# WIRE FEED RATE OPTIMIZATI ON FOR MIG WELDING OF ALLUMINIUM ALLOY 6063

**A Dissertation Submitted**

**In partial fulfillment of the requirement For**

**the Degree**

## MASTER OF TECHNOLOGY

**In**

**MECHANICAL ENGINEERING**

**With specialization In**

**“PRODUCTION AND INDUSTRIAL ENGINEERING”**

**By**


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**June 2022**

# CERTIFICATE

This is to certify that **Mr. Arun Pratap Singh** (Enrollment No. 2000101852) has carried out theresearch work presented in the dissertation titled **“Wire Feed Rate Optimization for MIG Welding of Aluminium Alloy 6063”** submitted for partial fulfillment for the award of the **Degree of Master of Technology in Mechanical Engineering** from **Integral University, Lucknow** under my supervision. The dissertation embodies result of original work, and studies are carried out by the student himself.

Therefore, I deem this work fit and recommend for submission for the award of the aforesaid degree.


**Dr. Shahnwaz Alam**

**Associate Professor**

**Department of Mechanical Engineering**

**Integral University, Lucknow**


**Date:**

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# DECLARATION

I hereby declare that the dissertation titled **"Wire Feed Rate Optimization for MIG Welding of Aluminium Alloy 6063"** is an authenticrecord of the research work carried out by me under the supervision of **Dr. Shahnwaz Alam**, Department of Mechanical Engineering, for the period from **2020** to **2022** at Integral University,Lucknow. No part of this dissertation has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the dissertation. I further certify that I have not willfully taken other's work, para, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at websites without their permission, and have not included those in this M.Tech. thesis citing as my own work.

**Date: -**

**Signature: -**

**Name: -** Arun Pratap Singh

**Enroll. No.: -** 2000101852

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At this moment of accomplishment, I wish to pay my heartfelt gratitude and sincerest thanks homage to my guide, Professor **Dr. Shahnwaz Alam**, Department of Mechanical Engineering, Integral University Lucknow. This work would not have possible without their able guidance, support, and encouragement. Under their guidance I have successfully overcome many difficulties and learned a lot. They used to review my dissertation progress, give their valuable suggestions, and made correction. Their unflinching courage and conviction will always inspire me, and I hope to continue to work on their noble thought.

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**Arun Pratap Singh**

**(Enrollment No.** 2000101852**)**

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# ABBREVIATION

| | |
|---|---|
| MIG | Metal Inert Gas |
| GMAW | Gas Metal Arc Welding |
| DOE | Design of Experiment |
| SMAW | Shielded Metal Arc Welding |
| ANOVA | Analysis of Variance |
| AISI | American Iron and Steel Institution |
| UTS | Ultimate Tensile Strength |
| ANN | Artificial Neural Network |
| AW | Wrought Alloy |
| FEA | Finite Element Analysis |
| V | Welding Arc Voltage |
| W | Wire Feed Rate |
| G | Gas Flow Rate |
| Hd | Hardness |
| H | Bead Height |
| W | Bead Width |
| D | Penetration |

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# ABSTRACT

MIG welding (metal inert gas welding) is an arc welding technology that generates metal coalescences by heating them with an arc between a filler metallic electrode that is constantly fed, and the work. MIG welding process lends itself to semiautomatic, robotic automation, and difficult automation welding packages. The alloy fabric variety for GMAW consists of carbon steel, chrome steel, aluminium (Al), magnesium (Mg), copper (Cu), nickel (Ni), and silicon bronze. This experimental study aims at optimization of the wire feed rate during MIG weld of aluminium sheets by developing the mathematically model for the tensile strength a hardness of the aluminium specimen. In this experiment Factorial design approach has been implemented for locating connection among diverse procedure parameters and weld deposit reason. MIG Welding of aluminium alloy 6063 with Al 4043 Wire and Argon gas shielding yields excellent results.

Despite the challenges of welding aluminium alloys, the research demonstrated that by precisely adjusting the most important parameters (or variables) and determining their ranges, adequate outcomes may be achieved. MIG Welding of aluminium alloy with Al 4043 wire and Argon gas shielding yields excellent results. Despite the complexity of the aluminium welding process, their Statistical design and optimization helps in enhanced visual quality, decreased costs, and produced a consistent and uninterrupted weld bead as envisioned. Wire feed rate and Hardness of material are highly dependent on the voltage and decrease with upsurge in voltage. Hardness reductions with increases in wire feed rate. As the heat input increases the hardness of material decreases.

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# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

Welding is a becoming a member of method wherein two comparable or distinctive metallic are joined collectively with software of warmth, with and without utility of pressure and with and without use of filler material. The problem that has faced by the manufacturer is the control of the process input parameters to obtain a good, welded joint with the required weld strength. Traditionally, it has been necessary to study the weld input parameters for welded product to obtain a weld joint with the required quality. To do so, it requires a time-consuming trial and error development method.

Then welds are examined whether they meet the requirement or not. Finally, the weld parameters could be chosen to acquire a welded joint that scrupulously meets the joint qualities. Also, what is not achieved or often considered is an optimized welding parameters combination, since welds can often be formed with very different parameters. In other words, there is often a more ideal welding input parameters combination, which can be used. In order to overcome this problem, various optimization methods can be used to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. Design of experiment (DOE) techniques has been applied to carry out such optimization. Taguchi method and Factorial method have been adapted for many applications in different areas. MIG welding is carried out on weld set up that provides the power to weld the work piece at a given welding current and to feed the welding torch at specified travel speed at specified voltage.

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Therefore, three welding parameters namely travel speed, welding voltage, welding current are needed to be determined in a welding operation. Performance evaluation of welding is based on the performance characteristics like cyclic time, power source, metal transfer technique, electrode size and composition, electrode stick out, shielding gas etc. The quality of weld surface depends upon factors that are surface finish and weld strength. Whenever two surfaces come in contact with one another, the quality of their joint plays an important role in the performance. The height, shape, arrangement, and direction of these surface irregularities with the required strength of the work piece depend upon a number of factors such as:

a) Travel speed.

b) Welding current.

c) Welding Voltage.

d) Type of Power source.

e) Type of shielding Gas.

f) Electrode size and composition

g) Gas Flow rate etc.

## 1.2 MIG WELDING

Metal inert gas welding (MIG) is an arc welding process which produces the coalescences of metals through heating them with an arc amongst a constantly feed filler metallic electrode and the work. MIG welding process lends itself to semiautomatic, robotic automation and difficult automation welding packages. The alloy fabric variety for GMAW consists of carbon steel, chrome steel, aluminium, magnesium, copper, nickel, and silicon bronze. (GMAW) Gas metal arc welding also known as MIG (metal inert fuel) if the fuel is inert, for example argon, or magazine (steel lively gasoline) if the gas has a content material of an active gasoline which include $CO_2$. In Europe the system Is likewise called MIG/magazine or simply MIG welding. This manner is used in a wide variety of plate thicknesses although it has been maximum dominant in skinny sheet welding. This is due to its easiness in beginning and stopping and thereby it's rather high productivity.

The principle of MIG welding is that a metal wire is fed with the assist of welding gun and melted in an arc.

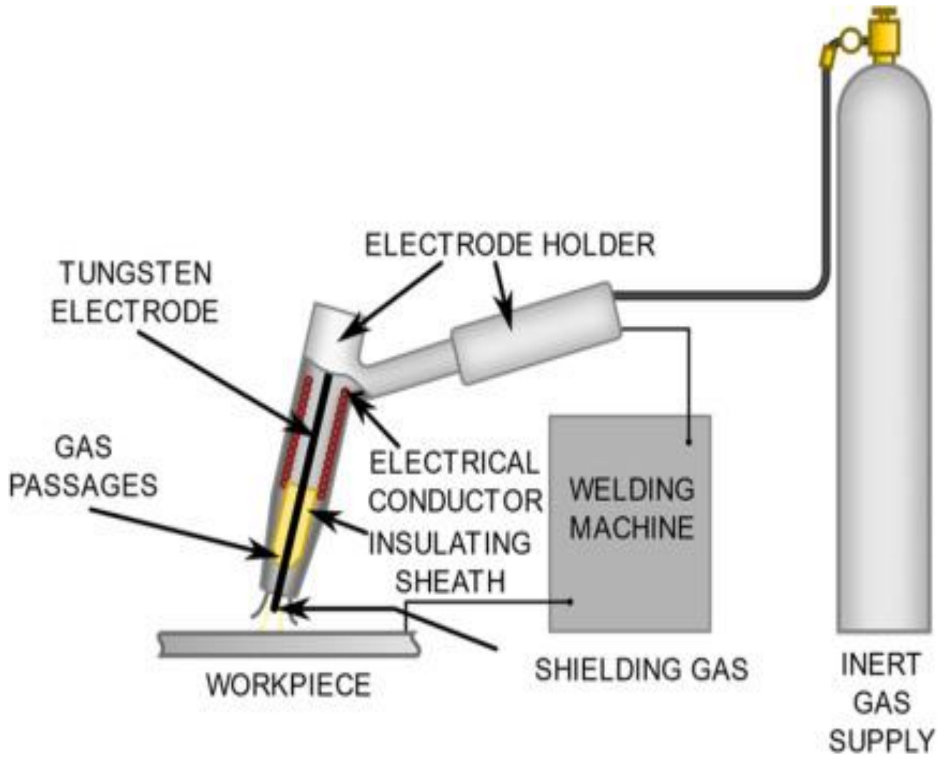


**Figure 1.1 Basic tungsten gas metal arc welding**

The twine serves the twin motive of appearing because the contemporary-sporting electrode and because the weld steel filler wire. electrical electricity for the arc is provided with the assist of welding energy supply. The arc and the pool of molten fabric are covered with using a defensive gas, which is inert or energetic. Inert gas does no longer react with the molten metal.

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## 1.3 PROCESS PRINCIPLES

A continuous consumable wire is fed through a suitable torch or gun which is used both as an electrode and filler, the gun or torch embodies a concentric gas nozzle which channels a protective gas which is usually fed from a separate cylinder out and around the newly formed weld preventing atmospheric contamination. The weld is formed due to the positive electrode (the continuous wire) coming into close contact with the negative electrode of the work piece allowing a large current to flow through the wire causing the tip to heat up beyond its melting point.

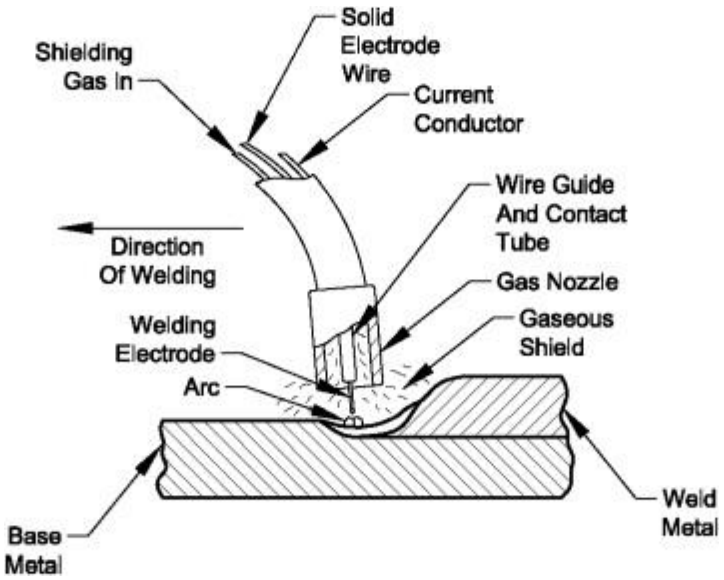


**Figure 1.2 Gas metal arc welding process**

The type of gas or gas mixtures employed in welding varies with the metal being joined. To some extent the gas is chosen to reduce costs, the inert gases being very expensive, but more often the gas is chosen for its effect on the arc characteristics, e.g., burn off rate, type of metal transfer and penetration. These important parameters play a large part while selecting gas. Gas mixture such as argon with carbon dioxide which combine the advantages of both gases. The main advantage of MIG welding process is high welding speed and greater deposition rates. In this process no slag is left behind, hence no need to

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clean the weld after finished welding operation; this saves lot of time of welder, enhancing the production rates. The important advantage is that low skill labour is required to operate the weld setup, provided all the welding process parameters are optimised.

