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EXPERIMENTAL INVESTIGATION AND WELD CHARACTERISTIC ANALYSIS OF FCAW WELDING PROCESS ON OHNS

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Abstract: In today's industrial sector, productivity and quality are crucial factors. Today's manufacturing industries face intense competition on the global market, making producing higher-quality goods at lower costs and with more productivity their primary goals. The most important and frequent procedure used to unite different elements is welding. The goal of the current research is to better understand different welding methods and identify the optimal method for steel. A lot of attention has been paid to FCAW-MIG welding. The second input parameter value in this experiment, 160 amps at -18 volts and a gas pressure of 4 bar, is really the optimum value, which is practically discovered. The Taguchi design and optimized parameters state that 160 amps of current, 22 volts of voltage, and 3 bar of gas pressure will yield the highest tensile strength for the 6 mm OHNS steel. Tensile strength is majorly influenced with gas pressure of the FCAW process found through ANNOVA. Alongside, the characteristics of hardness, corrosion, wear behavior and penetrant test (NDT) have been conducted to determine the FCAW performance.

Index Terms: FCAW, OHNS steel, Hardness, wear, corrosion, ANNOVA, NDT.

I. INTRODUCTION

Flux Core Arc Welding (FCAW) uses tubular wire that has been filled with flux. An arc forms between the workpiece and the continuous wire electrode. The flux, which is housed inside the core of the tubular electrode, melts while welding and shields the weld pool from the outside elements. Direct current electrode positive (DCEP) is often employed in the FCAW process, as shown graphically in Figure 1. With the proper filler metals (the consumable electrode), FCAW may be an "all-position" process, and some of the properties are as follows:

- Some wires don't require shielding gas, making them appropriate for windy or outdoor welding environments.
- a high-deposition rate procedure in the 1G/1F/2F (rate at which filler metal is added).
- Operator skill is less necessary than with SMAW and GTAW.
- Metal has to be cleaned less before use.
- The weld metal is initially shielded from outside influences until the slag is chipped away, which is one of the flux's metallic advantages.

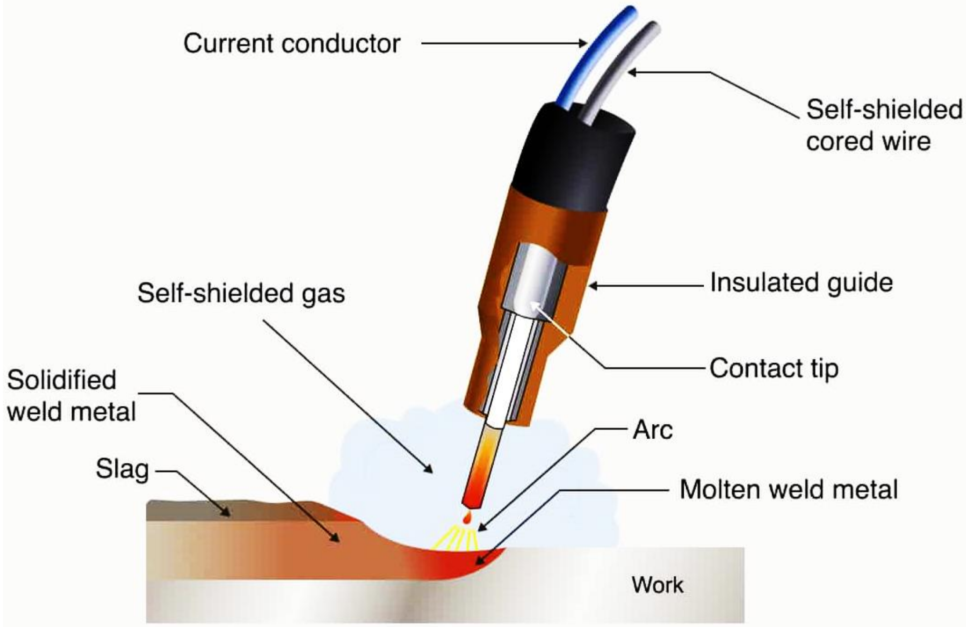

Figure 1. Schematics of FCAW

To allow arc welding automation and robotization, the process parameters for FCAW should be well identified and categorized. To guarantee optimum bead quality, precise welding processes must be chosen. To obtain the quality welds needed, it is important to have complete control over the relevant process parameters to obtain the minimum corrosion and wear relationship of a weldment-based weld. The GMAW procedure is automated in **Chetan et al.'s [1]** most recent work employing a welding speed-controlling articulator. A welding process specification created in accordance with ASME Section IX is used during experiments. A single "V"-shaped butt weld junction is used to produce weld samples. In light of this, **Midawi [2]** looked into how the filler material and the galvanized iron coating affected the strength of welds.

