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Wire Feed Rate Optimization for MIG Welding of Aluminum Alloy 6063

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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.*

Keywords— ***MIG Welding, Surfacing, Aluminum Alloy 6063, Factorial design approach.***

I. INTRODUCTION

The 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 Pressure, as well as the choice of filler material, are all factors to consider. MIG welding (metal inert gas welding) is an arc welding technology that generates metal coalescences by heating them together with a help of arc between a constantly feed filler metallic electrode and the given workpiece. Semiautomatic, robotic, and challenging automated welding packages are all possible using the MIG welding method. The alloy fabric variety for GMAW consists Carbon steel, chrome steel, aluminium (Al), magnesium (Mg), copper (Cu), nickel (Ni), and silicon bronze are some of the materials used.

(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 CO2. 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.

PROCESS PRINCIPLE MIG welding works on the idea of feeding a metal wire through a welding gun and melting it in an arc. The twine serves two purposes: as a current-sporting electrode and as a weld steel filler wire. With the help of welding energy supply, electrical current for the arc is provided. 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. The curve is struck among the work piece and the string this is frequently feed previously to supplant the steel this is softened away.

The string is provided on a reel or drums and is feed to the welding weapon through weight rollers, which drive the wire through a bendy conductor in the hose pack arrangement to the firearm. Electrical vitality is given the assistance of a welding quality supply. The welding present day is surpassed to the anode through a tip inside the welding firearm. This contact tip is commonly connected together with the fabulous shaft of the given power source supply, and the workpiece to the horrible post. Hanging the bendfinishes the circuit. The little measurement twine, for the most part around 1 mm, is feed by utilizing the twine feeder with a pace of a few meters in venture with moment. Circular segment length is then self-balanced depending on the voltage setting of the consistent ability quality source.

A protecting fuel that secures the cathode, the circular segment and the weld pool from the results of the incorporating air, streams through the protecting gas spout that encompasses the touch tip. This cautious gas might be both idle, in light of this that it is dormant and does now not partake in the procedures happening inside the weld pool, or vivacious.

II. LITERATURE REVIEW

H.J. Park, D.C. Kim, M.J. Kang, S. Rhee [1] studied about optimization of the wire and its feed rate for the duration of pulse formation in a 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, 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] Using Design Experiments, researchers looked at optimizing process circumstances in MIG welding of aluminium alloys. Results of the factorial design trials and its analysis of the variance (ANOVA) revealed that given arc voltage and the filler feed degrees are only two major factors among the given. The best arc voltage and the filler feed rate parameters are found using the method of regression analysis at voltage of 24 V and 7in/s, respectively, where the unpleasant weld strength found highest.

Tarun Kumar Jha,Bhuvnesh Bhardwaj, Kulbhushan Bhagat And Varun Sharma [3] The use of optimal methodology was used to investigate the optimization on the weld bead geometry in the GMA weld process. The end result shows when the feed rate of the wire does increases, the depth of the penetration increases. While the wire feed rate increases, so does the weld bead rate. For the improvement of mathematical copies to predict, a 5 level 4 factor full of FD matrix is generally based on the central of composite and rotatable of the design technique may rummaged- sale. WFR is the most significant and the influential component with a '+'ve effect among the given four method variables evaluated.

Satyaduttsinh P. Chavda et al., 2014 [4] They optimized the welding settings for medium carbon steel. Finally, execute the test to make compare the projected number to the given data of experimental number in order to corroborate the results of weld strength and penetration depth analysis.

Ajit Hooda1, Ashwani Dhingra and Satpal Sharma [5] The use of reaction surface methodology investigates the optimization of MI Gas welding process limits to forecast all-out yield strength in the ALSI 1040. The max yield strength each transverse and on the longitudinal, we experimented with the best values for process variables such as voltage of welding in volt, current of welding in amp, speed of wire in m/min, and gas flow rate. The end result suggests that the same weld combined of AISI 1040 material became industrialized which is effectively with in MI welding with an selected variety of a input and the given variable parameters. The transverse yield strength is found greater than the longitudinal yield strength indicating that the optimized procedure reduced cracks and porosity from 15.32 percent to 2.54%.