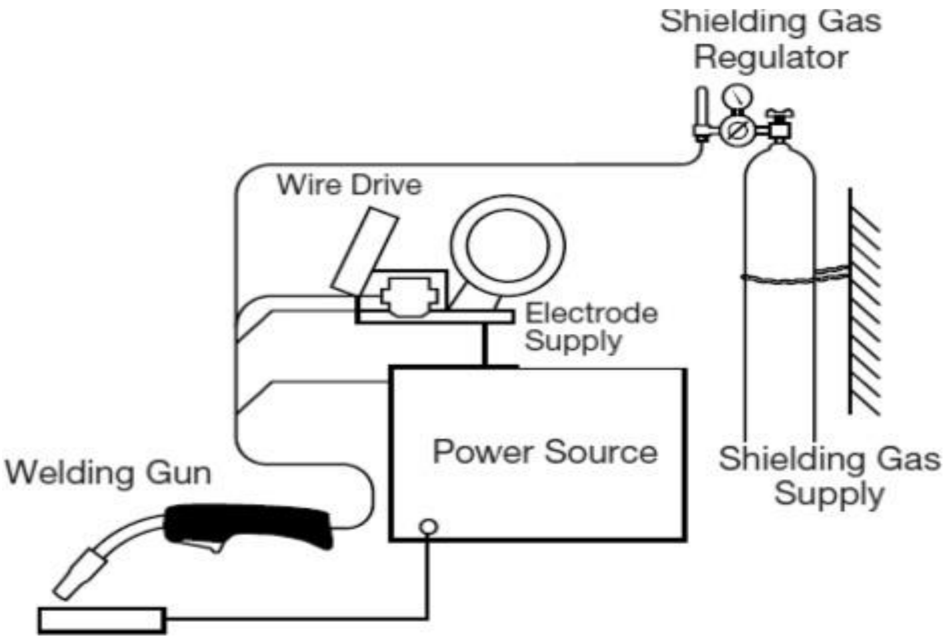


**Figure 1.3 Basic component of GMAW**

There is also one main advantage that, no stub end losses or wasted man hours for changing electrodes. A complete spool is employed as an electrode will last longer and is easily interchangeable. MIG welding process can be easily automated with the help of welding fixtures and Robots. MIG welding is the form of simple welding methods of metal welding as it does not require a high level of skill to achieve results.

The process is semi-automatic because an electrode wire and gas are automatically fed through the gun at a user defined speed or pressure when the operator pulls down the trigger, the electronic arc can also be user defined and carried out automatically on operation. MIG is a quick and easy form of welding; it is used often by robotics in automated production lines. The ability of a welding operation to produce a desired depth of penetration depends on various parameters.

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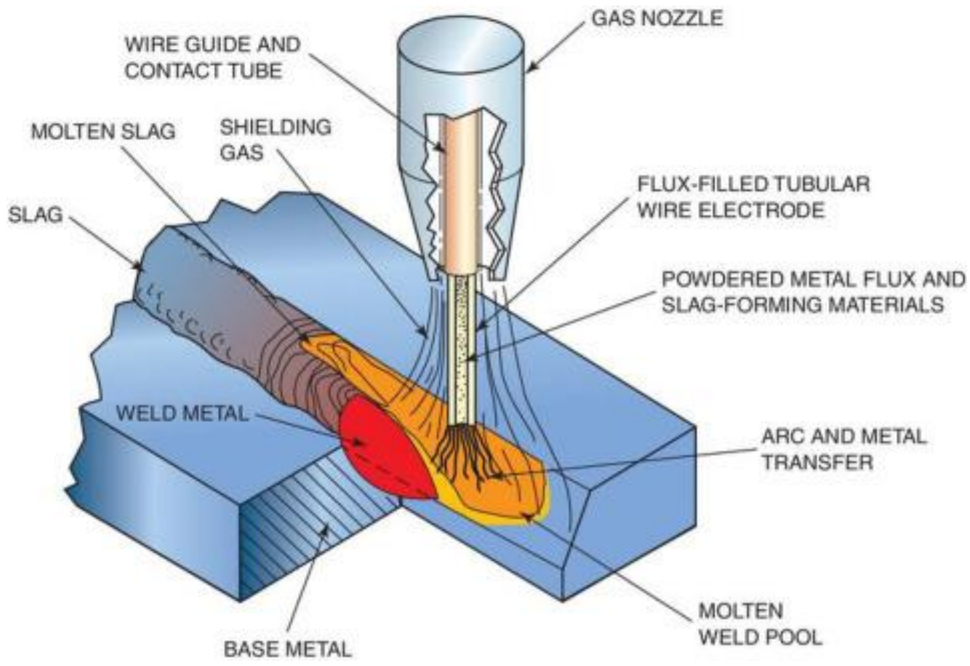


**Figure 1.4 Basic representation of gas metal arc welding**

In welding process, the penetration depends on current, voltage, gas flow, welding speed, wire diameter. Even small changes in any of the mentioned factors may have a significant effect on depth of penetration.

## 1.4 METAL TRANSFER IN MIG WELDING

There are four type of metal transfer in the MIG welding.

1. Short circuiting transfer.
2. Globular transfer.
3. Axial spray transfer.
4. Pulse spray transfer.

### 1.4.1 Short circuiting transfer

It occurs in the lowest range of welding currents and electrode diameters. It produces a small, fast-freezing weld suited for joining thin sections, for welding out of position, and for bridging large root openings. The wire electrode actually contacts the weld pool at the rate

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of 20–200 times per second. Inductance is used in the power supply to control the amount of heat available before the short circuit occurs. Under the instance heat of arc, electrode tip melts form globule of molten metal at the tip. As a electrode wire is feed toward the workpiece. Molten weld touch the weld metal pool and short circuit the electrode to the workpiece. This reduces the voltage across the arc. Metal tip get pinched by the surface tension of the weld metal pool. In this method the current range is 100 V - 160 V and the metal deposition rate is 0.9 - 2.7 kg/hr. The frequency of medium circuit is normally in the range of 50 ± 200 Hz.

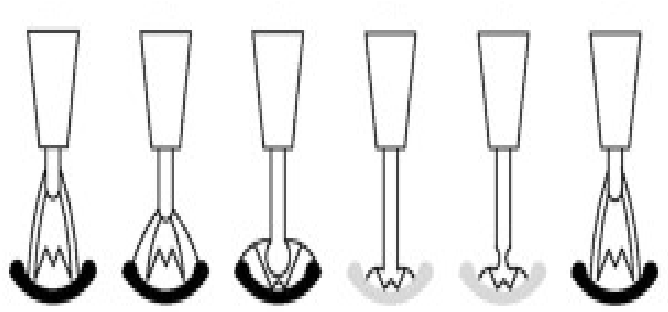

**Figure 1.5 Short circuit transfer**

### 1.4.2 Globular transfer

It takes place when the current is relatively low with all kinds of shielding gas but always occurs with $CO_2$ and helium. Globular or drop transfer of the molten metal occurs at slightly higher current. The high current melts the metal at higher rate and form globule of molten metal at tip of the electrode. This metal drop is considerably larger than the Electrode diameter. It stays with the as long as force due the surface tension is more the liquid gravity. When the size increases, the gravity pull it from the tip and metal droplet get deposited on the workpiece. It can be used for only flat position. In this method the current range is 150 V - 300 V and the metal deposition rate is 1.8 - 3.2 kg/hr.

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### 1.4.3 Axial Spray transfer

It produces a very stable spatter-free axial spray transfer when the current level is above the minimum transition current. As a current increased the magnetic pull on the molten metal increases and subsequently molten metal is detached for electrode tip irrespective of gravity force. This can be used where thick sheet are welded and welding is to be done at any position. In this method the current range is 200 V - 500 V and the metal deposition rate is 2.7 - 5.4 kg/hr. For welding aluminium, titanium, magnesium, and their alloys, the argon-helium mix gas is often used.

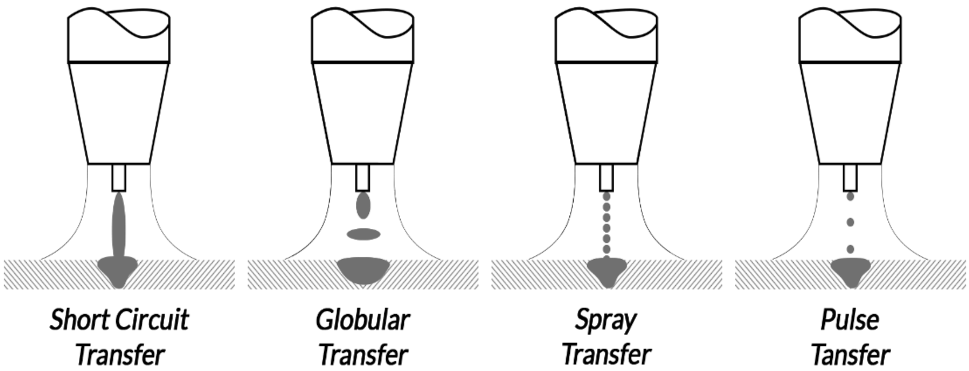


**Figure 1.6 Different Transfer Process**

### 1.4.4 Pulse spray transfer

Pulse spray metal transfer takes benefit of the excessive energy of axial spray steel switch and alternates this high energy (peak) present day with a lower strength (background) contemporary. Every cycle is called duration, and the period can repeat numerous hundred times in line with second. Beat MIG welding is utilized specifically for welding of aluminum, treated steel and carbon steel. The strategy requires a quality supply with capacity to offer suitable heartbeats having recurrence between 30 ± 300 Hz that controls the switch of the beads.

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This makes it practical to expand the shower bend range down to low welding records and gives a solid and scatter free curve as an appreciated plausibility to fast circular segment welding.

## 1.5 SURFACING

Surfacing is a technique of depositing one steel or alloy over base steel to enhance its put-on resisting houses like resistance to abrasion, corrosion, friction, or for reaching dimensional manage, and metallurgical wishes. Surfacing is of different kinds viz., cladding, tough facing, build up, and buttering to attain corrosion resistance (for chemical put on), wear resistance (for bodily put on), dimensional control (to rebuild worn components), and metallurgical desires respectively.