Using the Gas Metal Arc Welding (GMAW) procedure, **Glauco et al. [3]** examined and carried out an examination of various welding parameters during the welding of stainless-steel thin thickness tubes. A specially constructed experimental approach based on the development of three distinct levels of values for each of these factors was used to investigate the effects of three key parameters—welding voltage, movement angle, and welding current—on the quality of the welds. a tried-and-true method of increasing welding efficiency employing a particular weldment, the steel compensator (mounting insert) DN300 PN16 **Marian et al. [4].** The number of weld layers was decreased from five to three by using basic semi-automation and FCAW welding in place of conventional GMAW welding. For this DN300 PN16 compensator, the welding time was cut by roughly 12 minutes. This semi-automatic equipment is expected to be used to weld all varieties of mounting inserts and steel compensators. According to the findings **[5]**, when using 70% bead overlap, flux cored arc welding can produce desirable microstructures and hardness values. **Carolina et al. [6]** investigated the robotic GMAW welding procedure used to make duplex stainless-steel welds under various welding circumstances. Each welded plate yielded two tensile specimens, totaling 14 tensile specimens. The anticipated tensile strength values were then compared to the experimental tensile strength values acquired from the tensile test. The results indicate <2% error between observed and predicted values of mechanical properties when using the neural network model. **[7]** The experimental design is a central composite design (CCD), and the solder width is the surface response method (RSM) response. It has been demonstrated that keeping a proper parametric welding factor for a carbon steel plate results in significant welding width values.

Microstructural characterization was carried out by **Camila et al. [8]** using optical microscopy (OM) and scanning electron microscopy (SEM). We conducted the tensile test, Vickers hardness test, and impact test at room temperature and -40 °C for the mechanical characterization. When testing the behaviour in corrosive media during the electrochemical characterization, the samples were subjected to a 3.5% NaCl solution, which produced polarization curves. The findings demonstrated that both domestic and imported wires behaved equally and consistently with regard to their mechanical characteristics. The filling degree and electrode efficiency reported by **Stefan Burger [9]** were equivalent at 18–24% and 90–3%, respectively. There is no significant burning loss or gathering of alloying compounds during the welding metallurgical processes at FCAW, in spite of the welding consumables and shielding gas used. According to **Senthilkumar et al. [10],** To explain how the process variables impacted the responses of super duplex stainless steel claddings, response surface models were used. Using the information gathered from the central composite rotatable design of trials, response surface models were created using regression techniques.

II. METHODOLOGY AND MATERIALS

In many instances, the welder just has to be familiar with the actual welding procedures and need not be concerned about the kind or quality of steel being welded. This is true because a significant portion of the steel used to fabricate a metal structure is mild steel, often known as low-carbon or plain carbon steel. There are usually a few precautions needed when welding these steels using any of the standard arc welding methods, such as Stick MIG or TIG, to prevent modifying the characteristics of the steel. Higher carbon content or other alloy additions to steels may necessitate unique handling techniques, such as preheating and gradual cooling, to avoid cracking or modifying the steel's tensile properties.

The major goal of the project is to ensure that there are no metallurgical flaws and that the physical qualities of the material change as little as possible while being welded. Use should be made of a defect-free welding procedure to successfully weld high carbon material. Additionally, in this experimental study, several samples and quality checks will be carried out, along with destructive and microstructure testing. The evaluation of mechanical behaviour will allow Taguchi's design to optimize hardness and tensile strength. The following are the steps of this study:

- Selecting of base material for FCAW process
- Studying the effect of process parameter on MIG welding
- Groove & Parameter selection
- Conduct the Flux core welding process
- Evaluation of Wear & Corrosion
- Analysis of optical structure
- Optimization and confirm the output response

2.1 Material (OHNS-Steel)

In applications where high strength attributes are required, OHNS-steel is a high tensile alloy steel with wear-resistant qualities. Components having a large cross section and those under severe stress are used with OHNS. In short run cold forming dies, blanking dies, and cutting tools that operate at room temperature, OHNS steels are primarily employed as tooling. The elements that make up OHNS' chemical make-up include Carbon (0.94%), Manganese (1.2%), Silicon (0.30%), Chromium (0.50%), and Vanadium (0.15%).

