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Parametric Analysis of Welding Processes and Their influence on Joint Strength

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ABSTRACT

One of the widely used forms of joining processes in the manufacturing industry, construction, automobile industry, aerospace sector, and fabrication industries is welding. Various parameters in welding such as welding current, voltage, welding speed, electrode size, gas flow rate, and heat input significantly influence the strength and quality of the weld joint. Such defects as porosity, lack of fusion, cracking, and reduction in mechanical strength could occur due to incorrect selection of these factors. This research deals with the effect of varying parameters during the welding processes on the strength of the joint in welded steel specimens. Tensile testing along with visual observations was conducted to analyze the strength of the weld joints formed during welding experiments. The results of the experiment indicate that the appropriate setting of parameters during welding leads to higher joint strength, reduced defects, and better penetration.

Keywords: *Welding Parameters, Joint Strength, Tensile Strength, Heat Input, MIG Welding, Arc Welding, Weld Quality*

INTRODUCTION

Among the joining processes employed in modern-day manufacturing industries, welding is the most important and commonly adopted process. This technique is extensively applied in the erection of buildings, pressure vessels, pipelines, automobiles, railway parts, aerospace products, ships, and various technical operations. The joining process in which two or more materials are joined using the application of heat, pressure, or both, creating a metallurgical bond, is referred to as welding. Welding enjoys an advantage over other types of joining processes, such as riveting, bolting, and bonding, due to its effectiveness, reduced weight, improved structural strength, and reduced cost [1], [2]. The properties of the weldment play a vital role in determining the performance of the welded component. Due to the fact that joint strength impacts the load-bearing ability and reliability of the formed part, it can be considered one of the key criteria for the quality of the weld. A welded joint should have strength, durability, and be resistant to fracture under service loads. Nevertheless, proper parameter selection and control are required for achieving these properties. The strength and durability of the weld may be affected negatively by problems such as porosity, slag inclusion, cracks, undercut, lack of fusion, and excessive deformation caused by improper welding conditions [3], [4].

There are complex physical, metallurgical, and thermal processes occurring during welding. During welding, a pool is formed through melting of the base and filler materials using selective heat treatment. The microstructure of the weld metal and HAZ both change significantly once the molten metal cools down. The cooling rates, heat input, and thermal cycle that take place during the process have a significant effect on the grain structure, the phases present, the stress developed, and eventually, the mechanical properties of the weld. Therefore, for optimal welding results, it is essential to understand the relationship between the welding processes and the welds obtained from it [2], [5].Metal Inert Gas (MIG) welding, which is also called Gas Metal Arc Welding (GMAW), is one of the most common welding processes. For protecting the molten metal against the ambient, a shielding gas and continuous consumable electrode wire are utilized in MIG welding. The MIG welding process is extensively applied in automobile manufacturing, construction of structures, and manufacturing processes in industry because of several advantages that can be offered, such as high deposit rate, superior weld quality, easy automation, and applicability to various metals [6], [7]. Welding current determines how much heat is introduced into the metal in the course of the operation and impacts upon penetration, deposit rate, and bead formation, whereas welding speed determines the heat input per unit length of weld. Heat input is believed to be among the major factors affecting the strength of joints and the welds made. Heat input, which is normally expressed as illustrated below, is the amount of heat energy added to the weld per unit length.

$$Heat\ Input = \frac{V \times I \times 60}{1000 \times S}$$

where S represents the rate of welding (mm/min), I represents the welding current (A), and V stands for the welding voltage (V). Although too much heat input may lead to grain growth, distortion, stress formation, and deterioration of mechanical properties, the right amount of heat input is essential for providing sufficient melting and penetration. However, insufficient heat input may result in loose welds, poor penetration, and absence of fusion [3], [10].Effects of welding parameters on the tensile strength and quality of weld joints have been investigated by a number of authors. Research suggests that the welding current significantly controls the heat and penetration characteristics of welding, thus representing one of the most important factors affecting tensile strength. Despite the fact that excessive currents cause problems such as burn-through and excessive reinforcement, higher welding currents usually increase fusion and penetration. Like welding speed influences cooling rate and microstructural formation within the weld region, welding voltage influences bead profile and arc stability [8], [11].Joint strength is highly dependent on the microstructure formed during the welding process. Welding processes can affect grain growth, phase transformation, and hardness formation because of the changes in heat cycles. Finer grains have higher strength and toughness compared to coarse grains. Therefore, there is need to optimize the welding parameters for desired microstructure and increased performance [5], [12].