There are four types of surfacing methods:

### 1.5.1 Cladding

In cladding process, a thick layer of some weld metallic like stainless-steel is deposit onto a carbon or low alloy steel plate to make it corrosion resistant. Cladding wants to also resist localized corrosion together with pitting, crevice corrosion, inter granular corrosion, and strain corrosion cracking. For cladding, stainless steel or one of the nickel-base alloys are typically used though copper-base alloys, silver and lead are also used for some applications.

### 1.5.2 Hard facing

In hard facing process a metal is deposited over each other surface to increase the hardness of the surface and to make it evidence against abrasion, impact, erosion, galling, and cavitation. Like in cladding, the energy of hard going through layer isn't blanketed in the layout of the element. Abrasion resistance is the maximum vital software of hard going thrughu. In desired, a most of three layers of tough going through alloys are deposited. Due

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to the fact excessive dilution reduces the effectiveness of tough facing it is therefore vital to avoid immoderate penetration and bad tie-in of adjoining beads.

The design wants to be alongside to offer accurate enough assist for the surfacing and as some distance as viable it ought to be loaded in compression in place of anxiety or shear. Under these conditions difficult going through can show successfully its monetary advantages.

### 1.5.3 Build-up

Develop is the revamping of cleared out added substances to fix them to explicit structure and measurements. In assessment to cladding and intense experiencing the quality of the weld metallic shaping the gather up is a basic consideration inside the angle format due to the reality the material needs to refresh some of the particular piece of the segment which has eroded. Build-up approach of surfacing is extensively applied in earth moving gadget, for instance the tooth of dragline buckets, edges of bulldozer blades and scrapers are reclaimed with the useful resource of construct-up. Railways moreover hire construct-up for restoring the harm of the railway wheels in addition to rail elements and junctions.

### 1.5.4 Buttering

Buttering is the strategy for keeping one or additional layers of a material between the ones metallurgically non-like substances materials which in my view have similarity with the material framing the buttering layer. It's far utilized uniquely for turning into an individual from of treated steel to a carbon or low composite metal base metallic.

If no buttering layer is used the corrosion resistance of stainless-steel can be reduced however if a layer of excessive nickel or Ni-Cr fabric is deposited on the bass metallic earlier than depositing the immoderate alloy chrome steel no deterioration of corrosion resistance is discovered.

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## 1.6 PROCESS PARAMETER

There are seven main process parameters involved in welding.

1. Welding Current

2. Arc Voltage

3. Welding Speed

4. Electrode Size

5. Gas Flow Rate

6. Torch and joint position.

7. Welding Position

### 1.6.1 Welding Current

Welding current is the term used to describe the electricity that jumps across the arc gap between the end of the electrode and the metal being welded. An electric current is the flow of electrons. The resistance to the flow of electrons (electricity) produces heat. The greater the electrical resistance, the greater the heat and temperature that the arc will produce. Air has a high resistance to current flow, so there is a lot of heat and temperature produced by the SMA welding arc. Electrons flow from negative to positive. Welding requires extreme present day more than 80 A, and it could require over 12,000 A, in-spot welding. Welding machines are normally delegated ordinary bleeding edge or consistent voltage; a predictable current device shifts its yield voltage to keep an enduring present day while a customary voltage machine will change its yield present day to keep a fixed voltage.

Protected metal bend welding and gas tungsten curve welding will utilize an enduring bleeding edge source and gas metallic circular segment welding and transition cored circular segment welding typically utilize unfaltering voltage resources anyway relentless forefront is similarly feasible with a voltage detecting wire feeder.

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### 1.6.2 Arc Voltage

An arc voltage discharge is an electrical breakdown of a gasoline that produces an ongoing electrical discharge. The current via a typically non-conductive medium consisting of air produces plasma; the plasma might also produce seen light. An arc discharge is characterized by a lower voltage than a glow discharge, and it is predicated on thermionic emission of electrons from the electrodes assisting the arc.

### 1.6.3 Welding Speed

Travel speed is a function of time and distance traveled. Distance traveled represents the real period for which weld steel is deposited from the initiation of the arc to the termination of the arc. Travel speed is generally expressed in inches consistent with minute. Be aware that the welder's journey speed will typically alternate with welding variables together with role, filler metallic diameter, joint accessibility, and so forth.

### 1.6.4 Electrode Size

GMAW, gas metal arc welding once in a while cited by the use of its sub types metal inert gas (MIG) welding or steel lively gas (MAG) welding, is a welding machine wherein an electric arc bureaucracy amongst a consumable wire electrode and the workpiece, which heats the workpiece, causing them to melt and join.

### 1.6.5 Gas Flow Rate

One aspect that many people frequently ignore but which has a big impact on the weld's quality is the gas flow rate. The gas drift ought to be adjusted to the arc. At low current 10 liters consistent with minute may be enough at the same time as at higher welding information up to 20 liters may be vital. Welding in aluminium wishes greater gas than steel fixes.

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## 1.7 LITREATURE SURVEY

**H.J. Park, D.C. Kim, M.J. Kang, S. Rhee [1]** studied about optimization of the wire feed rate for the duration of pulse MIG welding of Al sheets via the usage of the form factors of weld beads, which govern the mechanical physiognomies of the welding of aluminum sheet. In this test they use Pulse –MIG welding method, lap joint fillet weld, 1.6 mm thick aluminum sheet use for automobile body, wire feed speed 0.5 m/min, 1 m/min and 1.5 m/min Welding power source – 500 A, Inverter, form of wire –solid wire diameter is 1.2 mm (Al 4043), Shield gas-100 % Ar-20 lit/min and base metal- Al 6K21 , thickness is 1.6 mm. Result suggests that Bead breadth increases when the wire feed hurry will increase. As wire feed speed increases, the drop cross-section area will become wider. If the wire feed is gradual relative to welding speed, imperfect penetration is found. If the wire feed rate is rapid then extreme melting wire occurs.

**Omar Bataineh, Anas Al-Shoubaki, Omar Barqawi [2**] studied approximately the Optimizing process situations in MIG Welding of Aluminum Alloys with the aid of using Design Experiments. Effects of factorial design trials and the analysis of alteration (ANOVA) confirmed that arc voltage and filler feed degree are the only big factors of the 5. Premiere settings of arc voltage and filler feed rate were reached the usage of regression evaluation at 24 V and 7in/s, correspondingly, at which the nasty weld strength is maximum.

**Tarun Kumar Jha, Bhuvnesh Bhardwaj, Kulbhushan Bhagat And Varun Sharma [3]** studied approximately the optimization of weld bead geomety in gas metal arc welding process via the usage of D-optimal methodology. End result indicates that with upsurge in wire feed rate, depth of penetration increase. While wire feed rate will increase, its weld bead rate also increases. A 5 level 4 factor complete factorial design matrix founded on the

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central composite rotatable design technique may be rummage-sale for the improvement of mathematical copies to predict. Out of the four manner variables considered wire feed rate become the maximum substantial and influential factors having the positive effect.

**Ajit Hooda1, AshwaniDhingra and Satpal Sharma [4]** studied about the optimization of MIG welding process limits to forecast all-out yield strength in AISI 1040 with the aid of the usage of reaction surface Methodology. End result suggests that the same weld combined of AISI 1040 material became industrialized effectively with MIG welding with selected variety of input variable parameters. The maximum yield strength each transverse and longitudinal, on the optimum values of process variables-welding voltage, welding current, wire speed and gas flow rate became experimented. The longitudinal yield electricity is greater than the transverse yield strength and the result confirmed that the optimized process reduce the cracks and porosity from 15.32 to 2.54%.

**S. R. Patil et al. [5]** Studied the impact of effort welding limits like welding current, welding voltage, welding at the ultimate tensile strength (UTS) of AISI 1030 mild steel material throughout welding process. They accepted Taguchi approach for research and to plot the graph of, gesture to noise (S/N) ratio and analysis of variance (ANOVA) are hired to have a look at the welding characteristics of material & optimize the welding parameters. End result indicates that the fundamental effect is produced by current & voltage it's far maximum great parameter among 4 to be had. Current at value of 120 A current we become the maximum s/n ratio of 52.8128 and final tensile strength of 434.34(N/mm2 ) .

While the current is too little the molten metal fails to wet the joint surface and motive lack of fusion. With increasing current the melting rate of the electrode is increases, the predominant impact is produced by way of speed it's miles giant parameter amongst 4 available. Speed at value of 5.5(M/Min) velocity we got most sign to noise ratio as 52.81

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and at same speed 5.5 (M/Min) we get most ultimate tensile strength of 434.34(N/mm2 ), the linear rate (express in cm/min or mm/sec) at which the arc movements round along the joint ,termed arc travel speed, impacts weld bed size and penetration. With other variables reserved consistent, there's a certain value of travel haste at which the weld penetration is maximum.

**K Abbasi et al. [6**] Deliberate the impact of MIG welding limits at the weld bead and shape factor function of vibrant drawn reasonable steel specimen by the use of Taguchi approach. They makes use of contribution parameter of welding current, arc voltage, welding pace, heat input rate and studied impact on intensity of penetration and weld width. Result suggests that the welding hurry is maximum swaying factors and gas flow rate is least influencing factor.

**Hakenates et al. [7]** has been carried out an trial in which low carbon steel plates (15 x 150 x 450 mm) were fused underneath 180 A and 28 V. MIG/MAG welding device became used, and $CO_2$, Ar and $O_2$ mixtures of three gases were secondhand as the shielding media. The flow rate of the shielding gas was 15l/min, and the experiment was did by setting the contact tip to the workpiece distance of 15 mm. The electrode wire has a diameter of 1.2 mm. A take a look at carried out to research the mechanical properties in these experiments. artificial neural networks (ANNs) using for prediction of fuel metal arc welding parameters. input parameters of the version consist of gas mixtures, while, the outputs of the ANN model consist of mechanical residences which includes tensile strength, impact strength, elongation and weld metal hardness, respectively. The have a look at has proven the possibility of the usage of neural networks for the calculation of the mechanical goods of welded low alloy metal the use of the GMA method.

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**Joseph I. Achebo et al. [8]** Appeared with the guide of his work that on choosing input parameters alongside welding current, voltage, speed and time towards response of extreme rigidity of steel, streamlining was executed with the assistance of Taguchi strategy**.** From the evaluation carried out by making use of the Taguchi technique, an ultimate method parameter of welding current of 240 A, welding time of 2.0 mins, welding pace of 0.0062 m/s, and welding voltage of 33 V, turned into recommended. Those superior parameters have been observed to have an improvement of 2.32 dB of the S/N ratio, and 1.11 times over the United States of America of the existing method parameters. This observe elucidates a step-by-step method for making use of the Taguchi technique.

**D.S. Nagesh et al. [9]** Examined around the dot geometry and entrance by methods for choosing input parameters which incorporates terminal feed rate, circular segment length, curve voltage, bend current, bend span and by utilizing ANN approach for streamlining of yield parameters comprising of dot stature, globule width, power of infiltration, territory of entrance and circular segment travel rate. The test outcomes presumed that utilization of either preheated plates or low bend travel charge or high circular segment power yielded higher combination. Each the globule stature and width lower with the expansion in circular segment travel rate anyway the diminishing in tallness is nearly more noteworthy to make a compliment dot with a superior curve travel charge. The infiltration and HAZ blast with the development in anode feed rate keeping circular segment length steady.

