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Investigation of Process Parameters on Low Carbon Steel Weldments for Improving Welding Strength

K. Vivek Vardhan[1]; R. Chethan Goud[2]; S. Vishal[3]; C. Labesh Kumar[4]
Department of Mechanical Engineering, Institute of Aeronautical Engineering, Dundigal, Hyderabad. India

Abstract:- Welding is among the methods for joining metals. It can be conducted in both solid and fusion states. In the welding of the fusion state, the amount of the generated heat highly influences the weldments quality from the viewpoint of mechanical properties. carbon steel is the most commonly used material in construction and manufacturing due to its good properties, but the performance of welded joints is critical to the reliability of the structure. To study this effect, Arc Welding technique was used to weld low carbon steel. The Mechanical properties of the welded joints will be evaluated using mechanical tests such as tensile strength. In this work, the mechanical properties of low carbon steel were studied using the Arc welding process. V groove edge preparations on a size 06- mm thick low-carbon steel with the welding parameters: various welding currents at 100, 110, and 120 Amperes.

Keywords:- *ARC Welding, Low Carbon Steel Material, Welding Current, E6013 Electrode, Tensile Strength.*

I. INTRODUCTION

Low carbon steel is the most common option used as it offers better mechanical properties along with a lower price and improved weldability. Welding is one of the most fundamental manufacturing and construction processes which help in joining material with strong structures. It is the strength and integrity of the finished product which is drawn from the quality of the welded joints. However, the optimal choice of weldment is a function that depends on many factors such as the filler material selected and also control of the parameters involved in the process, such as the welding speed, arc voltage, and current. Knowledge of how these parameters interact and affect the weld is therefore a critical step to optimize weld quality.

- **Welding Processes:** A process of joining metals by heat, pressure results in a permanent weld which cannot be disassembled without damaging the two joined parts. Welding is divided into two classes. These are: solid-state welding, fusion welding.
- **Weldability of low carbon steel:** Weldability is defined as the ability of material for welding; it is treated as an index for the welded material to conserve identical mechanical characteristics after the welding process against the matrix metal. Low carbon steel has excellent weldability. Generally, the more the carbon level, the less is the weldability. Low carbon level completely prevents the chances of the formation of a martensitic phase in HAZ. Almost all of the fusion and solid state welding processes can be utilized for assembling mechanical parts made from low carbon steel.

II. METHODOLOGY

A. Material Selection

Mild steel, or low-carbon steel, is any form of carbon steel with a carbon content up to 0.05% to 0.25%. It is versatile and has wide applicability within industries owing to its high ductility and malleability and an excellent weldability. Mild steel is further known for its cost effectiveness as well as good fabrication. Thus, it has applications in construction, automotive manufacturing, and general engineering. It is commonly used for structural beams, pipelines, and machinery parts, but mild steel exhibits poorer corrosion resistance relative to the higher-carbon steels or stainless steel, so it is often protected by surface treatments such as painting or galvanizing. Low tensile strength relative to other steels can also restrain it from high-stress applications, though its cost-effectiveness and ease of use make it popular for many projects.

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Fig 1: Welded Samples

Mild steel is the type of material widely applied in industrial fields. This type of steel has less cost and a low content of carbon between 0.16-0.29%. Its melting point is pretty high; about 1450-1520oC because it contains less carbon in it, which is very higher in other steels used as high carbon contents in that. With such a high melting point of mild steel, there will be an increased ductility upon heating, making the metal perfect for cutting, welding, forging, or drilling. Easy to make, it is not meant for through hardening but could be case hardened if one introduces chemically reactive carbon sources during heating.

Table 1: Material Chemical Composition

Carbon	**Manganese**	**Silicon**	**Sulphur**	**Phosphorus**
0.25%	1.03%	0.208%	0.050%	0.040%

B. Process Approach ARC Welding

Flow Chart 1: Process Approach

III. PROCEDURE

The work piece dimensions are drawn with the help of the designing software Auto CAD. The dimensions are:

- Total length of work piece = 300mm.
- Width of work piece = 50mm.
- Thickness of work piece = 6mm.