K Abbasi et al. [6] Using the Taguchi technique, consider the impact of MIG welding limitations on bead of the weld and form factor function of a vibrant drawn reasonable on specimen of steel. They investigated the impact of welding current, pace utilising welding, arc voltage, and heat input rate to determine penetration intensity and the weld width contribution parameters of current of welding, voltage of arc, welding pace, and the heat input rate. This result show that welding speed is the most swaying component, whereas gas flow rate is the least swaying factor.

Hakenates et al. [7] A test was conducted on steel plates which is made of low carbon steel dimension (15 x 150 x 450 mm) were fused at 180 Amp and 28 Volt. CO2, Argon, and O2 mixes of 3 gases were employed as a shielding medium, and a MIG/MAG welding machine was used. The shielding gas and its flow rate was 15 l/min; thus the joining of w/p was taking place by positioning the minimum contact of a tip with a distance of a 15 mm from the work piece. The diameter of the electrode wire is 1.2mm. From a study it was conducted to investigate the mechanical properties of these.

Prediction was made of fuel metal arc welding & its parameters, artificial neural networks (ANNs) were used. The version's input parameters are gas mixes, whereas the ANN model's outputs are mechanical residences such as tensile & impact strength, elongation of metal, and hardness of the welded metal. The research gives demonstrated the feasibility of using neural networks to calculate the mech properties of weld low alloy metal using the GM Arc method.

Vineeta Kanwal *et al.*, 2015 [8] Taguchi method was used to conduct tests on optimizing MI gas welding parameters for measuring the hardness of Al and its alloys. Aluminum alloys having grades 6k61 and 5k83, with dimensions of (7.5x6.0x0.6) cm, were used. Argon (Ar) gas was employed as a shielding gas in this experiment. Finally, he used to discover that both aluminium (Al) alloys of 5k83 and 6k61 are extremely hard, and that welding current found to have a greater impact on the hardness on prepared weld sample.

Joseph I. Achebo et al. [9] Streamlining was carried out with an the help of Taguchi method on choosing input parameters alongside welding current, voltage of the welding, speed of a weld, and time towards reaction of extreme rigidity of steel. Based on the results of the Taguchi approach evaluation, a final method parameter of 240 Amp of a welding current, 2.0 min welding time, 0.0062 m/s welding speed, and 33 V welding voltage was recommended. These superior parameters were found to enhance the S/N ratio by 2.32 dB and 1.11 times over the present technique parameters in the United States of America. This observation explains how to utilize the Taguchi approach in a step-by-step manner.

D.S. Nagesh et al. [10] 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 results of the tests suggested that using preheated plates, a low bend travel charge, or a high circular segment power resulted in a better combination. The globule height and width both decrease as the circular segment, rate of the travel of weld increases, but then occur of a decrease in tallness is virtually larger noticeable when creating a complement dot with a formation of higher curve travel charge. With the large increase in anode feed rate, the infiltration and HAZ blasts continue while the circular segment length remains at a constant.

D. S. Correia et al. [11] Use of a genetic set of principles was used to enhance a proper study of the optimization of MIG welding and its parameters (gasoline). The search for the near-optimal became done in stages, with the present of GA anticipation the next exp are based on all of the previous one & without knowing the knowledge & study of the MIG welding method's, modeling of equations presence between the inputs & its outputs. With having a relatively limited numbers of sample and experiments, the GA was able to set up near to the most favorable conditions. The optimization using GA approach, on the other hand, necessitates a fantastic placement of its having own sets of parameters & such as producing the number of generation, numbers of population length, and so on. Otherwise, there is a risk of the search area not being sufficiently spread out.

Wahab H. Khuder et al. [12] Using MIG spot welding, researchers investigated & found out the effect occur on the weld process and its parameter over weld joints of various metal alloy & metals. The foundation materials chosen for welding in this study we are having a austenitic stainless steel which is of type AISI 316L & Carbon metal. E80S-G is the filler metal utilized to weld this diverse steel, and CO2 is used as a defensive fuel. The test was completed by considering the input parameters of cord feed, feed duration, and weld current. Using the experiment, the effect of all this parameter on the dia of the spot & shear force was been projected. The results found that as the weld & current of a weld is increased, dimensions of the spot and its weld & shear pressure increase gradually, whereas the shear force of weld decreases as weld time increases. They also discovered that as welding technology and time improves, the diameter of the weld sector expands, and the shear force reduces.