**D. S. Correia et al. [10]** studied about the optimization of MIG welding parameter the usage of Genetic set of rules (gasoline). The look for the close to-optimum turned into done little by little, with the GA predicting the following experiment based on the earlier and without information of the modelling equations between the inputs and outputs of the MIG welding method. The GA become capable of set up close to most suitable situations with a distinctly

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small quantity of experiments however, the optimization via GA technique calls for an amazing putting of its own parameters, such as variety of generations, populace length, and many other, there may be a threat of an insufficient widespread of the search area.

**Wahab H. Khuder et al. [11]** studied approximately the impact of welding method parameter in welding joint of diverse metallic by using the use of MIG spot welding. On these studies the base material decided on for welding are austenitic stainless-steel-type AISI 316L and carbon metal. The filler metallic use for welding this varied steel is E80S-G and $CO_2$ is used as defensive fuel. The test become accomplished by way of thinking about feed of cord, time of feed and weld current as input parameter. The impact of these parameters on diameter of the spot and shear force turned into predicted via doing the experiment. Result suggest that the dimensions of spot weld and shear pressure is increase with increasing welding current at the same time as the shear force is decrease with increase of welding time also, they located that the increasing welding modern and time of welding can even surge diameter of weld sector and decreases the shear force.

**Amit Kumar et al. [12]** studied about the optimization of MIG welding parameters the use of synthetic Neural network (ANN) and Genetic set of rules (GA). In this research work they make mathematical model through the use of ANN technique for prediction effect of welding parameter inclusive of welding voltage, welding speed and welding present day on closing tensile strain at some stage in the welding of varied cloth inclusive of stainless-steel grade 304 and grade 316. The argon fuel become taken as shielding gasoline and test become performed on full factorial.

# CHAPTER 2

## MIG WELDING FOR ALUMINIUM AND ITS ALLOYS

### 2.1 PROPERTIES OF ALUMINIUM AND ITS ALLOY

Aluminium has a face-centered cubic contour of comparable type to the austenitic chrome steel. Because of this the durability does no longer substantially reduction whilst the temperature is decreased. The microstructure of dense aluminium and its alloys does not alternate on heating and cooling. The warmth and electric conductivities are high. The deformations at some stage in welding also are excessive relying at the tall coefficient of thermal enlargement Aluminium is likewise non-magnetic. Unalloyed aluminium is very gentle. One application is electric contacts with excessive demands on electric conductivity. Alloying element growth the strength by way of stable answer hardening or by way of precipitation hardening. Magnesium, manganese, copper and zinc are frequently used. Silicon may be brought intentionally but is also current as an impurity collectively with iron from the ore.


**Figure 2.1 MIG welding machine**

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## 2.2 SOME IMPORTANT PROPERTIES FOR THE WELDING OF ALUMINIUM AND ITS ALLOY

A robust and tough oxide could be very effortlessly shaped at the surface and may cause weld defects if now not properly removed or damaged up. The oxide has a low electric conductivity. The heat supply for welding have to be very extreme the aluminium oxide has a melting temperature of about 2060°C, that's lots better than the melting temperature of pure aluminium at 660°C. The oxide has a higher density than aluminium and might consequently continue to be in the melted aluminium and form slag inclusions inside the strong material. Aluminium has a excessive solubility for hydrogen within the molten nation however now not within the stable phase. This may very easily lead to porosity for the reason that hydrogen has insufficient time to disappear at some stage in solidification.

Aluminium has a low melting point and it's miles difficult to look whilst it melts due to the fact that there may be no color alternate.

**Table 2.1 Designations for alloys of wrought aluminium.**

| Alloying Element | Wrought |
|---|---|
| None (99%+ Aluminium) | 1XXX |
| Copper | 2XXX |
| Manganese | 3XXX |
| Silicon | 4XXX |
| Magnesium | 5XXX |
| Magnesium + Silicon | 6XXX |
| Zinc | 7XXX |
| Lithium | 8XXX |

There is no arc blow caused by the material itself since aluminium is nonmagnetic, but the arc can bounce considerably from the electrode route. this will have unique motives.

`

The electrical present day usually chooses the very best path (shortest or least resistance). The oxide layer additionally impacts this behaviour. Magnetic fields generated with the aid of the modern-day, the tilting of the welding torch and the connection of the go spinal cable additionally have a power.

## 2.3 DESIGNTION OF ALUMINIUM ALLOYS ACCORDING TO EUROPEAN STANDARD

The prefix AW is used which means a wrought product followed by a four-digit number. The first digit denotes the main alloying elements.

1. 1000 Commercially pure aluminium
2. 2000 Copper
3. 3000 Manganese
4. 4000 Silicon
5. 5000 Magnesium
6. 6000 Silicon + magnesium
7. 7000 Zinc + magnesium
8. 8000 Others.

1. The group 1xxx is aluminium with a most of 1% of impurities. On this institution the ultimate digits provide the quantity of aluminium, e.g. AW 1070 consists of at the very least 99.70% aluminium. Inside the other corporations the closing two digits are consecutive numbers. The second digit tells whether or not some adjustment of the composition of the original alloys within the groups has been made. The alloys inside the group 1 (natural aluminium), 3 (aluminium-manganese), 4 (aluminium-silicon) and 5 (aluminium-magnesium) are not heat-treatable. The alloys in group 2 (aluminium-copper), 6 (aluminium-magnesium-silicon) and 7 (aluminium-zinc-

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magnesium) are warmness-treatable by precipitation hardening. For the exclusive alloys there's additionally a mood designation related to the situations of shipping of the material, e.g. form of heat remedy, bloodless working, and precipitation hardening.

2. Changes in impurity limits are indicated by the second digit. When the second digit is zero, unalloyed aluminium with naturally occurring impurity limitations is indicated, and when it is one through nine, specific impurities or alloying elements are indicated.
3. The final two numbers of the 2XXX to 8XXX groups designate various aluminium alloys within the group. The second digit represents changes to the alloy. The original alloy is represented by a second digit of zero, while successive alloy changes are represented by the numbers 1 to 9.
4. For the divergent alloys there is additionally a mood designation associated with the conditions of shipping of the material, e.g. type of warmness medicine, bloodless working, and precipitation hardening.F ± as fabricated
5. O ± means annealed
6. H ± means cold worked
7. W ± means solution heat treated
8. T ± means thermally treated, which means the state for alloys that are aged.

For the heat-treatable alloys the T-designation is accompanied by using a digit to outline in greater detail the heat treatment collection. a few examples are:

1. T4 ± means solution heat treated and naturally aged
2. T6 ± means solution heat treated and artificially aged
3. T7 ± means solution heat treated stabilized.

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## 2.4 PROBLEM IN WELDING OF ALUMINIUM

### 2.4.1 Lack of fusion

Lack of fusion is a failure to fuse together both the base metallic and weld metal or beads in multipass welding because of failure to elevate the temperature of base metallic or formerly deposited weld layer to melting point for the duration of welding. A rolled-over bead crown is another symptom of lack of fusion. Once more, it is typically brought on by a very slow travel speed and attempting to form a weld that is too massive in one pass. Lack of fusion can be eliminated by using well cleaning of floor that's to be welded, selection of proper current, proper welding approach and correct length of electrode.

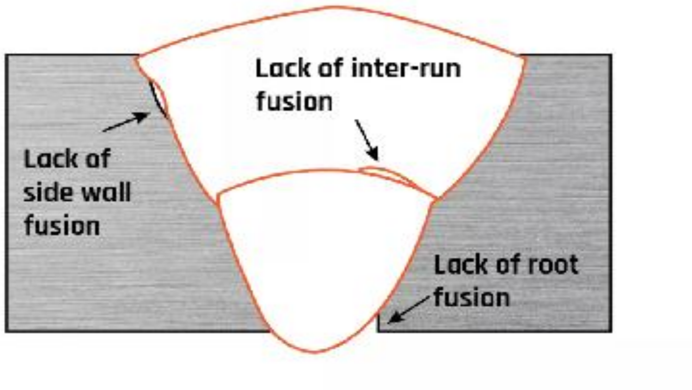


**Figure 2.2 Lack of Fusion & Root Defect**

### 2.4.2 Root defects

A root crack is the crack which is formed by the short bead at the root of the welding, low current at the beginning and because of unsuitable filler material used for welding. The main reason for going on of those sorts of cracks is hydrogen embedment. These styles of defects may be reduced by using the use of excessive modern-day on the beginning, exact best of filler cloth, preheating and proper joint formation. Toe crack happens because of moisture content gift within the welded vicinity, it as a part of the floor crack so may be easily detected.

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### 2.4.3 Porosity

Porosity is a disorder which happens when the gases are entrapped in the solidifying weld metal. The ones gases are generated from the flux or coating substances of the electrode or shielding gases and absorbed moisture within the coating at some stage in welding. Rust, dirt, oil and grease present on the floor of labor pieces or on electrodes also are supply of gases throughout welding. Porosity can be minimized by preventing the work portions are from rust, dust, oil and grease. Porosity additionally may be managed by using presenting excessively immoderate welding currents, quicker. Welding speeds and lengthy arc lengths are avoided flux and lined electrodes are well baked.


**Figure 2.3 Porosity in Welding**

### 2.4.4 Solidification cracks

Cracks can be of micro length, macro size and can appear in the weld metallic or base metal or base metallic and weld metal boundary. There are one-of-a-type varieties of cracks like longitudinal cracks, transverse cracks or radiating/superstar cracks and cracks within the weld crater. Cracks occur at the same time as localized stresses exceed the very last tensile energy of cloth. the ones stresses are evolved due to reduction at some stage in solidification of weld metal.

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### 2.4.5 Spatter

Method of welding entails melting of parent material and depositing molten filler material in the molten pool. This surroundings is a pool of molten pool in which molten metallic is being brought externally. Obviously all this happens at very high temperatures and the reactions are fairly risky. This volatility due to arc forces, gas pressures, wind and even magnetic forces splashes the molten steel out of the weld region inside the form of globules. These globules are available contact with the cold determine fabric and solidify and also get wedged at the surface. This is referred to as spatter.

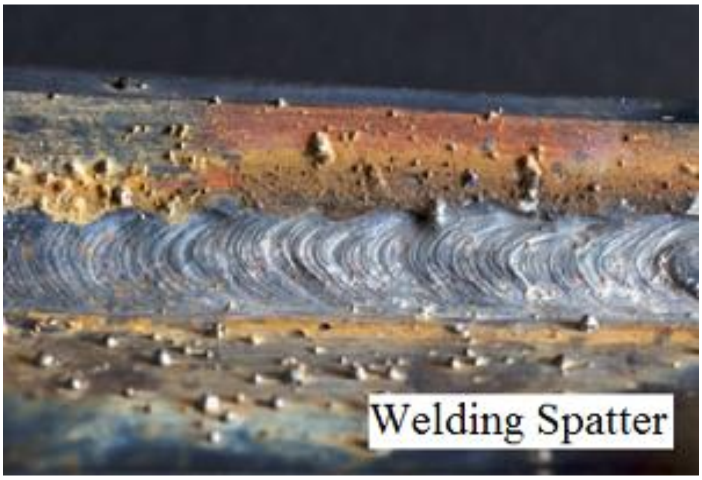


**Figure 2.4 Welding Spatter**

### 2.4.6 Undercut

Undercut arise whilst the weld reduces the cross-sectional thickness of the base metal and decreases the strength of the weld and workpieces. The main reason for this kind of defect is excessive current, causing the edges of the joint to soften and drain into the weld, the usage of an incorrect filler metal, because it will create more temperature gradients among the center of the weld. Every other motive is if a poor approach is used that doesn't deposit enough filler metal along the edges of the weld. Another purpose is causes include too small of an electrode angle, a dampened electrode, excessive arc length, and slow speed.