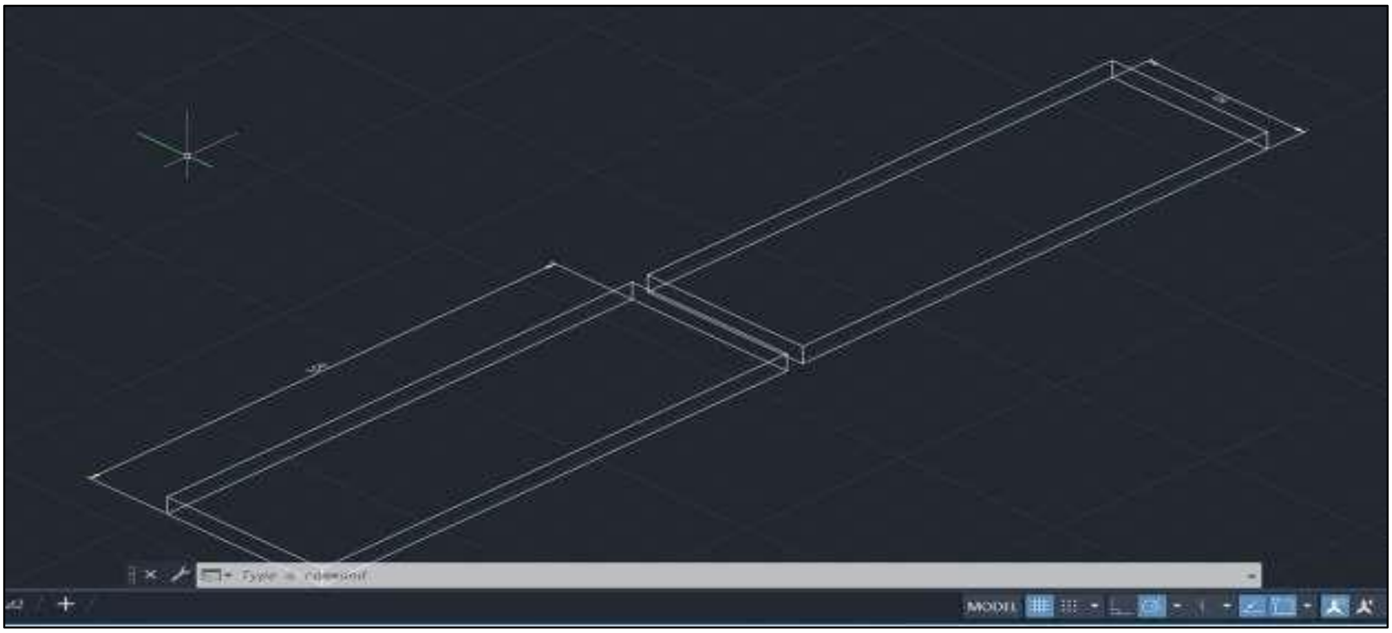

Fig 2: Sample Drawing

A. *Work Material*

➢ *E6013 Electrode*

E6013 is a electrode used to weld the low carbon steel with high titanium-potassium type coating and it can be used both on AC as well as DC. This welding electrode is intended for welding of medium to light penetration. E6013 is used for weld automobile bodies, truck frames and bodies, bridges. Size of electrode is 2.5 x 350mm.

Table 2: Electrode Chemical Composition

Elements	C	Mn	Si	P	S
Content	0.10	0.40-0.60	0.30	0.031	0.03

The tensile strength rises, the hardness rises and ductility reduces with increase in percentage of carbon. E6013 contain manganese 0.40 percent to 0.60 percent. Higher percentage increases the hardness and tensile strength.

The percentage Si increases with the rise in tensile strength.

Fig 3: E6013 Electrode Material

B. *Butt Welding*

Butt welding involves a straightforward and simple process for two metal pieces to be fixed along the edges with robust, strong bonding. Welding offers excellent advantages as they do not harm the internal strength of the component under attachment while remaining clean without wrinkles and with smooth faces. It is widely used in industries for the joining of pipes, structural beams, automotive parts, and aerospace parts-these are the places where stronger, effective joints are necessary for better performance and safety. This process has commonly been used in manufacturing industries, construction, and their repair industries where a strong joint is required.