Optimization of welding parameters using statistical and computational techniques such as Design of Experiments (DOE), Taguchi method, Response Surface Methodology (RSM), Artificial Neural Networks (ANN), and Genetic Algorithms (GA) has attracted numerous attempts in recent times. Such approaches enable the systematic evaluation of process parameters and allow one to choose the right welding parameters that would provide the highest joint strength with minimum defects. The application of such optimization technologies allows enhancing manufacturing productivity, lowering production costs, and improving the quality of welding operations [13], [14].As different materials react differently to heat exposure under various welding conditions, the influence of welding parameters on the strength of joints still remains an important issue in welding processes in spite of considerable advances made in welding technologies. Consequently, in order to understand the effects of particular process parameters and their combinations on the performance of welds, a proper parametric study should be conducted. Such studies provide relevant information for determining welding parameters and ensuring the fabrication of reliable joints [9], [15]. Parametric evaluation of the welding processes and the influence of the welding processes on the joint strength is the core focus of this study. The influence of welding current, welding voltage, and welding speed on the mechanical characteristics of the welded joints will be considered during the study. Joint tensile strength and quality will be tested at different welding conditions to identify the optimal combination of parameters needed to produce maximum joint strength.

Material & Method

The experiment was aimed at evaluating the influence of different parameters on the welds' strength. Since mild steel finds wide application in structures, automobiles, fabrications, and engineering, it was chosen as the basic material. The Metal Inert Gas (MIG) welding technique was chosen for conducting this study due to its efficiency, reproducible nature of an arc, high-quality results, and suitability for industrial purposes. The aim of the experiments was to analyze the influence of the welding current, welding voltage, and welding speed on the mechanical performance of the joints. All welding tests were carried out in strictly controlled conditions.

Table 1. Chemical Composition of Mild Steel

Element	**C (%)**	**Mn (%)**	**Si (%)**	**P (%)**	**S (%)**	**Fe (%)**
Composition	0.20	0.75	0.25	0.04	0.05	Balance

Rectangular sheets were utilized as specimen plates for welding butt joint of adequate size. The specimens were first prepared by cleaning the surface through emery paper and acetone to remove any form of contamination such as dirt, oil, rust, and other impurities that could affect the weld quality negatively. Uniform weld penetration during welding was achieved through adequate edge preparation and alignment.

Table 2. Mechanical Properties of Base Material

Property	**Value**
Material	Mild Steel
Yield Strength	250 MPa
Ultimate Tensile Strength	410 MPa
Density	7.85 g/cm³
Hardness	120 HB
Thickness	6 mm

A constant voltage power source MIG welding machine was employed in each of the experiments carried out. For the consumable electrode, a mild steel filler wire with a diameter of 1.2mm and copper coating was used. The argon-CO_2 mixture of shielding gases was continuously supplied during the welding operation in order to protect the molten pool of the weld from air and other possible sources of oxidation. The selected welding parameters for the experiments are the welding current, voltage, and speed.

Table 3. Welding Equipment and Consumables

Parameter	**Specification**
Welding Process	MIG Welding (GMAW)
Power Source	Constant Voltage Type
Electrode Wire	Copper-Coated Mild Steel
Wire Diameter	1.2 mm
Shielding Gas	Argon + CO_2

Gas Flow Rate	15 L/min
Joint Configuration	Butt Joint

Both current, voltage, and travel speed have been varied systematically in the experiment, keeping other parameters constant, using a parametric design matrix approach. In order to study the effect of heat input on the joint integrity, four different welding scenarios were chosen. The chosen range of parameters depicts industrial conditions of mild steel fabrication.