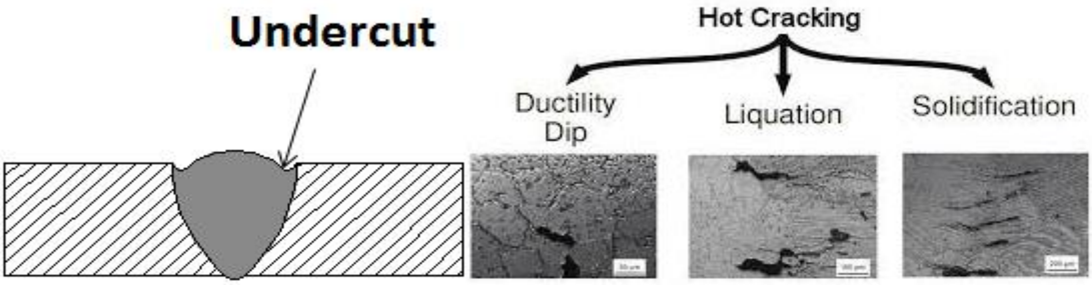


**Figure 2.5 Undercut & Hot Cracking in welding**

### 2.4.7 Hot Cracking

Hot cracking is also referred to as solidification cracking. It can occur with all metals and happens within the fusion region of a weld. To dispose of the opportunity of this form of cracking, extra material restraint must be prevented, and a right filler material ought to be applied. Every other reason of this sort of disorder consists of too high welding cutting-edge, bad joint design that does not diffuse warmness, impurities like sulfur and phosphorus, preheating, speed is just too fast, and long arcs.

### 2.4.8 Stress Corrosion Cracking

Stress corrosion cracking is a boom formation of crack inside the corrosive environment. It could lead to surprising sudden failure of normally ductile metals subjected to a tensile strain, mainly at improved temperature. pressure corrosion cracking progresses unexpectedly and is more common amongst alloys than natural metals. The unique surroundings is of vital importance, and most effective very small concentrations of positive particularly energetic chemical substances are needed to produce catastrophic cracking, often main to devastating and surprising failure.

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# CHAPTER 3

## OPTIMIZATION TECHNIQUES

There are various types of optimization tools and technique which is used for optimization of processes and process parameters. Generally, trial and error method-based experimentations are carried out which takes much more productive time and economical investment. The results obtained after experimentation are not up to the mark, leads to unsatisfactory results. To overcome these losses various optimization techniques are used for efficient experimentation and analysis though which satisfactory results can be achieved. Following are various methods used for optimization of process and parameters.

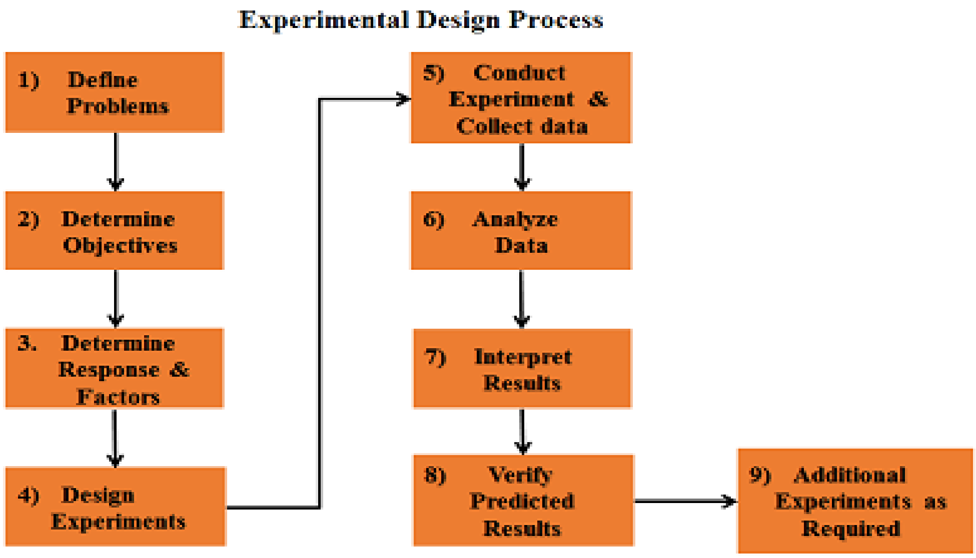


**Figure 3.1 Flow chart illustrates the DOE process**

### 3.1 SPOT WELDING SIMULATION

Simulation and optimization of spot weld system parameters can be executed by means of the usage of SORPAS simulation software. SORPAS is professional weld simulation software program utilized by engineers in enterprise (inclusive of automotive, metallic

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making, welding system, electronics and different metallic processing industries) to support layout and evaluation of cloth weld ability. in this software, mixtures in addition to layout and choice of electrodes and standard optimization of welding system parameters can be accomplished. It can be used to evaluate theoretical and realistic outcomes.

### 3.2 FUZZY LOGIC

Fuzzy logic is a judgment is a shape of many-esteemed common sense wherein the reality ideals of variables can be some actual variety among 0 and 1 inclusive. It is far some distance hired to knob the concept of fractional reality, wherein the reality charge may also range among absolutely actual and absolutely false. Via contrast, in Boolean logic, the fact values of variables might simplest be the integer values 0 or 1.

It is a ways based totally at the declaration that people make choices primarily based on non-numerical records, fuzzy models or units are mathematical technique of representing difficult to understand statistics, as a end result the time period fuzzy. These models have the functionality of spotting, representing, manipulating, deciphering, and utilizing data and statistics which may be indistinct and absence fact.

### 3.3 ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural networks are calculating structures unclearly inspired by the organic neural networks that represent animal wits. The neural network himself isn't an set of rules, but somewhat a framework for lots one-of-a-kind scheme learning algorithms to work together and procedure complicated information contributions.

An Artificial Neural Network based totally on a set of related gadgets or nodes known as artificial neurons which loosely perfect the neurons in a organic brain. Every joining, like

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the synapses in a organic brain, can convey a sign from one artificial neuron to another. An artificial neuron that receives a signal can procedure it after which signal additional artificial neurons linked to it.

## 3.4 FINITE ELEMENT ANALYSIS (FEA)

The finite element process is a numerical technique that's used to remedy the issues regarding engineering and mathematical physics. There are various kind of regions of hobby include structural analysis, heat transfer, fluid glide, mass shipping, and electromagnetic potential. The analytical answer of these hassle, generally require the answer to boundary fee issues for partial differential equations. The finite detail technique components of the hassle outcomes in a machine of algebraic equations. In this approach the material are divided into small parts which is called detail. The easy equations that version these finite factors are then assembled into a bigger device of equations that fashions the complete trouble.

## 3.5 TAGUCHI METHOD

Taguchi method is one of the most significant statistical implements of total quality management for designing excessive exceptional of structures at reduced cost. It's far a powerful device for the layout of high great structures. Taguchi method is used for designing a device that operates constantly and optimally over an expansion of conditions. For determine the quality design it calls for the use of strategically designed experiments. Taguchi recommends a 3-stage process to obtain applicable product pleasant through System design.

A. Parameter design.

B. Tolerance design.

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A big range of experiments have performed while the variety of the procedure limits increases. To solve the assignment, the Taguchi method habits a unique design of orthogonal arrays to homework the whole system parameter area with most effective a small variety of experiments. The use of an orthogonal array to layout the experiment could assist the designers to have a look at the influences of multiple controllable factors on the quality characteristics.

Steps followed in Taguchi method are as follows:

1) Identification of the main tricky which is to be to be enhanced and its side effects and letdown mode.

2) Identification of issues like noise factors, testing conditions and quality characteristics.

3) Identification of the main functions which is to be situated optimized.

4) Identification of the control factors and their levels.

5) Collection of orthogonal array and matrix experiment.

6) Conducting the matrix experiment.

7) Studying the data and prediction at the optimum level.

8) Determine the contribution of the parameters on the act.

## 3.6 FACTORIAL DESIGN APPORCH AND TECHNOLOGY

Factorial experiments let in to assess the blended impact of two or extra experiments variables whilst assessed simultaneously. Statistics received from factorial experiments is more whole than the ones obtained from a series of single element experiments, in the experience that factorial experiments permit the assessment of interplay effect. Factorial designs are greater green than one-issue-at-a-time experiments. They provide greater statistics at comparable or lower value.

# CHAPTER 4

## DESIGN OF EXPERIMENT

It was decided to go for a statistically designed experiment to develop a mathematical model which would relate the welding condition of Argon welding with Al 4K43 Wire of 1.6 mm diameter to mechanical properties (especially tensile and hardness). Taking literature survey as the basis, it can be concluded that strength and hardness in general affected by welding heat input, shielding gas and microstructure of the weld bead.

In the analysis three independently controllable parameter namely Arc Voltage (V), Wire Feed rate (W), and gas flow rate (G). Wire selected for the study is given in the table. Wire feed rate selected in place of welding current as current is largely dependent on wire feed rate and it is easier to set a desire wire feed rate than to get a welding current.

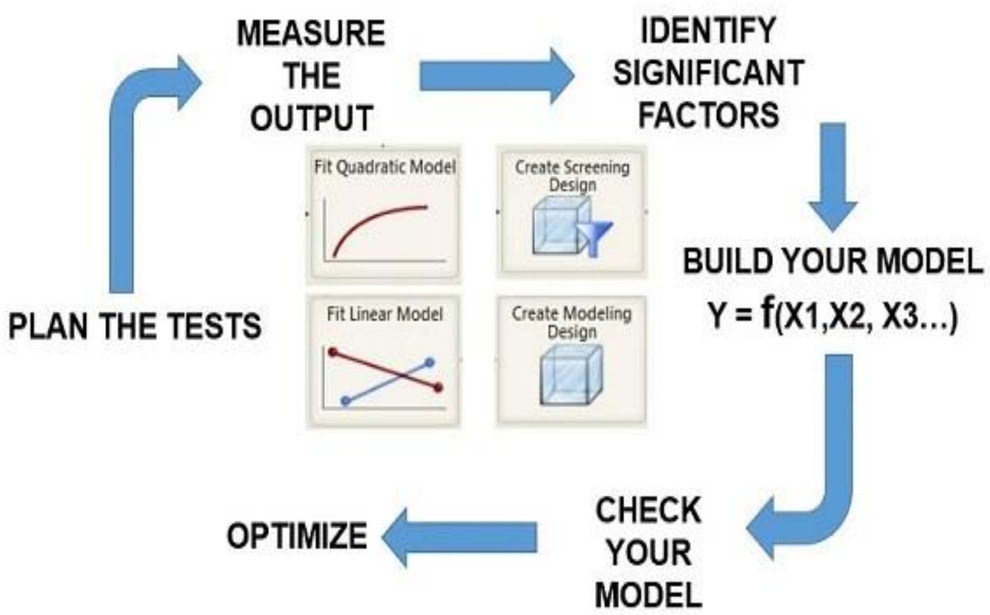


**Figure 4.1 DOE Process chart**

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The design of experiment is based on full factorial design technique, which has gained significant importance in the formulation of experiential equation in welding as well as other fields. A two-level factorial design is one of the most popular statistical designs and commonly used. A complete 3 factor each at three levels factorial design would require $2^3=8$ trails for fitting on equation. So, the last problematic was to develop mathematical models which would relates3 welding parameter of MIG welding with Al 4K43 wire and Argon shielding gas to strength and hardness with a statistically experiment to remain out at 3 level in 8 trails.