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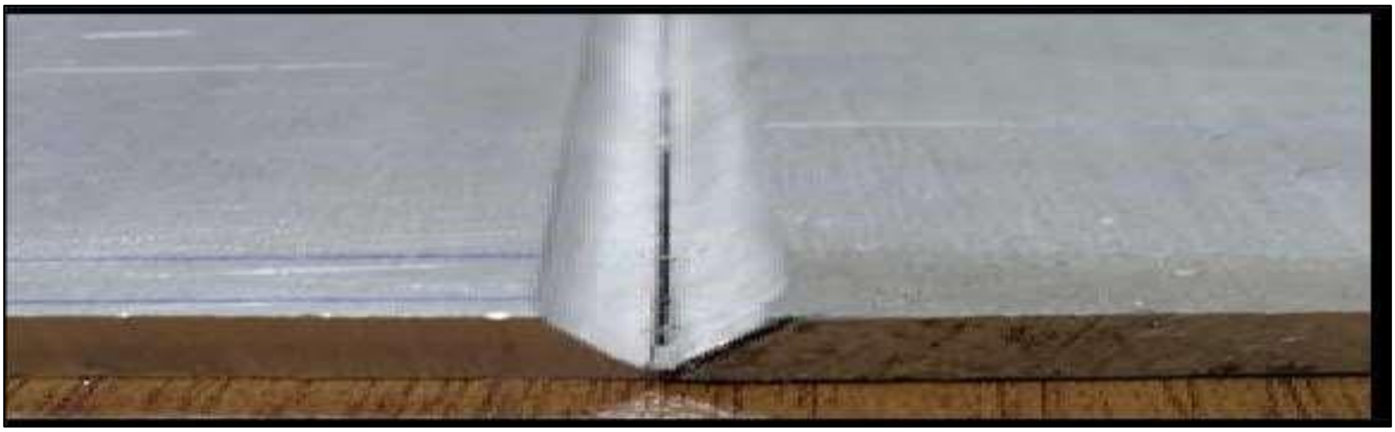

Fig 4: Butt Welding

C. Testing of Welded Joints

A UTM is a universal testing machine used for applying various kinds of loading to test mechanical properties of materials, parts, and structures in tension and compression. The primary function of the UTM is to apply controlled mechanical forces on the tested specimen and to measure

Deformation, strain, and stress are among the basic mechanical properties. These properties help determine the tensile strength, yield strength, and elongation at break. Modern UTMs are normally equipped with computerized control systems so that test parameters like force rate, displacement rate, and test time may be controlled with a very high accuracy. Acquisition systems monitor data in realtime, providing graphs and numerals.

Tests performed in various laboratories around the world on a UTM follow international standards set up by organizations like ASTM International, ISO, and many more. Hence, the tests repeated will be as repeatable and reliable for test results. Universal Testing Machines give necessary data on the behavior of materials under different loadings and play a very crucial role in materials testing and research. They are the most accurate and versatile tools in any area of engineering and material science.

Fig 5: Universal Testing Machine

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➢ *Test Parameters*

Table 3: Parameters Table for Welding Process

S.NO	CURRENT (A)	VOLTAGE (V)	WELD SPEED
1.	100 A	75V	100 MM/MIN
2.	100A	85V	200 MM/MIN
3.	100A	95V	300 MM/MIN
4.	110A	75V	300 MM/MIN
5	110A	85V	200 MM/MIN
6	110A	95V	100 MM/MIN
7	120A	75V	100 MM/MIN
8	120A	85V	200 MM/MIN
9	120A	95V	300 MM/MIN

IV. RESULTS AND DISCUSSION

Table 4: Tensile Strength Values for Low Carbon Samples

EXPERIMENT NUMBER	SAMPLE	TENSILE STRENGTH (KN)
1		78 KN
2		80 KN
3		82 KN
4		112 KN
5		114 KN
6		118 KN
7		124 KN

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8		128 KN
9		132 KN

A. Mean Effects Plots for SN Ratios

The SN ratio is determined on experimental data; the higher is the ratio, the better are the performance and consistency. The plots will enable engineers to view the effects of every parameter and the respective levels that produce the most robust weld. The optimization of welding processes, on analyzing mean effects plots, can be decided to provide superior strength and reliability for the final product.

Table 5: Response Table for Signal to Noise Ratios

Level	Current	Voltage	Weld Speed
1	38.24	40.34	40.65
2	41.41	40.90	40.91
3	42.43	40.84	40.51
Delta	4.20	0.56	0.40
Rank	1	2	3

These plots are a part of the Taguchi method and graphically represent average SN ratios for each level of a parameter. The higher the SN ratio, the better the performance and the higher the process robustness to variability. Engineers can graphically identify the levels of which parameters yield the highest tensile strengths and least inconsistency through trends in these plots.