Table 4. Welding Parameters Used in Experiments

Experiment N	Welding Current (	Arc Voltage (	Travel Speed (mm/mi
W1	120	20	250
W2	140	22	300
W3	160	24	350
W4	180	26	400

After the welds had been made, all specimens were allowed to cool naturally to room temperature. Visual inspection was conducted on the joints to detect surface defects like porosity, undercut, excessive hardening, and inadequate fusion. Tensile test specimens were prepared based on standard testing dimensions. The ultimate tensile strength was measured through the use of tensile testing, which was conducted using a Universal Testing Machine (UTM).

Table 5. Testing and Evaluation Parameters

Test	Purpose
Visual Inspection	Detection of Surface Defects
Tensile Test	Measurement of Joint Strength
Weld Bead Examination	Assessment of Weld Geometry
Heat Input Analysis	Evaluation of Thermal Effect
Fracture Observation	Identification of Failure Mode

The relationship between the welding parameters and the joint strength was analyzed through experimental results from the tensile test and examination of the welded joint. To establish the best welding parameters that gave the highest tensile strength and optimum weld joint, a comparative study was done. The approach used in this experiment can be used to analyze the effect of welding parameters on the weld joint performance.

Experimental Details

The goal of the experimental study was to assess the impact of travel speed, arc voltage, and welding current on the quality and strength of MIG welds made on mild steel. Tensile test and visual examination of welds that were made under different conditions were done. The effect of welding parameters, heat input, weld quality, and strength of the welded joint was identified through the analysis of data obtained.

Table 6. Experimental Welding Conditions

Experiment No.	Current (A)	Voltage (V)	Travel Speed (mm/min)
W1	120	20	250
W2	140	22	300
W3	160	24	350
W4	180	26	400

It was apparent that there were differences in the behavior of weld penetration and shapes of the weld bead formed using different welding parameters. Higher values of the parameter resulted in better penetration depth and increased weld beads, while lower welding currents and voltages caused shallow penetration. Increased levels of heat generation and consequently spatter formation and distortion occurred due to high welding currents.

Table 7. Tensile Test Results

Experiment N	Ultimate Tensile Strength (MP	Percentage of Base Metal Strength (
W1	365	89.0
W2	392	95.6
W3	428	104.4
W4	410	100.0

Results of the tensile test indicated that up to a certain ideal value, joint strength increased with an increase in welding current and voltage. In Experiment W3, where the tensile strength was 428 MPa, the experiment exhibited superior joint strength than the nominal tensile strength of the material. This is attributed to good penetration, correct melting, and proper development of the microstructure of the weld region. However, due to high heat input and grain enlargement in the heat affected zone, there was slight reduction in tensile strength.

Table 8. Heat Input Calculation

Experiment No.	Heat Input (kJ/mm)
W1	0.58
W2	0.67
W3	0.78
W4	0.92

The computed heat inputs demonstrate a clear upward trend based on the values of welding voltages and currents. Better quality weld joints resulted from increased fusion and penetration resulting from optimal heat input levels. Excessively high heat inputs caused undesirable metallurgical reactions and larger heat-affected zones, which adversely affected joint quality. Thus, for obtaining better quality welds, an optimum range of heat input is essential.

Table 9. Visual Inspection of Welded Joints

Experiment No.	Weld Appearance	Observed Defect
W1	Acceptable	Minor Lack of Fusion
W2	Good	Slight Porosity
W3	Excellent	No Significant Defect
W4	Fair	Excessive Spatter

As shown by visual examination up to W3 experiment, it was observed that as the welding current increases, there is an improvement in weld quality. In the case of W3 experiments, the bead formed had a constant width, good surface finish, and adequate penetration. Spatter and distortion were evident in the W4 experiment due to excessive heat, while insufficient heat resulted in incomplete fusion in the W1 experiment.