2.2 MIG Welding:

For this welding investigation, MIG 500 IGBT machine was used with flex cored filler rod. By using MIG welding technique, the test specimens were prepared for standard size of 6 mm thickness. Totally 4 number of specimens have prepared under process parameters of current 140 and 160 amps whereas voltage 18 and 22 Volt. Figure represents the weld specimen and its characteristics are listed below:

- Specimen 1 (S1) – 140 amp / 18 V
- Specimen 2 (S2) – 140 amp / 22 V
- Specimen 3 (S3) – 160 amp / 18 V
- Specimen 4 (S4) – 160 amp / 22 V

Figure 2. Welding Specimens

III. MECHANICAL CHARACTERISTICS WITH DOE

Design of Experiment (DOE), When there are more process parameters, there must be a lot more tests performed. The Taguchi technique utilizes a unique design of orthogonal arrays to explore the full parameter space with a minimal number of tests in order to address this issue. The signal-to-noise (S/N) ratio is then created using the testing findings to determine which quality features deviate from the target range. Three kinds of quality characteristics—lower is better, higher is better, and nominal is better—are commonly used in the analysis of the S/N ratio. The S/N ratio is compared at each level of the process parameter based on the S/N analysis. Therefore, a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic where it was done by Minitab software. The Taguchi orthogonal array is designed for experiment results of hardness and tensile test have evaluated.

3.1 Hardness Test:

Based on the depth to which a steel ball or a diamond tip may penetrate, Rockwell Hardness Systems employs a direct readout system to calculate the hardness number. A material's low Rockwell Hardness value was demonstrated by deep penetration. The obtained hardness results are tabulated below table 1 whereas Taguchi analysis in table 2. The obtained minimum hardness strength is about 43 for specimen 2 and maximum for specimen 4 (54 HR). Based on L4 array, the mean effect and the SN ratio has been derived and represented as graph (figure 4 & figure 5). The Taguchi analysis shows that the welding parameters of specimen 4 achieved greater hardness strength than others.