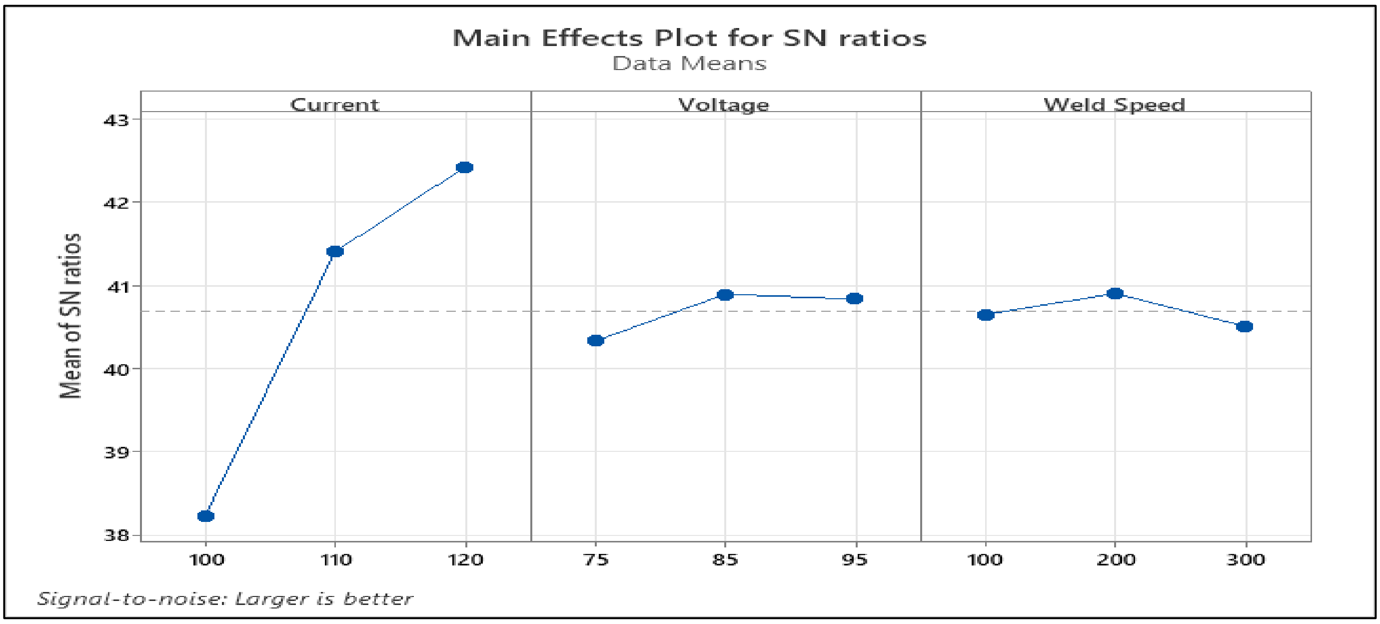

Fig 6: Mean Effects Plots for SN Ratios

B. Main Effects Plots for Means

Mean effects plots for means are graphs that help to describe the effect of weld parameters such as current, voltage, and weld speed on mean welding strength. Their use in a Design of Experiments typically includes plots of parameter levels changes and their impact on mean tensile strengths of welds. Each point on the plot represents average welding strength of that level of a parameter, and the trends indicate whether increasing or decreasing the parameter improves strength., The mean effects plot might display that higher levels of current increase tensile strength to an optimal point past which continues to decrease due to defects like overheating.