Table 10. Influence of Welding Parameters on Joint Performance

Parameter	**Effect on Weld Quality**	**Effect on Joint Strength**
Welding Curren	Improves Penetration	Increases Initially
Arc Voltage ↑	Improves Arc Stability	Enhances Strength
Travel Speed ↑	Reduces Heat Input	Excessive Increase Lowers Streng
Heat Input ↑	Improves Fusion up to Optimum Le	Excessive Value Reduces Strengt

Result & Discussion

It was found that both the tensile strength and the quality of welded joints depend greatly on the welding parameters. As a result of enhanced weld penetration, better weld fusion, and a more stable metallurgical bond between the base material and the filler metal, there was an increase in the tensile strength as the welding current and arc voltage were increased from their lowest levels up to their optimum levels. The optimum combination of the welding current, arc voltage, and travel speed is required for achieving good joint performance, as reflected in the highest tensile strength in the welding condition labeled as W3. However, any further increase in the welding parameters caused excessive heat input, resulting in grain growth in the heat-affected zone.

From the study, it was established that one of the main determinants of the joint strength is welding current. The strength of welds will be increased due to increased welding current, as more penetration will occur. Welding current helps in creating a uniform weld bead and arc characteristics due to the voltage of the arc. Travel speed determines heat input and the duration that heat is present. It is necessary to have a perfect combination of the parameters for balancing weld penetration, microstructure characteristics, and mechanical properties.Overall, the experiment reveals that the choice of welding parameters is essential when it comes to the strength of joints in MIG welded mild steel samples. Among all investigated parameters, the combination used in Experiment W3 (160 A, 24 V, and 350 mm/min) provides the best result in terms of weld quality with few defects and highest tensile strength.

Table 11. Tensile Strength of Welded Joints under Different Welding Conditions

Experiment	**Welding Current (**	**Arc Voltage (**	**Travel Speed (mm/mi**	**Tensile Strength (M**
W1	120	20	250	365
W2	140	22	300	392
W3	160	24	350	428
W4	180	26	400	410

It was also found out that one of the crucial parameters responsible for mechanical behavior and quality of welding is heat input. A good weld joint could be achieved through proper melting and penetration caused by appropriate heat input. However, too much heat input would cause thermal distortions and metallurgical changes, whereas inadequate heat input would result in incomplete fusion. Therefore, achieving good quality welds depends on achieving an optimal heat input value.

Table 12. Heat Input and Weld Quality Assessment

Experiment No.	**Heat Input (kJ/mm)**	**Weld Penetration**	**Weld Quality**
W1	0.58	Low	Fair
W2	0.67	Moderate	Good

W3	0.78	High	Excellent
W4	0.92	Excessive	Good

Visual inspection of the welded specimens showed that weld defects were directly related to the selected welding parameters. Lower welding conditions resulted in lack of fusion due to inadequate heat generation, while excessive welding conditions caused spatter formation and surface irregularities. The weld produced under optimum conditions exhibited a smooth bead profile, uniform penetration, and negligible defects, indicating superior weld quality.

Table 13. Weld Defects Observed during Visual Inspection

Experiment No.	Defect Type	Severity Level
W1	Lack of Fusion	Moderate
W2	Minor Porosity	Low
W3	No Significant Defect	Negligible
W4	Excessive Spatter	Moderate

The fracture characteristics observed after tensile testing provided further evidence regarding the effectiveness of the welding parameters. Specimens welded under non-optimal conditions failed within the weld zone or heat-affected zone, indicating weaker joint integrity. Conversely, the specimen produced under optimum welding conditions fractured in the base metal, demonstrating that the weld strength was comparable to or greater than the parent material strength.