Table 1. Rockwell Hardness Test Results

Samples	**S1**	**S2**	**S3**	**S4**
Hardness value	52	43	51	54

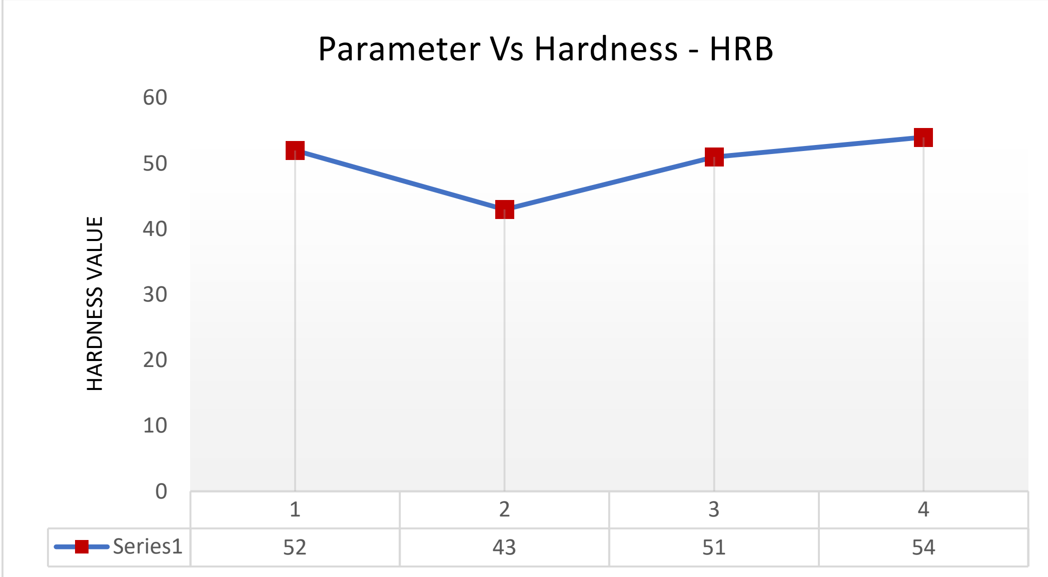

Figure 3. Variance of Hardness Value

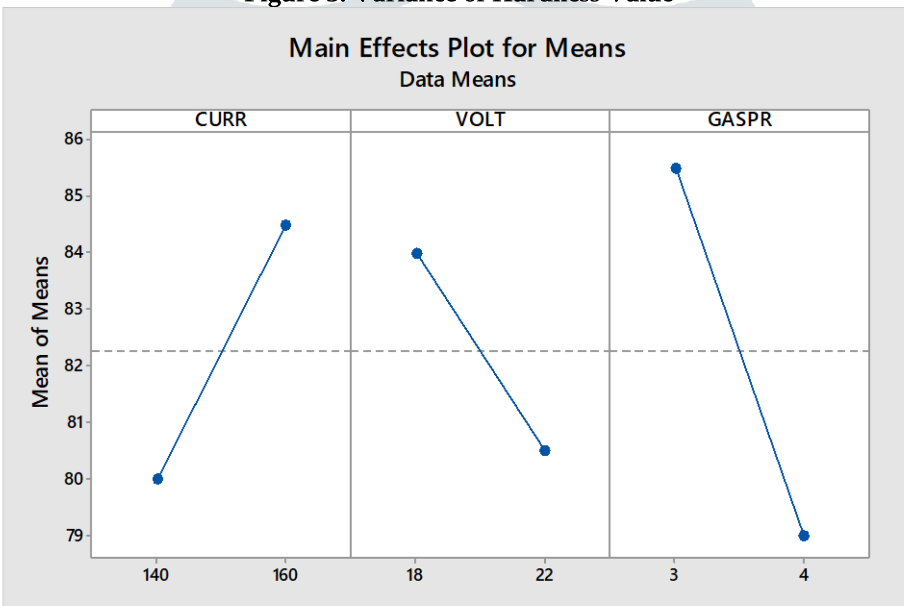

Figure 4. Effect of Mean (Hardness)

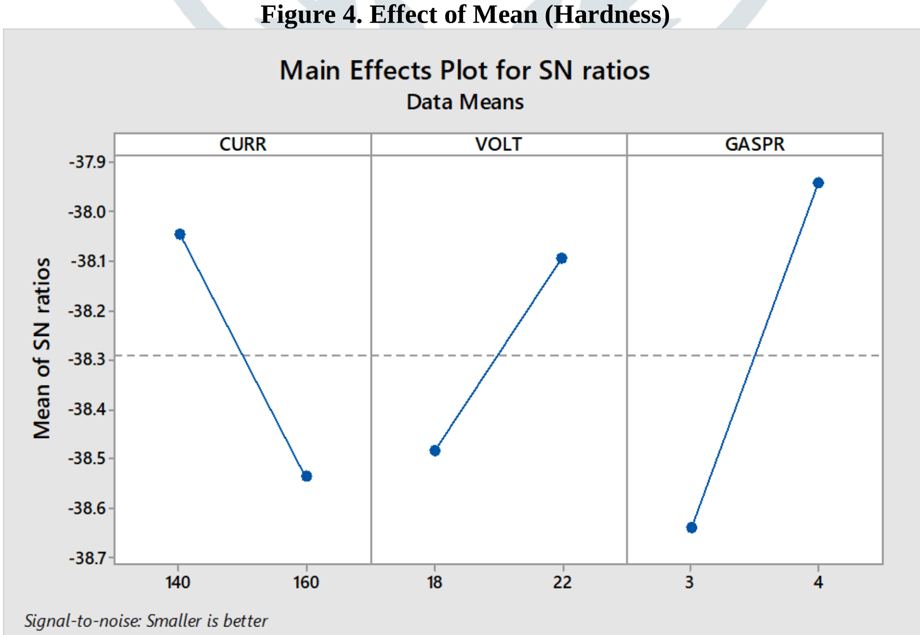

Figure 5. Effect of SN Ratio (Hardness)

Table 2. Taguchi Analysis of Hardness Test

S. No	Current	Voltage	Gas Pr.	Hardness	SN Ratio
1	140	18	3	52	-34.3201
2	140	22	4	43	-32.6694
3	160	18	4	51	-34.1514
4	160	22	3	54	-34.6479

3.2 Tensile Test:

The mechanical characteristics of friction-treated joints for welding are assessed using tensile testing. A tensile test can be used to measure a variety of tensile parameters, including tensile strength, yield strength, percentage of elongation, percentage of area reduction, and modulus of elasticity. The preparation of the weld specimens followed ASTM guidelines. A 40-tone FIE universal testing machine (UTM) was used for the test. The derived results tensile results were tabulated table 3 and also its Taguchi analysis data in table 4. The maximum tensile strength 266 N/mm2 attained for specimen 3 (Figure 6) where the process parameters of current 160 amp and voltage 18 V. The DOE effects of mean and SN ratio for tensile strength is represented graphically in figure 7 and figure 8. Considering tensile characteristics, the suitable process parameters to conduct welding in OHNS material is 160 amp of current and voltage 18 V.

