strength and hardness of the weld to designate the distinguished parameters and current is. With a current (140 Amp), gas flow rate (10 L/min) and angles of rush, the highest traction resistance is 229,25 MPa (70 degree) [10].

The most important variables affecting quality, productivity and cost of welding are the MIG welding parameters. This paper described the effect on weld quality and welding geometry of medium carbon steel material in welding, welding current, welding voltage, gas flow rate, wire feed rate, and so on. The parameters can be improved and the best parameters mixed with the objective quality by using DOE technology. The DOE strategy review can give the essential characteristics of the parameters because it can or does not affect changes in item quality and quality. An arrangement of analyses dependent on Taguchi procedure has been utilized to get the information. An Orthogonal exhibit and examination of fluctuation (ANOVA) are utilized to research the welding attributes of Medium Carbon Steel material and advance the welding parameters. At last the adaptations tests have been done to contrast the predicated qualities and the test esteems affirm its adequacy in the investigation of weld quality and Depth of entrance [11].

The Taguchi technique was applied to locate an ideal setting of the MIG WELDING process. The outcome from the Taguchi technique picks an ideal arrangement from blends of components in the event that it gives augmented standardized consolidated S/N proportion of focused yields. The L-9 OA was utilized to oblige three control factors and each with 3 levels for exploratory arrangement chose process parameters are Current (120,140,160 Amperes), Voltage (22,24,26 volts, Gas flow rate are (15,20,25 lit/min). The outcomes are summed up as from the examination, obviously the three procedure parameters, Current, Voltage and Gas flow rate have critical impact on penetration. The investigation of difference demonstrates that the most affecting parameters on entrance are current and voltage. While gas stream is least critical when contrasted with current and voltage. 3 The consequence of present examination is substantial inside indicated scope of procedure parameters Also the forecast made by Regression Analysis is inacceptable concurrence with Confirmation results [12].

II. METHODOLOGY

A. *SMAW Welding Effecting parameters*

Weld quality and deposition rate are both influenced by different welding settings and joint geometry. In general, various welding mixtures and joint shapes can produce a welded junction. These factors govern the rate of weld deposition and the quality of the weld. The weld bead geometry, penetration depth, and good weld quality provide the accompanying operating variables.

- Electrode size, Welding current, Arc voltage
- Arc travel speed, welding position
- Gas Flow rate, Shielding Gas composition
- Electrode extension (length of stick out)

i. *Electrode Size*

The electrode diameter across impacts the weld bead configuration, (for example, the size), the depth of penetration, bead width and consequently affects the movement speed of welding. When in doubt, for a similar welding current the arc out to be additionally entering as the electrode diameter decreases. To get the greatest deposition rate at a given current, one ought to have the littlest wire conceivable that gives the vital infiltration of the weld. The bigger electrode diameters make weld with less entrance yet welder in width. The wire electrode diameter decision depends on the thickness of the workpiece being welded, the sudden penetration necessary, the ideal weld profile and affidavit rate, the welding situation and the cost of the wire. Electrodes of (mm): 2, 2.5 and 3.18; 4, 5 and 6 mm are usually used for electrodes. Each size has a usable range depending on wire creation and a bend or short circuit arc of the type of shower is used.

ii. Welding Current

In SMAW, the value of weld current affects the deposition rate, the size, shape and penetration of the weld beads. Metals with direct current polarity electrodes are usually welded with SMAW welding, as this provides the maximum input of heat to the work and therefore can obtain a relatively deep penetration. Increased currents increase welding penetration depth and width and weld bead size when all other welding parameters are constantly maintained.

iii. Welding Voltage

The arc length (arc voltage) is one of the most significant factors in SMAW that must be held levelled out. At the point when all the factors, for example, the electrode composition and sizes, and the welding procedure are held consistent, the arc length is straightforwardly identified with the arc voltage. High and low voltages cause a temperamental arc. Inordinate voltage causes the development of unreasonable spatter and porosity, in fillet welds it builds undercut and creates smaller beads with more noteworthy convexity, however an extreme low voltage may cause porosity and covering at the edges of the weld bead. Also, with steady voltage power source, the welding current increment when the electrode taking care of rate is expanded and decreased as the electrode speed is decreased, different elements staying consistent. This is a significant variable in SMAW welding, essentially on the grounds that it decides the sort o metal exchange by affecting the pace of bead move over the arc. The arc voltage to be utilized relies upon base metal thickness, type of joint, electrode composition and size, protecting gas composition, welding position, type of weld and different factors.