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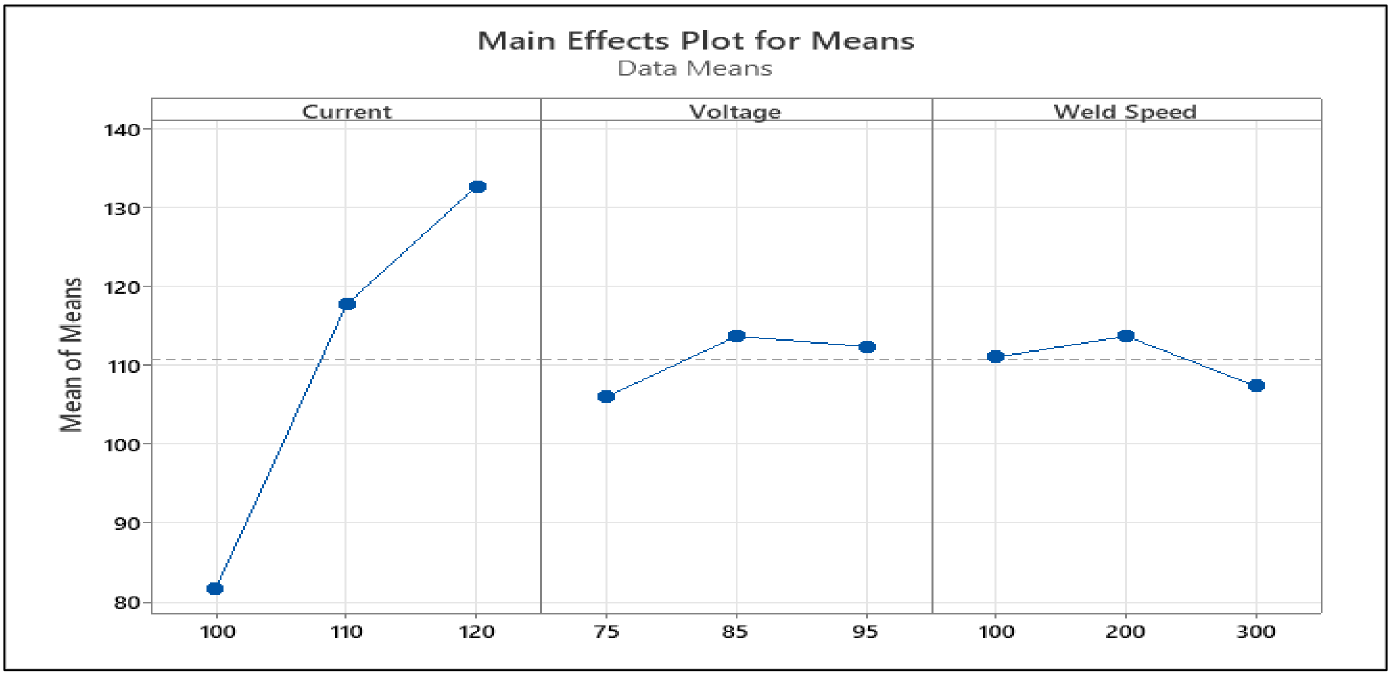

Fig 7: Main Effects Plots for Means

C. General Linear Model: Weld Strength Versus Current, Voltage, Weld Speed

A GLM is one that assumes, in addition to main effects for all factors, interaction between the parameters to determine what extent they affect tensile strength of welds. Experimental data is collected based on a designed experiment, such as factorial or Taguchi approaches, where systematically the parameters are varied. The model produces coefficients and the p-values, which express the significance of each factor and interaction between them, while the results from ANOVA reveal the percentage contribution of each factor toward the strength of welds.