Table 3. Tensile Test Results

Specimen	Load (kN)	Tensile Strength (N/mm2)
S1	22.78	162.71
S2	31.87	227.64
S3	37.24	266
S4	10.22	73

Table 4. Taguchi Analysis of Tensile Strength

S. No	Current	Voltage	Tensile Strength	SN Ratio
1	140	18	162.71	44.2283
2	140	22	227.64	47.1450
3	160	18	266	48.4976
4	160	22	73	37.2665

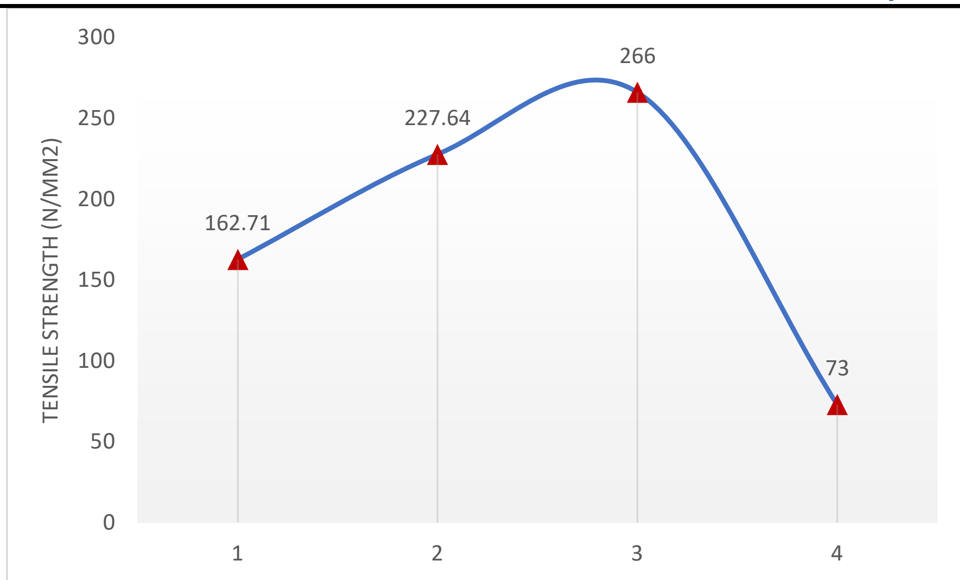

Figure 6. Variance of Tensile Strength

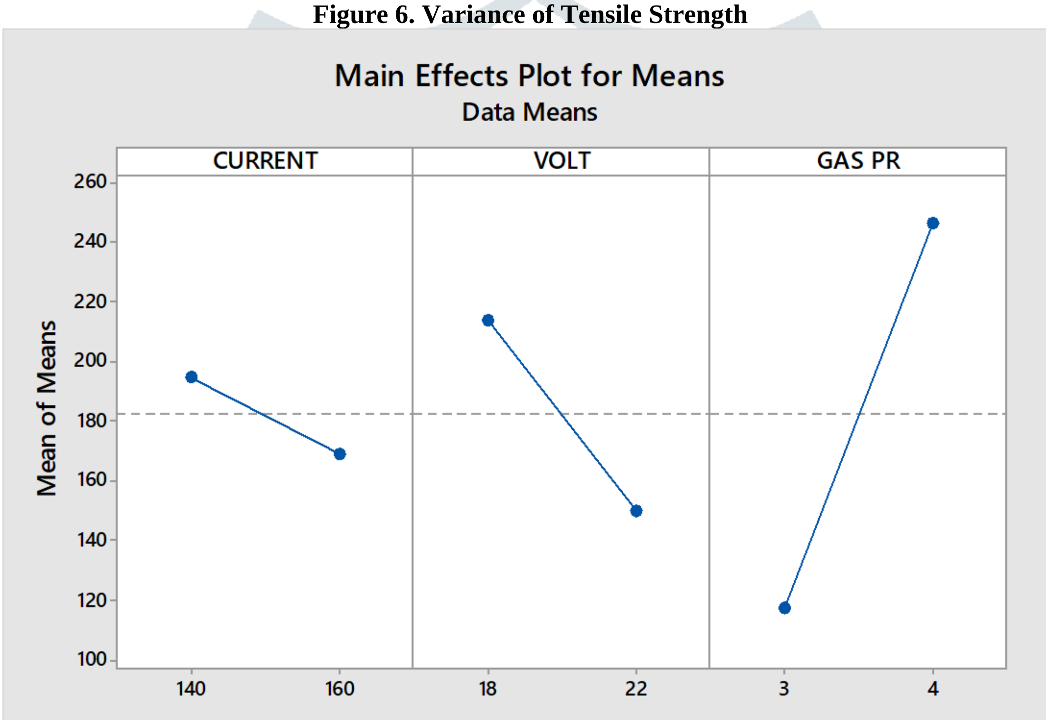

Figure 7. Effect of Mean (Tensile)

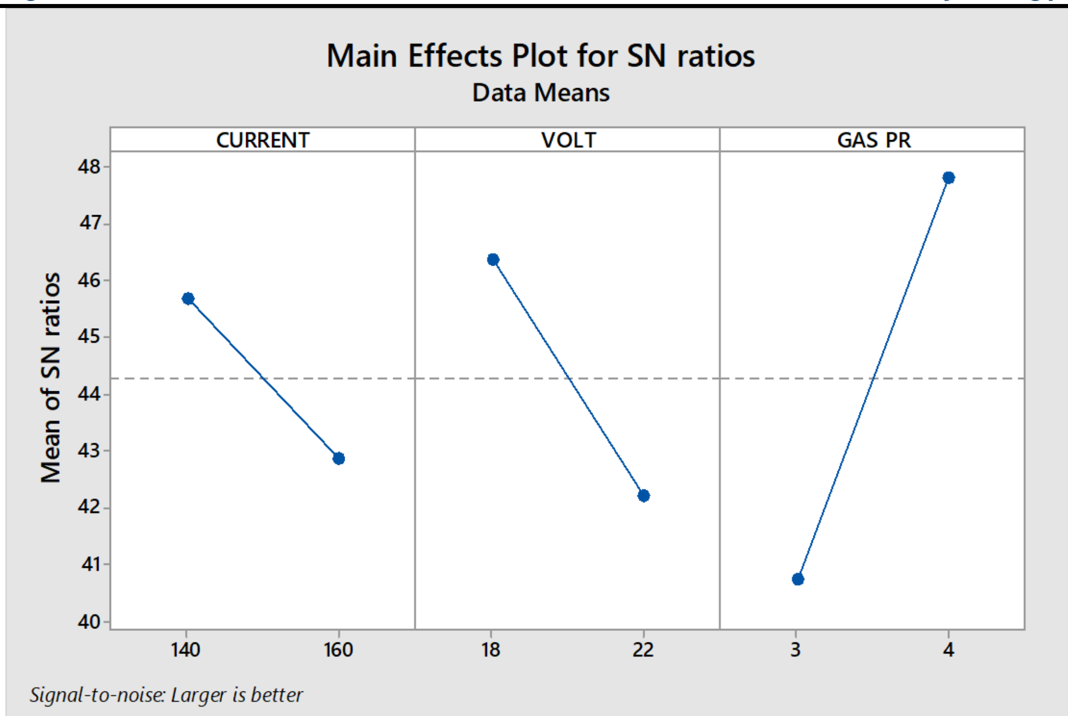

Figure 8. Effect of SN Ratio (Tensile)

3.3 Corrosion Behavior:

The chemical composition, residual tension, and metallurgical structure of the weld zone can all affect how resistant to corrosion a welded junction is. Weld joint corrosion may be avoided by selecting the right welding materials, filler metal, welding techniques, and finishing procedures. Welding corrosion can happen even when the metals are precisely matched and the finest procedures are used, for a multitude of reasons. The heating and cooling cycles that take place during the welding process regularly alter the surface and microstructure composition of the nearby base metal as well as the weld deposit. This can reduce the corrosion resistance of the base metal and the welding substance. The salt spray test has been used in this study to figure out how quickly welded OHNS steel corrodes. Equation (below) was used to calculate the corrosion rate of the specimens of welded steel under examination:

$$Corrosion\ Rate = \frac{K\,W}{A\,T\,D}$$

Where, K = Constant

T = Time of Exposure

A = Area (cm^2)