## 4.1 DESIGN OF EXPERIMENT

Three experiment levels of 3 factors selected for the experiment are given in the Table 4.1 and table no. 4.2. The heights of arc voltage(V), wire feed rate (W) and gas flow rate were selected, after carrying out a large number of trails. Globular metal transfer is used for $CO_2$ welding as used in many cases with 100% $CO_2$ atmosphere. During the course of trail being carried out it was ensured that the weld produced were of acceptable quality and did not any apparent objectionable defects.

**Table 4.1 Variables selected for the experiment**

| **S. No.** | **Variable** | **Notation** | **Unit** | **Designed by** |
|---|---|---|---|---|
| 1. | Gas pour rate | G | L/min | $X_1$ |
| 2. | Wire Feed Rate | W | m/min | $X_2$ |
| 3. | Voltage | V | Volt | $X_3$ |

`

**Table 4.2 Pulse Parameter**

| S. No. | Current (A) | Voltage(V) | Wire feed rate(W) | Gas flow Rate (Lit/min) |
|---|---|---|---|---|
| 1 | 240 | 14.4 | 3.0 | 15 |
| 2 | 240 | 14.7 | 2.5 | 14 |
| 3 | 240 | 14.0 | 3.5 | 14.5 |
| 4 | 240 | 15.6 | 4.0 | 20 |
| 5 | 240 | 15.9 | 4.5 | 16 |
| 6 | 240 | 16.1 | 5.5 | 13 |
| 7 | 240 | 16.7 | 6.0 | 18 |
| 8 | 240 | 17.0 | 6.5 | 16 |

## 4.2 FACTORIAL DESIGN APPROCH AND TECHNOLOGY

Factorial examination grants to assess the joined impacts of or more analyses factors when assessed simultaneously. Records gained from factorial trial is additional entire than gotten from a grouping of unmarried-thing tests, in the sense that factorial examinations let in the development of factors above and past that which can be predicts from the factors thought about one by one. For the need of factorial test, the measurements gathered can be utilized to make choice, which has a wide scope of materialness. notwithstanding insights about how the investigations factors works in relative disconnection. It might be foreseen, what will show up when or more noteworthy factors are utilized in total. Beside the insights about connections, the gauge of the results of the individual factors is an additional reasonable use. In this case of fragmentary analyses, the populace to which summarizing’s can be made is more prominent comprehensive than the relating populace for an unmarried component test. Components can be marked as medicines and type components.

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1. Arrangements factors foundation the trial units into the classes which may be homogeneous with acknowledge to what's being classified.
2. Treatment elements diagram test circumstances connected to an exploratory unit.

The organization of cure components is underneath the direct oversee of the experimenter, while arrangement components are not, in sense. The aftereffects of the cure variables are of essential enthusiasm to the experimenter, though characterization techniques are ensured in a trial to decrease trial bungles and arrange understanding of the results of the treatment factors.

The design of factorial analyses is worried about addressing the accompanying inquiries:

1. What components should be secured?
2. what number of dimensions of each factor should be covered?
3. In what capacity should the dimensions of the components be divided?
4. what number of test gadgets ought to be chosen for each cure conditions?
5. Could the aftereffects of essential interests be foreseen fittingly from the test data with a reason to be gotten?

A factor is an arrangement of related cures or related groupings. The related medicines making an issue comprise the levels of that part. The scope of extents inside an issue is resolved in enormous part by means of the careful quality with which a trial needs to look at the component. As a substitute, the scopes of a thing controlled by method for the sort of deduction the test needs to make upon a finish of test. the size of a factorial examination is shown through the quantities of levels of each issue. For the instance of r*q factorial test, RQ selective cure mixes are plausible. As wide assortment of part will increment, or in light of the fact that the wide assortment of degrees inside a segment will expand, the wide assortment of cure blends in a factorial examination will increment quickly.

`

In an analysis, the elements decided beneath everything about treatment combos will regularly be an irregular example from a couple focused on masses. This populace can likewise contain most likely boundless scope of components. On the off chance that n component is to be found underneath everything about total in r*q factorial test, an arbitrary example of npq components from masses is required.

The nrq components are then subdivide aimlessly to the cure combos. The R limit stages can be gathered into R levels (r<q) by either consolidating contiguous stages or deliberately choosing what are viewed as expert levels. While r = R then the issue is known as the fixed part. At the point when the choice of the r degrees from the potential R levels is chosen through some precise, non-arbitrary system, the likewise the component is thought about a fixed segment. On this later case, the decision procedure, decrease the potential R levels to be powerful stages. under this sort of decision framework, the successful, potential number of levels of thing inside the populace can be indicated as R compelling and R variable = r. In appraisal to this efficient decision way, if the r scopes of issue A covered inside the trial speaks to an arbitrary example from the potential r stages, at that point the thing is viewed as irregular part. In most reasonable circumstances wherein irregular components are experienced, r is very little to in respect to R, and the proportion r/R is very near 0. The proportion of the assortment of degrees of a factor in an investigation to the potential number of degrees in the masses is known as the examining part for a factor. In term of this testing portion, the meaning of fixed and arbitrary elements can be outlined as referenced in table.

**Table 4.3 Relationship between sampling fraction and fixed random factors.**

| Sampling fraction | Factor |
|---|---|
| r/R or r/R effective = 1 | A is a fixed factor |
| r/R = 0 | A is a random factor |

`

Cases wherein the examining division expect a cost somewhere in the range of 0 and 1 do happen by and by. Be that as it may, cases in which the examining portion is both 1 and near 0 experienced more noteworthy frequently. Principal results are portrayed as far as parameters. Direct gauges of these parameters may be reachable for relating records.

The essential effect for the degree is the refinement among the mean of all limit perceptions at the organized variable at the dimension and excellent mean of every potential perception. The collaboration among special reaches is proportion of the volume to which the model mean for the treatment total can not to anticipated from the total of the relating significant outcomes. From numerous elements of points of view, the transaction is a proportion of the non-additivity of the rule impacts. To a point the presence or non-ways of life of associations relies on the size of estimation. As an occurrence, the interchange may not be found in expressions of a logarithmic size of estimation, while in expressions of a couple of various size of estimation an association might be blessing. In the event that elective picks are available, than that scales which winds up in the least complex added substance model will normally give the most whole and adequate synopsis of the test records.

## 4.3 METHODOLOGY

For this venture, subsequent to directing the related writing study we found that the most significant parameters were voltage, current, wire feed rate and gas stream rate. So, these four factors were utilized as treatment variable for the model.

Treatment Variables:

1. Voltage.
2. Current.
3. Wire feed rate.
4. Gas stream rate.

`

For leading the preliminary runs esteems or dimensions of the factors were picked haphazardly from a vast potential dimension for example the testing portion for these preliminary runs was equivalent to zero, notwithstanding, we got an unpleasant range from the writing we overviewed. With the assistance of these preliminaries run effectives, agent's dimensions were created for each factor.

The quantity of levels for incorporated into the investigation was picked for each factor according to the structure. These quantities of level were to be each so according to the definition. It is a $2^n$ (2*2*2) factorial investigation. Where n is number of variables. On the off chance that full division approach had been drilled, the number treatment blend would have been 8.

**Figure 4.2 Welding**

The dimensions for each factor were the most noteworthy esteem and the least estimation of the components in the middle of and at which the result was satisfactory. These qualities were results of preliminaries runs. Most noteworthy esteem has been spoken to by '+' and the least esteem has been spoken to by '- ' as referenced in Table 4.4 according to the plan framework the last runs were led and the reaction for example the elasticity and hardness

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was estimated and noted down against every blend. At that point the estimation of different coefficients was determined according to the displaying. Those estimations of coefficients speak to the significance of comparing components (variable) on the response. Better the cost of coefficients, better can be the effect of the variable on the reaction. Negative expense of coefficients demonstrates the converse dating among variable and response.

The computation was done according to the accompanying model.

**Table 4.4 Model showing the treatment variable**.

| S.No. | Gas Flow Rate (G) | Wire Feed Rate (W) | Voltage (V) |
|---|---|---|---|
| 1. | + | + | + |
| 2. | - | - | - |
| 3. | + | + | - |
| 4. | + | - | + |
| 5. | - | + | + |
| 6. | - | + | - |
| 7. | + | - | - |
| 8. | - | - | + |

`

# CHAPTER 5

## EXPERIMENTAL WORK

The experiment was carried out at production lab of Mechanical Engineering Department, Integral University Lucknow and Rahman welding shop, Lucknow. This chapter contains the details of specimen size selection, welding parameter and testing.

### 5.1 SELECTION OF SPECIMEN

As we know that there is no effect of length on the strength of the material like tensile strength and hardness. We select the specimen having dimensions 2000 mm*20 mm*6 mm for experiment. For this experimentation a pair of aluminium plates are required for each 8 trials, the weight of the specimen was also kept in mind for ease of handling during the entire course of experimentation.

**Figure 5.1 Preparation of specimen**

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**Figure 5.2 Surface Welding of Specimen**

**5.2 PREPREATIN OF SPECIMEN**

Keep in the mind the requirement of each trial of 8 plates having the dimension 200 mm*20 mm*6 mm and cut from 2000 mm*20 mm*6 mm plate procured from the market. Hand hacksaw or power machine is required to cut the plate into 8 plates.

The welding conditions that kept constant during the experimentation condition were:

1. Welding process-MIG with NANO CORE of aluminium 4043 wire,

2. Electrode diameter-1.6 mm.

3. Shielding gas- Argon Gas.

4. Thickness of the plate – 6 mm.

5. Torch angle – $65^0$.

6. Electrode polarity – DCEP.

7. Type of weld – Surfacing.

## 5.3 WELDING OF SPECIMEN

Welding bead was laid on the specimen with the help of a welding manipulator which has the facility of adjusting the torch angle. The arc voltage is varied with the help of knob provided on the power source. The desired wire feed rate is obtained with the help of control panel of the machine manipulator. The gas flow rate of the shielding gas was set with the help of flow meter provided and fitted with the gas regulator on the cylinder.