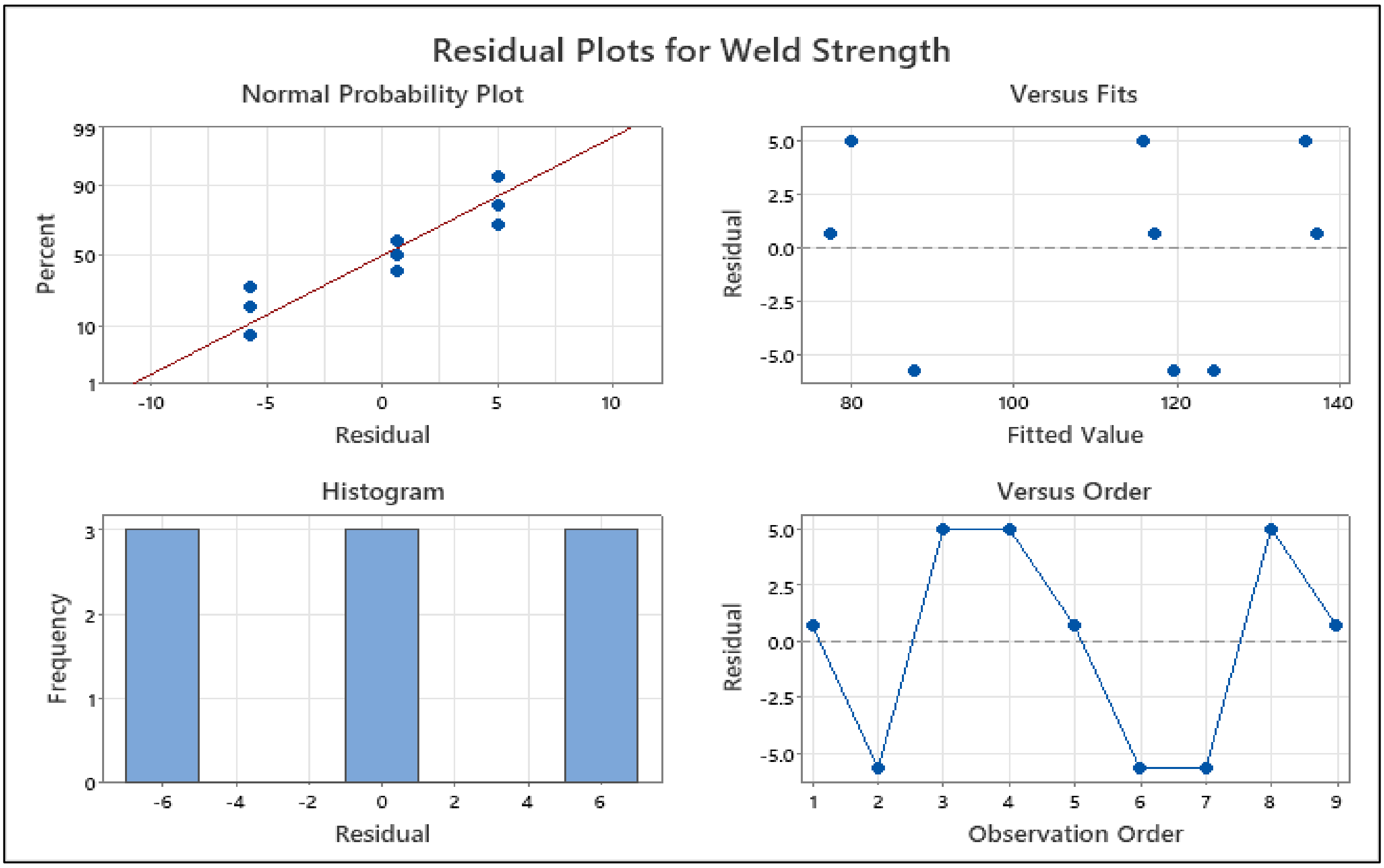

Fig 8: General Linear Model: Weld Strength Versus Current, Voltage, Weld Speed Graphs.

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V. CONCLUSION

The optimization of the parameters of low carbon steel weldments had been dealt with in the research by focusing on arc welding techniques. Tensile strength and weld quality were considered. The welding manufacturing process is highly efficient in the automotive, constructional, and aerospace industries owing to its capacity to generate powerful joints. Thus, at the end, the quality of low carbon steel weldments will be systematically studied in terms of variables influencing weldment as current, voltage, and weld speed. Results obtained from universal testing machines, along with a statistical analysis through SN ratios and models of optimization, depict intricate connections between variables concerning welding and mechanical properties.

A. Welding Parameter Influence:

- Higher currents (120 A) with higher potentials (95 V) and medium welding speeds of 300 mm/min had repeatable results of higher tensile strengths up to 132 KN.
- Penetration and bonding with these was not optimum, and as the weld strength was compromised it was done with smaller currents and slower speeds.

B. Material Behavior and Weldment Characteristics:

- Low carbon steel demonstrated excellent weldability with minimal distortion, confirming its viability for industrial applications. The study reinforced the material's compatibility with E6013 electrodes, which contributed to optimal arc stability and bead quality.
- HAZ was found at extremely low levels with proper parameter control, thus giving uniformity in microstructure and mechanical consistency.

C. Optimization Insights:

- Taguchi methods and mean effects plots for SN ratios were deployed in order to set up proper welding parameters. Such an approach systematically reduced 'trial-and-error' processes in order to guarantee efficiency in the use of resources and accuracy.
- This study significantly contributes to the existing knowledge base on arc welding based on the thorough analysis of parameter interactions. With high tensile strength and minimized defects, the findings will provide direct actionable knowledge for industries relying on weldments from low-carbon steel.

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