W = Weight (g)

D = Density (g/cm^3)

Table 5. Observation of Corrosion Test

Specimen	Initial Weight (g)	Final Weight (g)	Weight Loss (g)
T1	3.507	3.321	0.186
T2	3.097	3.014	0.083
T3	3.985	3.724	0.261
T4	3.001	2.451	0.55

Table 5 has the weld specimen weight in before and after test conditions. Based on this data, the corrosion rate has been derived by standard formula which discussed above. The derived outcomes have tabulated below table 6 and variations shown in figure 9. The salt spray corrosion analysis clears that the maximum corrosion formed at 4th welding parameter specimen whereas minimum corrosion rate obtained in 2nd welding parameter specimen.

Table 6. Derivation of Corrosion Rate

K	WL	T	A	D	Corrosion Rate (mm/Year)
0.000876	0.186	72	0.7225	7.84	3.99513E-07
0.000876	0.083	72	0.7225	7.84	1.78277E-07
0.000876	0.261	72	0.7225	7.84	5.60607E-07
0.000876	0.55	72	0.7225	7.84	1.18135E-06

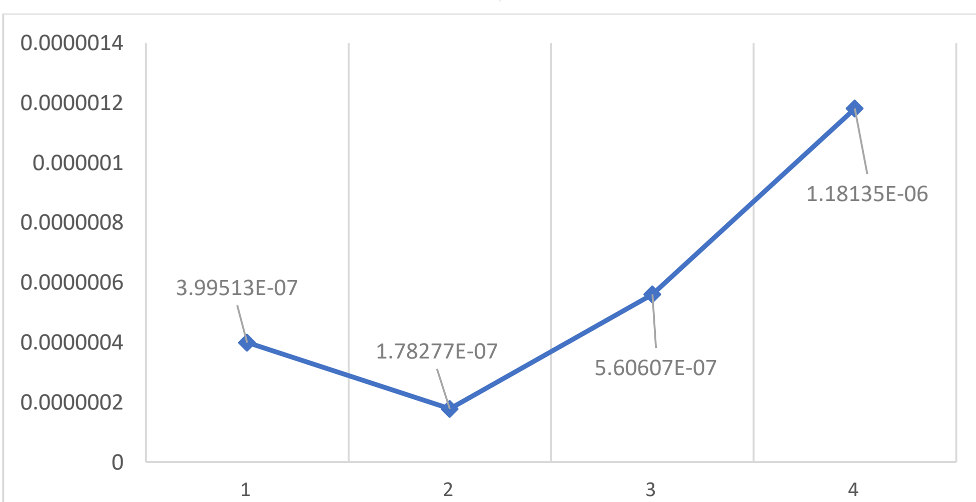

Figure 9. Corrosion Behavior of OHNS Steel

3.4 Wear Analysis:

In solid state contact between two solid surfaces, wear is the process of material loss from one or both surfaces. Surface modifications of current metals are more suitable and cost-effective than developing wear resistant alloys since wear is a surface removal phenomenon that predominantly affects exterior surfaces. Here, Pin on Disc method was used to conduct wear analysis. The process parameters of wear analysis are 400 rpm speed, 2 Kg of load, 60 mm specimen and track radius 30 mm. The test was carried for the duration of 15 minutes. According to the wear test have found the wear rate the welding sample 3 is very low wear rate occurred during this wear investigation. During the investigation third test plate parameter with Amps 160, Volt 18 and Gas pressure 4 Kg/cm2 is occurred very low wear rate. Figure 10 shows the wear rate comparison for 4 specimens and obtained results tabulated in table 7.