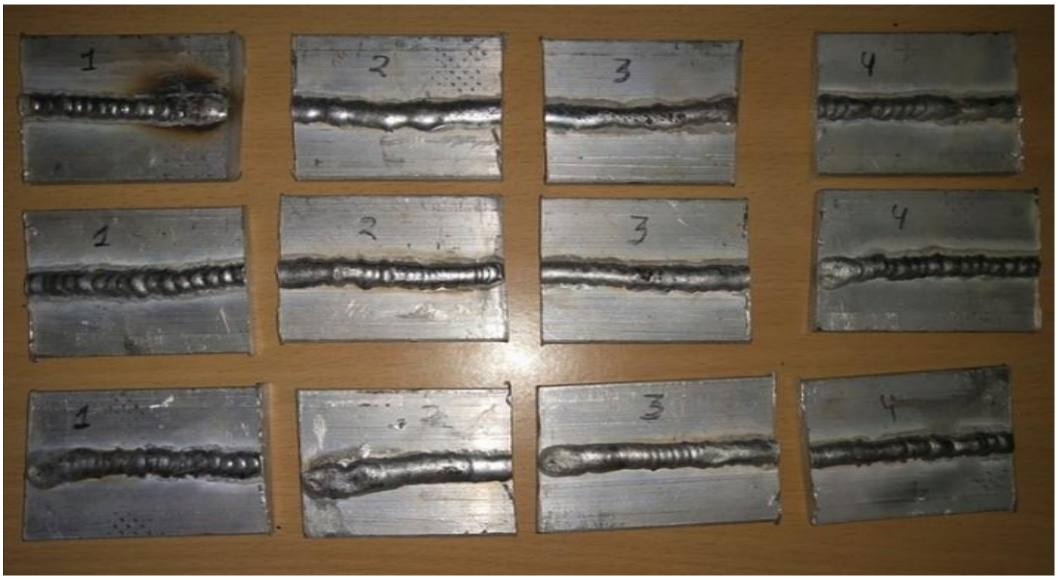

**Figure 5.3 Sample 1 to 4 after Welding**

**Figure 5.3 Sample 5 to 8 After Welding**

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## 5.4 WELDING AS PER DESIGN MATRIX

A flat mild steel plate having dimensions 100 mm*5 mm*300 mm was made on the welding manipulator table. The specimen which is to weld (surfacing) is placed over this plate for the welding. The arrangement was required to avoid the penetration which might have occurred due to high heat input rate of certain treatment combination.

The welding parameter held constant during the experiment are given in the previous chapter were set. The welding torch was aligned with the desire weld line. The welding condition required to be varied for 8 plates are taken from the design matrix. The run was made in sequence of the weld bead which overlap each other for surfacing.

During the course of experimentation, the welding torch nozzle was frequently cooled and clean. For avoid clogging of the nozzle with the spatter the anti-spatter was used.

**Table 5.1 Data Collection**

| S.No. | Bead height (mm) | Bead Width (mm) | Bead Penetration (mm) | Bead Hardness (HRB) |
|---|---|---|---|---|
| 1 | 0.30 | 0.82 | 0.35 | 28.3 |
| 2 | 0.20 | 0.78 | 0.34 | 41.3 |
| 3 | 0.26 | 0.76 | 0.42 | 35 |
| 4 | 0.20 | 0.88 | 0.38 | 32 |
| 5 | 0.26 | 0.90 | 0.34 | 37 |
| 6 | 0.15 | 0.91 | 0.32 | 28 |
| 7 | 0.24 | 0.91 | 0.45 | 36.6 |
| 8 | 0.24 | 0.86 | 0.30 | 35 |
| **Average** | **0.2473** | **0.865** | **0.3625** | **34.15** |

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# CHAPTER 6

## DEVELOPMENT OF MATHEMATICAL MODEL AND RESULT

This chapter first describes the selection of model and then calculation of the magnitude of the main effects and intersection or constant of the equation.

### 6.1 SELECTON OF MODEL

A model method the reaction work Q = f (G, W, V)

Where f is the response function.

Select a model choosing the form of this function and writing down its equation. To choose one of them, this depends on requirement of the experimenter. It is quite obvious that the requirement is simply predict the results with the require accuracy at all the points of a certain predetermined region. Several different models to correspond to the needed requirement but preference should be given to the simplest one.

Assuming the value of response as Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8 against the treatment combination 1,2,3,4,5,6,7,8 respectively (as per the serial number in the matrix design) Y as the optimize the value of response. Relation between main effects interaction effects and the response has been shown in the following equation.

$$Q = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_{12}(X_1\ X_2) + B_{13}(X_1\ X_3) + B_{23}(X_2\ X_3)$$

Here, Y is the optimize weld deposit area, $Y_i$(i =1,2,3----8) is the response of the $i^{th}$ treatment combination, $b_0$ is the mean of all the response, $B_j$(j = 1,2,3) is the coefficient of the $j^{th}$ main factor j = 1 for voltage, 2 for wire feed rate , 3 for gas flow rate ) and $B_{jk}$(j, k = 1,2,3) is the coefficient of interaction factor.

`

$B_0 = \sum Y_i / 8$

$= [(Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8)] / 8$

$B_1 = [(Q_1 - Q_2 + Q_3 - Q_4 + Q_5 - Q_6 + Q_7 - Q_8)] / 8$

$B_2 = [(Q_1 + Q_2 - Q_3 - Q_4 + Q_5 + Q_6 - Q_7 - Q_8)] / 8$

$= [(Q_1 + Q_2 + Q_5 + Q_6) - (Q_3 + Q_4 + Q_7 + Q_8)] / 8$

$B_3 = [(Q_1 + Q_2 + Q_3 + Q_4 - Q_5 -Q_6 - Q_7 - Q_8)] / 8$

$= [(Q_1 + Q_2 + Q_3 + Q_4) - (Q_5 + Q_6 + Q_7 + Q_8)] / 8$

$B_{12} = [(Q_1 - Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8)] / 8$

$= [(Q_1 + Q_4 + Q_5 + Q_8) - (Q_2 + Q_3 + Q_6 + Q_7)] / 8$

$B_{13} = [(Q_1 - Q_2 + Q_3 - Q_4 - Q_5 + Q_6 - Q_7 + Q_8)] / 8$

$= [(Q_1 + Q_3 + Q_6 + Q_8) - (Q_2 + Q_4 + Q_5 + Q_7)] / 8$

$B_{23} = [(Q_1 + Q_2 - Q_3 - Q_4 - Q_5 - Q_6 + Q_7 + Q_8)] / 8$

$= [(Q_1 + Q_2 + Q_7 + Q_8) - (Q_3 + Q_4 + Q_5 + Q_6)] / 8$

## 6.2 HARDNESS

Presently according to the condition referenced in Table 5.1 the estimations of various impacts can be determined as underneath:

$B_0 = 34.15$

$B_1 = -0.125$

$B_2 = 0.125$

$B_3 = 0.375$

$B_{12} = -1.25$

$B_{13} = -2.875$

$B_{23} = 1.00$

`

The relative between main interaction effects and the reply has been following equation:

$$Hd = 34.15 - 0.125X_1 + 0.125X_2 + 0.375X_3 - 1.25X_1X_2 - 2.875X_1X_3 + X_2X_3$$

## 6.3 BEAD HEIGHT

As per the equation mentioned in Table 5.1 the values of effects on bead height can be intended as below:

$B_0$ = 0.231

$B_1$ = 0.021

$B_2$ = 0.212

$B_3$ = 0.213

$B_{12}$ = 0.168

$B_{13}$ = -0.006

$B_{23}$ = 0.026

The relations for bead height are shown in the equation:

$$H= 0.231 + 0.021X_1 + 0.212X_2 + 0.213X_3 + 0168X_1X_2 - 0.006X_1X_3 + 0.026X_2X_3$$

## 6.4 BEAD WIDTH

As per the equation mentioned in Table 5.1 the values of effects on bead width can stay as below:

$B_0$ = 0.865

$B_1$ = 0.0125

$B_2$ = -0.030

$B_3$ = 0.000

$B_{12}$ = -0.027

`

$B_{13}$ = -0.027

$B_{23}$ = 0.0025

The relations for bead width are shown in the equation:

$$W= 0.8525 + 0.0125X_1 - 0.030X_2 + 0X_3 - 0.0275X_1X_2 - 0.0276X_1X_3 + 0.0025X_2X_3$$

## 6.5 BEAD PENETRATION

As per the equation mentioned in Table 5.1 the values of effects on bead penetration can be calculated as below:

$B_0$ = 0.3625

$B_1$ = 0.0275

$B_2$ = 0.1625

$B_3$ = 0.01

$B_{12}$ = -0.015

$B_{13}$ = -0.015

$B_{23}$ = -0.087

The relations for bead penetration are shown in the equation:

$$D = 0.3625 + 0.0275X_1 + 0.1625X_2 + 0.01X_3 - 0.015X_1X_2 - 0.015X_1X_3 - 0.087X_2X_3$$

## 6.7 RESULT AND ANALYSIS

The effect of the various parameters like bead hardness (it is calculated with the help of Rockwell Hardness Testing machine), bead geometry, bead height (Vernier Caliper), bead penetration and all other parameters were calculated. And the graphs were plotted by the computer with respect to data which are obtained while performing the testing of the desired welding specimen.

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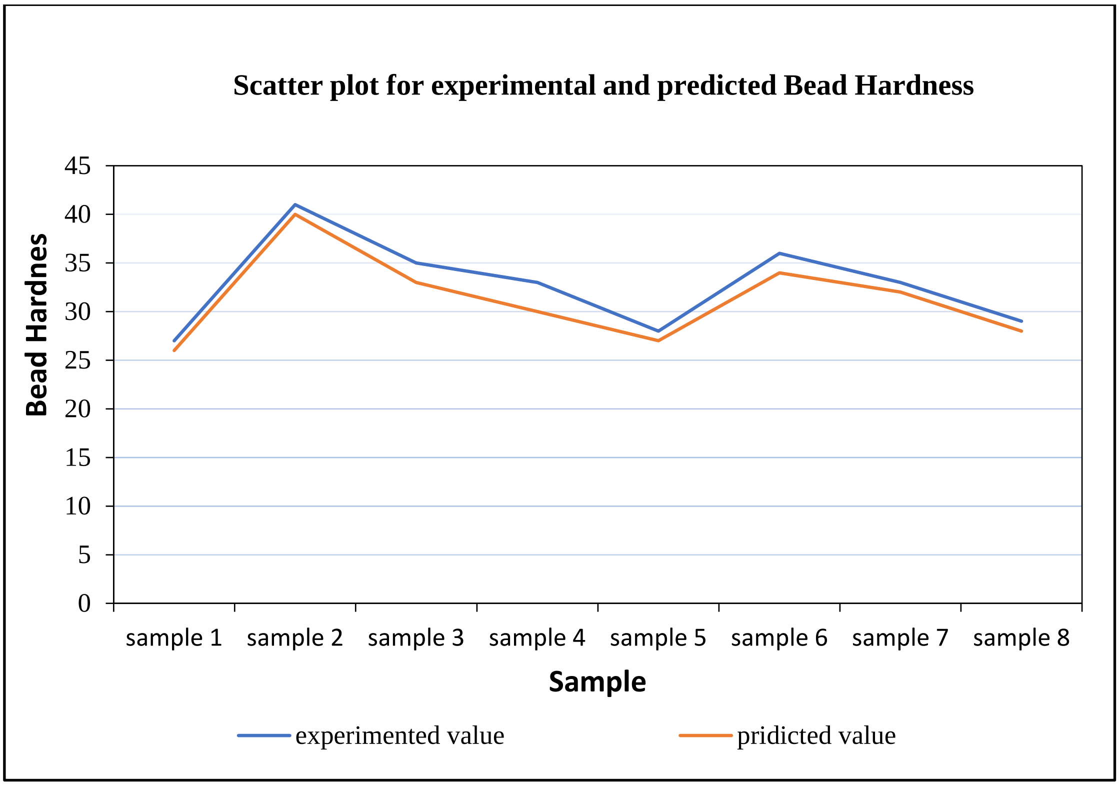