B. Design of Experiments (DOE)

Design of Experiments (DOE) is an amazing measurable procedure presented by R. Fisher in England in the 1920's to consider the impact of different factors at the same time. The DOE utilizing Taguchi approach can monetarily fulfil the necessities of critical thinking and product/process design optimization projects. By learning and applying technique, engineers, scientists, and researchers can fundamentally diminish the time required for trial examinations. DOE is a method of characterizing and putting every conceivable blend in a trial including numerous variables and to recognize the best combination. In this, various elements and their levels are distinguished. Structure of analyses is additionally valuable to join the variables at suitable levels, each with the separate adequate range, to deliver the best outcomes but then display least variety around the optimum results. Accordingly, the target of a carefully planned arranged structured trial is to comprehend which set of factors in a procedure influences the exhibition most and afterward decide the best levels for these factors to get agreeable yield practical execution in items.

The benefits of experimental design are as follows:

- There is a significant reduction in the number of trials.
- Important decision variables can be identified that control and improve product or process performance.
- The parameters can be identified optimally.
- The parameters can be qualitatively estimated.
- It is possible to estimate the experimental error.
- Details can be made about parameter effects on process characteristics.

The experiment design (DOE) is therefore a method for identifying, identifying and resolving important factors in a process. The process parameter optimization work in welding is then used in the DOE techniques.

- Full factorial technique
- Fractional factorial technique
- Taguchi orthogonal array
- Response Surface method (Central Composite design)

ANOVA represents Analysis for Variance and it is the instrument utilized for the examination of commitment of each procedure parameter on reaction parameter. Scientific models are utilized to set up the connection between the information and yield parameters in welding forms. "MINITAB" and "Design Expert" are the product utilized for DOE strategies.

C. Material Properties of Specimen

Mild Steel AISI 1020 material is used for specimen, which is made for testing process. Properties and composition of selected material as follows.

TABLE 1
PROPERTIES OF WORKPIECE MATERIAL

Material	Percentage Composition (%)
C	0.08
MN	2
P	0.045
S	0.03
SI	1
AL	0.016
CR	0.006

TABLE 2
MECHANICAL PROPERTIES OF WORKPIECE MATERIAL

Material Properties	Value
Yield strength (Mpa)	275.00
Ultimate Tensile strength (Mpa)	462.00
% Elongation(mm)	34.00
Reduction in Area(mm2)	59.00
Specimen diameter at welding section (mm)	12
Specimen diameter at knurling section (mm)	16
Specimen length(mm)	220

C. Welding Setup of SMAW

- Filler metal: Electrode -3.15,4,5 mm dia.
- Voltage range of SMAW welding machine: 0-100 V
- Current range of SMAW welding machine : 0-240 A

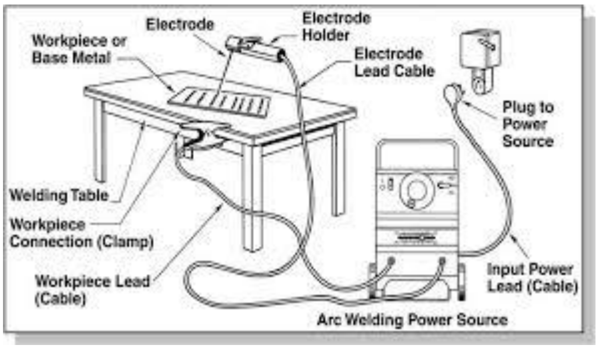

Figure 2: Welding Setup of SMAW

D. UTM Setup Used for Testing Process

The tensile strength and compression strength of a material are tested using a UTM, also known as a universal testing machine, material testing machine or material test framework. The extensometer is a previous name for a tensile testing machine. The "universal" part of the name reflects the fact that numerous standard compression tests on materials, components and structures can be conducted.

Figure 3: UTM Setup

TABLE 3

UTM SETUP SPECIFICATIONS

Maximum Capacity	400 Kn
Measuring Range Resolution	0.1 kN Above 80 kN
Maximum Clearance for Tensile Test	50-700 mm
Clearance Between Column	500 mm
RAM Stroke	200 mm
Straining Load	0-150 mm/min
Weight (Approx.)	2500 kg

E. *Steps in Taguchi Method*

i. Identify the main goal of the experiment first of all.
ii. Identify the output and measurement system.
iii. Find out which factors can affect the response to output, the level and the main interactions.
iv. Select the appropriate orthogonal range.
v. Carry out tests carried out in the OA trials.
vi. The data is analyzed using the signal-to-noise statistical techniques to determine the significance of the process parameters by the analysis of variance and factor effects.
vii. Search for optimum variable levels.
viii. Confirmatory experiments to verify the optimum design parameters.

F. *Software used for Optimization Process*

For optimization and analysis, Minitab 17 software is used. Minitab was created by researchers Barbara F. Ryan, Thomas A. Ryan Jr., and Brian L. Joiner at Pennsylvania State University in 1972. The program was started as the light version of OMNITAB 80, a NIST program for statistical analysis. Software for statistical analyzes, like Minitab, automates calculations and graph creation, enabling users to concentrate more on data analysis and results interpretation. It's supported by other software by Minitab, Inc.