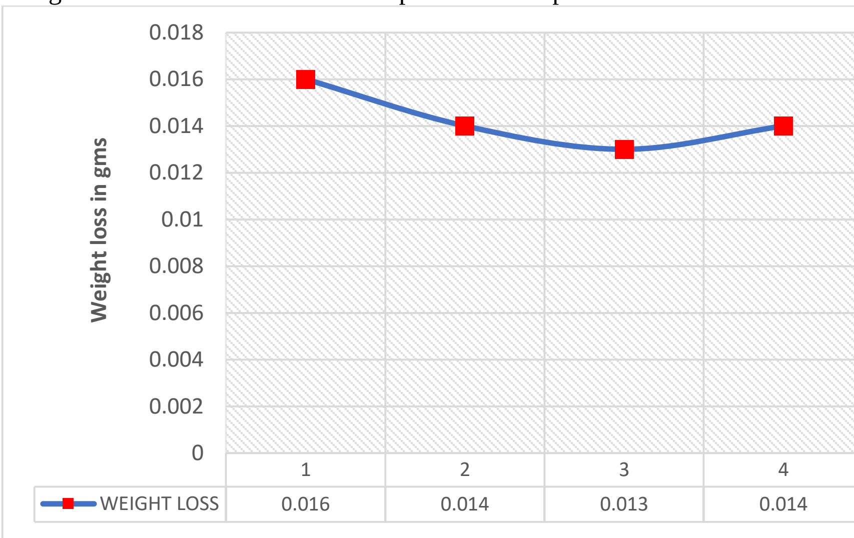

Figure 10. Wear Rate for Welded Specimen

Table 7. Observation of Wear Analysis

DENTIFICATION	BEFORE WEIGHT	AFTER WEIGHT	DIFFERENCE
T1	3.5979	3.5821	0.016
T2	3.2458	3.2314	0.014
T3	3.0077	3.9944	0.013
T4	3.0712	3.0575	0.014

IV. PENETRANT TEST (NDT)

A non-destructive test (NDT) of penetrant test have been carried out to find the crack formed while welding. After welding all welded testing samples evaluated through Penetrant test. All the samples have accepted in the NDT test tabulated below table 8. The figure 11 shows the penetrant test samples that all process parameters have no cracks in weld area.

Table 8. Penetrant Test Results

Specimen	Current	Voltage	Indicators	Result
1	140	18	NI	Accept
2	140	22	NI	Accept
3	160	18	NI	Accept
4	160	22	NI	Accept

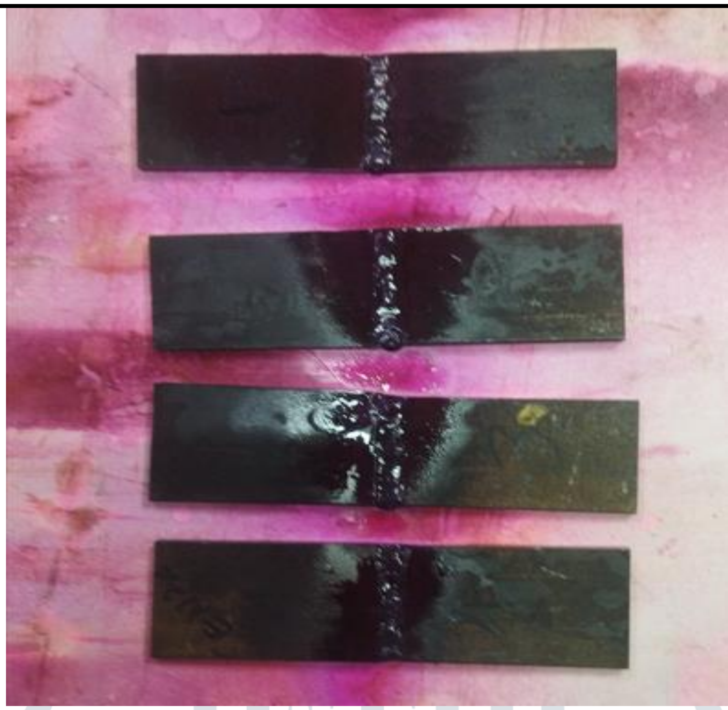

Figure 11. Penetrant of Welded Specimens

V. RESULT AND CONCLUSION

OHNS may be joined effectively with FCAW welding. The treated joints have enhanced metallurgical and mechanical properties. The incorrect variations in heat value in our experiment were linked to the specimen failures. We discovered that the highest tensile strength attained using the input parameter values of 160 amps (18 V BC) and 4 Bar of gas pressure (3rd test sample) did not result in any significant modifications or failures in the testing procedure. During the investigation third test plate parameter with Amps 160, Volt 18 and Gas pressure 4 Kg/cm2 is occurred very low wear rate. During the salt spray corrosion analysis maximum corrosion formed at 4th welding parameter specimen. Very minimum corrosion rating shows 2nd welding parameter specimen. It was finally discovered what input parameter was best for OHNS material with a 6mm thickness during FCAW welding. optimum Taguchi design optimization parameter for tensile strength.

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