**Figure 6.1 Scatter plot for experimental and predicted Bead Hardness**

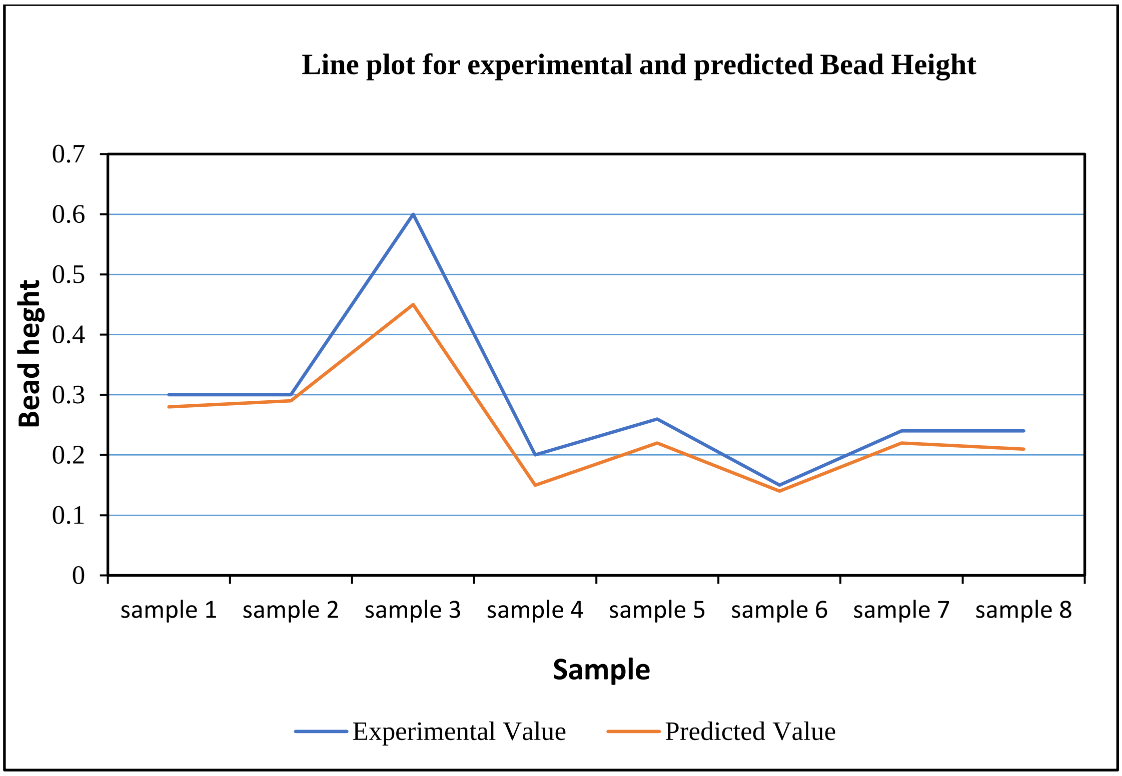


**Figure 6.2 Line plot for experimental and predicted Bead Height**

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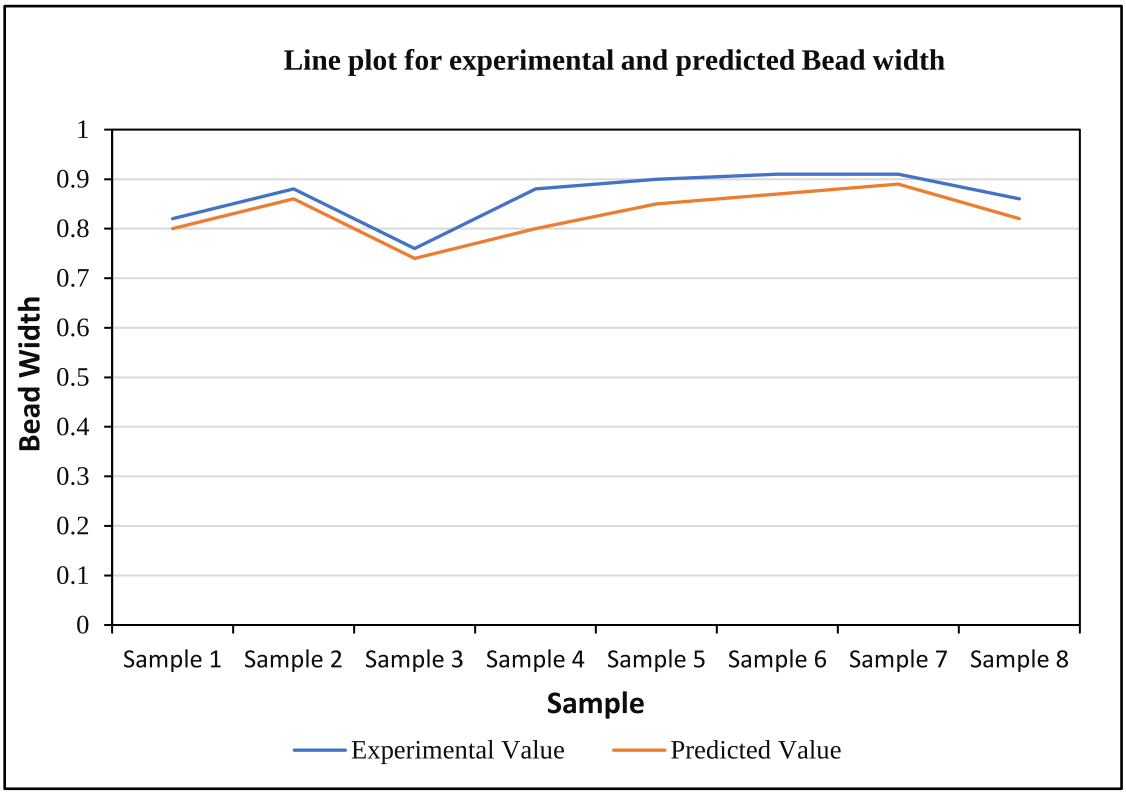


**Fig 6.3: Line plot for experimental and predicted Bead width**

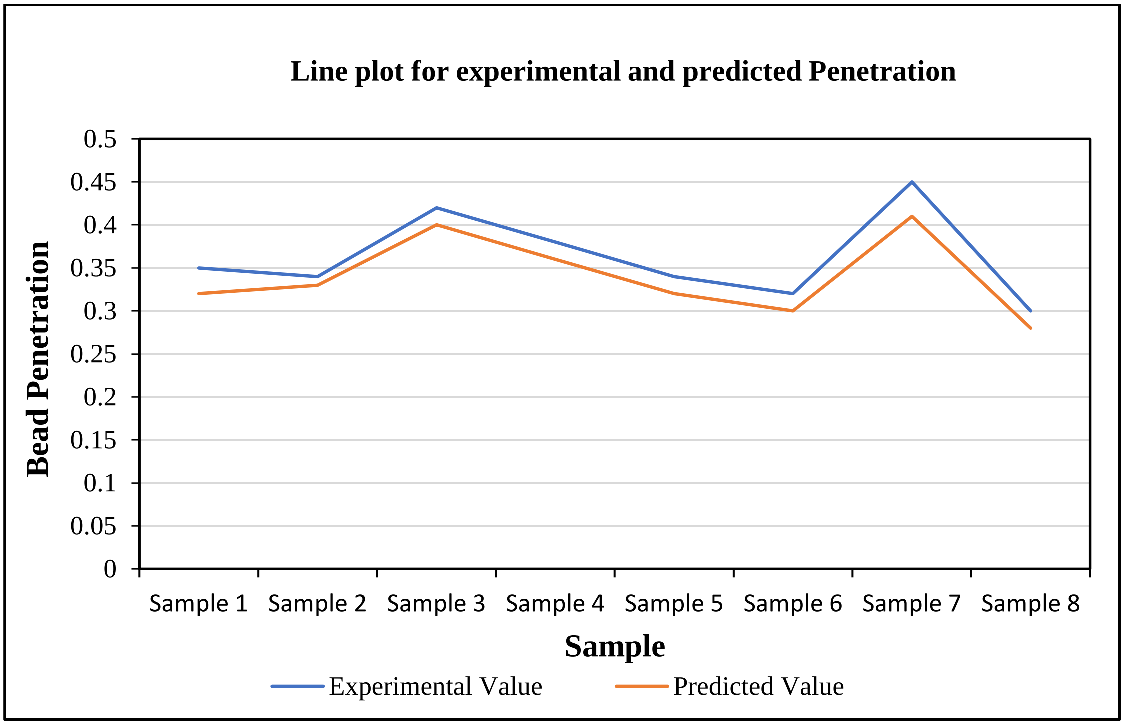


**Figure 6.4 Line plot for experimental and predicted Penetration**

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# CONCLUSION

We can conclude following points based on effects in table no.

1. Despite the challenges of welding aluminium alloys, the research demonstrated that by precisely adjusting the most important parameters (or variables) and determining their ranges, adequate outcomes may be achieved.
2. For sample no. 2 the following results are best shown
   a. Wire Feed Rate 2.5m/min
   b. Bead height 0.20mm
   c. Bead width 0.78mm
   d. Bead penetration 0.34mm
   e. Bead Hardness 41.3 HRB
3. MIG Welding of aluminium alloy with Al 4043 wire and Argon gas shielding yields excellent results. Despite the complexity of the aluminium welding process, their Statistical design and optimization helps in enhanced visual quality, decreased costs, and produced a consistent and uninterrupted weld bead as envisioned.
4. Wire feed rate and Hardness of material are highly dependent on the voltage and decrease with upsurge in voltage.
5. Hardness reductions with increases in wire feed rate. As the heat input increases the hardness of material decreases.

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# LIST OF PUBLICTIONS

1. **"Process Parameter Optimization in Dissimilar Joining with MIG Welding between SAPH 440 steel and Aluminium Alloy 6063",** Arun Pratap Singh, Dr. Shahnwaz Alam. International Journal for Research in Applied Science & Engineering Technology, Volume 10, Issue VI, June 2022, ISSN NO: 2321-9653.
2. **"Wire Feed Rate Optimization for MIG Welding of Aluminium Alloy 6063",** Arun Pratap Singh, Dr. Shahnwaz Alam, International Journal of Enhanced Research in Science Technology & Engineering (IJERSTE), ISSN No: 2319-7463, in the Vol. 11, Issue 6, June 2022. Paper has been Accepted.

# APPENDIX I


## International Journal of Enhanced Research in Science Technology & Engineering (IJERSTE), ISSN No: 2319-7463

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## Manuscript Acceptance Letter


**Accepted on: 28-06-2022**
**Paper Id: STE/286202224**


Dear Authors,

Based on the recommendations from the peer review board, I am delighted to inform you that your following manuscript has been accepted for possible publication in "International Journal of Enhanced Research in Science Technology & Engineering (IJERSTE), ISSN No: 2319-7463, in the Vol. 11, Issue 6, June, 2022.

**Paper Title:** Wire Feed Rate Optimization for MIG Welding of Aluminium Alloy 6063

**Authors:** Arun Pratap Singh, Dr. Shahnawaz Alam

**Status:** **Paper Accepted**

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