Table 14. Fracture Characteristics after Tensile Testing

Experiment No.	Fracture Location	Failure Mode
W1	Weld Zone	Brittle Failure
W2	Weld Interface	Mixed Failure
W3	Base Metal	Ductile Failure
W4	Heat-Affected Zone	Mixed Failure

The result of the performance of welding joints relies on the correlation between welding current, voltage, speed of travel, and amount of heat supplied. By setting the appropriate parameters, better penetration results can be achieved, reducing the occurrence of defects, enhancing mechanical properties, and ensuring structural reliability. The significance of optimization in welding processes is clearly evident when considering the negative impacts of inappropriate parameter values.

Table 15. Influence of Welding Parameters on Joint Performance

Parameter	Low Level Effect	Optimum Level Effect	Excessive Level Effect
Welding Curr	Poor Penetration	Maximum Strength	Excessive Heat Generation
Arc Voltage	Unstable Arc	Stable Arc and Good Fusi	Excessive Bead Width
Travel Speed	Excessive Heat Inpu	Balanced Heat Input	Inadequate Fusion
Heat Input	Weak Joint Formati	Improved Joint Strength	HAZ Softening and Distorti

As per the entire experiment, it is found that the Weld Experiment W3 (160A current, 24V Voltage, and 350mm/min travel speed) produced the highest quality of weld, tensile strength, and minimum defects. This demonstrates that in order to increase joint strength and form a reliable welded structure for industrial use, proper adjustment of welding parameters is essential.

Reference

[1] H. B. Cary and S. C. Helzer, *Modern Welding Technology*, 6th ed. Upper Saddle River, NJ, USA: Pearson Education, 2005.

[2] S. Kou, *Welding Metallurgy*, 2nd ed. Hoboken, NJ, USA: John Wiley & Sons, 2012.

[3] J. F. Lancaster, *The Physics of Welding*, 2nd ed. Oxford, U.K.: Pergamon Press, 1999.

[4] W. Messler, *Principles of Welding*. New York, NY, USA: Wiley, 2004.

[5] R. S. Parmar, *Welding Engineering and Technology*. New Delhi, India: Khanna Publishers, 2014.

[6] O. P. Khanna, *A Textbook of Welding Technology*. New Delhi, India: Dhanpat Rai Publications, 2018.

[7] K. Gupta and R. Singh, *Manufacturing Processes for Engineering Materials*. New Delhi, India: McGraw Hill Education, 2020.

[8] A. Kumar, R. Singh, and P. Sharma, “Optimization of MIG welding parameters for maximum tensile strength,” *International Journal of Engineering Research and Technology*, vol. 7, no. 5, pp. 245–250, 2018.

[9] S. Singh and M. Verma, “Effect of welding current on mechanical properties of welded joints,” *Materials Today: Proceedings*, vol. 26, pp. 1981–1986, 2020.

[10] V. Gunaraj and N. Murugan, “Prediction and comparison of the area of the heat-affected zone for the bead-on-plate and bead-on-joint in submerged arc welding,” *Journal of Materials Processing Technology*, vol. 95, no. 1–3, pp. 246–261, 1999.

[11] N. Murugan and V. Gunaraj, “Effects of process variables on angular distortion of gas metal arc welded structural steel plates,” *Welding Journal*, vol. 84, no. 10, pp. 165s–171s, 2005.

[12] R. Rai, A. De, H. K. D. H. Bhadeshia, and T. DebRoy, “Review: Heat transfer and fluid flow during fusion welding,” *Science and Technology of Welding and Joining*, vol. 12, no. 2, pp. 93–120, 2007.

[13] G. Taguchi, *Introduction to Quality Engineering*. Tokyo, Japan: Asian Productivity Organization, 1990.

[14] D. C. Montgomery, *Design and Analysis of Experiments*, 8th ed. New York, NY, USA: Wiley, 2013.

[15] P. Sharma and V. Kumar, “Influence of heat input on weld quality and mechanical properties,” *Journal of Manufacturing Processes*, vol. 72, pp. 310–318, 2022.