IV. Experimentation For Optimization Of SMAW

A. *Welding Parameters*

- Welding Voltage: 21, 23, 25 V
- Welding Current: 180,200,220 A
- Welding Rod Diameter: 3.15,4,5 mm

TABLE 4

LEVELS OF WELDING PROCESS PARAMETERS

Welding parameters	Units	Level 1	Level 2	Level 3
Current(I)	Amp	180	200	220
Voltage(V)	Volt	21	23	25
Welding Rod Diameter (D)	Mm	3.15	4	5

TABLE 5

ORTHOGONAL ARRAY FOR TAGUCHI METHOD

Sr. No.	Current	Voltage	Rod Diameter
1	180	21	3.15
2	180	23	4
3	180	25	5
4	200	21	4
5	200	23	5
6	200	25	3.15
7	220	21	5
8	220	23	3.15
9	220	25	4

TABLE 6

ULTIMATE TENSILE STRENGTH FOR L9 ORTHOGONAL ARRAY

Exp. No.	Current	Voltage	Rod Dia.	UTS (MPa)
1	180	21	3.15	380
2	180	23	4	400
3	180	25	5	450
4	200	21	4	395
5	200	23	5	439
6	200	25	3.15	360
7	220	21	5	430
8	220	23	3.15	356
9	220	25	4	370

IV. Results

After calculating ultimate tensile strength from experiment that data is entered into Minitab 17 software for further optimization. Minitab software is statistical analysis software it provides statistical data from software analysis. Results as follows: Regression Equation

UTS = -704 + 29.0 I + 2.76 V+ 13.8 Dia.

TABLE 7

ANALYSIS OF VARIANCE FOR S/N RATIOS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
I	2	0.44770	0.44771	0.22386	45.51	0.020
V	2	0.06926	0.06926	0.03463	7.50	0.118
Diameter	2	4.04463	4.04463	2.02231	438.24	0.002
Residual Error	2	0.00923	0.00923	0.00461		
Total	8	4.57083				

TABLE 8

RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS LARGER IS BETTER

Level	I	V	Diameter
1	44.00	47.28	47.10
2	50.38	46.61	46.85
3	49.05	49.55	49.48
Delta	6.38	2.94	2.63
Rank	1	2	3

TABLE 9

RESPONSE TABLE FOR MEANS

Level	I	V	Diameter
1	168.8	247.6	244.6
2	331.1	234.2	240.2
3	284.7	302.7	299.8
Delta	262.3	68.5	59.6
Rank	1	2	3

TABLE 10

S/N RATIOS FOR THE ULTIMATE TENSILE STRENGTH MEASUREMENT

Current	Voltage	Rod Diameter	UTS (MPa)	S/N Ratio
180	21	3.15	380	61.13
180	23	4	400	61.58
180	25	5	450	62.60
200	21	4	395	61.47
200	23	5	439	62.39
200	25	3.15	360	60.66
220	21	5	430	62.21
220	23	3.15	356	60.57
220	25	4	370	60.90

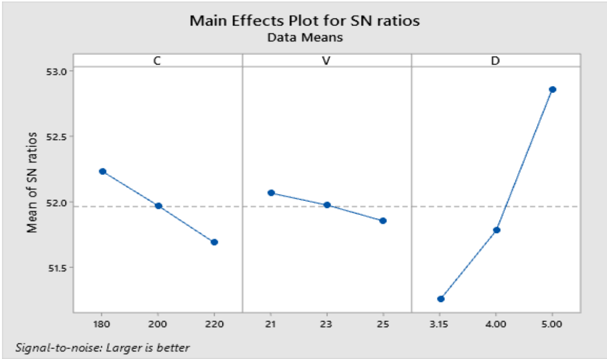

Figure 4: Graph of S/N Ratio v/s Process Parameters

V. CONCLUSIONS

The present research work describes the use of Taguchi method and statistical techniques for analyzing and optimizing the Process Parameters in SMAW welding of AISI 1020.

From the study, the following conclusions are drawn: -

- Main effect plots reveal that voltage and current has significant influence on Tensile strength.
- The optimum welding condition obtained by Taguchi method for maximum strength is AISI 1020 Mild steels (i.e. current = 180 ampere, voltage = 21 volts, Rod Diameter).
- Maximum ultimate tensile strength found on maximum current, intermediate level voltage and low-level gas flow rate. Minimum ultimate tensile strength found on low level voltage and intermediate level current and gas flow rate.
- Welding voltage and current affects output UTS more than Welding Rod Diameter.
- In this project varying noise parameters current, voltage, Welding Rod Diameter to get accurate signal parameter in this project UTS. We found high S/N ratio (62.60) at current = 180 ampere, voltage = 25 volts, Welding Rod Diameter= 5mm and minimum S/N ratio (60.57) current = 220 amperes, voltage = 23 volts, Welding Rod Diameter= 3.15mm.

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