Amit Kumar et al. [13] The usage of a synthetic neural network (ANN) and a genetic set of rules was used to investigate the optimization of MIG weld parameters (GA). In this study, they create a mathematical model using the ANN technique to forecast the effect occur over the all weld & its parameters like weld voltage in volts, welding speed in m/s, and welding current in Amp on closing tensile strain at various stages during the welding of stainless steel grades 304 and 316. The argon fuel was used as the shielding gasoline, and the tests were conducted on a full factorial basis.

Vikas Mukhraiya *et* al., 2014 [14] The Taguchi approach was used to conduct an experiment has been a parametric optimization of welding of MIG (metal inert gas) weld in study. Represent the inquiry into the optimization of weld parameters, as well as their impact on the impact of torsional rigidity of MI Gas welded ST-37 rod of a steel.

Praful Kumar in 2015 [15] MIG welding was used to conduct an exp on the parametric of optimization on an angular distortion on the w/p mild steel. Because it was very difficult to be obtain a thorough analytical way of solution to foresee angular way in the distortion in welding. When they are employing Mild Steel of the AH36 which is of grade 20 mm plates in this experiment. At last, they conclude that the at an ideal angle distortion value is of 6.640, & that the obtain angular distortion will be increases as the no. of passes increases with in the selected of design range & approach of the given parameters.

Er. Rahul Malik *et* al., 2015 [16] Using the Taguchi technique, an experiment was conducted on tensile strength & the hardness parameter optimization MI Gas welding joints of High-Speed Steel (HSS) and on MS. They are experimenting with HSS which is of given grade M2 and steel of low carbon % under various conditions. Finally, decided to come the conclusion that the Taguchi parametric design technique is the most cost-effective.

Faseeulla *et al.* (2012) [17] an exp was carried out & at last, of the following exps, they are able to obtain the welded sample's maximum tensile shear strength.

G. Haragopal et *al.* (2011) [18] an exp was taken on the L9 & the orthogonal array was used in this experiment. Finally, they decided to do a confirmation test that has been performed & ensure that the exp analysis was proper, & it was done in the best possible conditions.

Omar Bataineh *et al.* (2012) [19] an exp has be carried out then they came to the conclusion about when the voltage is 24 V & the filler rate of weld material is 7 in/s, the value of mean weld has a strength which is maximum.

III. 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 shielding gas as Argon, welding with Al 4043 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 was chosen over welding current because current is mostly determined by wire feed rate and setting a desired wire feed rate is easier than getting a welding current.

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.

Three experiment levels of 3 factors selected for the experiment are given in the Table 1 and Table no. 2. After a significant number of trials, the arc voltage (V), wire feed rate (W), and gas flow rate heights were chosen. Globular metal transfer is used for MIG welding as it is used in many cases with 99% Argon gas. During the course of trail being carried out it was ensuring that the weld produced were of acceptable quality and did not any apparent objectionable defects.

Table 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 2: Pulse parameter

S.No.	Current (A)	Voltage (V)	Feeding rate of wire (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

Factorial Design Approach 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. Aside from gaining insights into relationships, assessing the outcomes of individual components is also a viable option.

1. The trial units are divided into classes based on the arrangement's factors, which may or may not be homogeneous depending on what is being classed.

2. Treatment elements depict test scenarios associated with an exploratory unit.

The organization of cure components is underneath the direct overseen 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.

Table 3: The sampling of the fraction and fixed random factors have a relationship.

Sampling of the fraction	Types of Factor
r/R or r/R effective = 1	A is form of a fixed factor
r/R = 0	A is form of a random factor

As a substitute, the scopes of a thing controlled by method in Table 3 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*s factorial test, RS 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 are to be found underneath everything about total in r*s factorial test, an arbitrary example of nrs components from masses is required. The nrs components are then subdivide aimlessly to the cure combos.

The R limit stages can be condensed into R levels (r<s) by either condensing contiguous stages or purposely selecting expert levels. When r=R, the problem is referred to as the fixed component. When the r degrees from the potential R levels are chosen using a precise, non-arbitrary system, the component is also considered a fixed segment. The decision mechanism in this situation reduces the potential R levels to powerful stages. The successful, prospective number of levels of thing within the population can be stated as R persuasive and R viable = r in this type of decision framework.

0 and 1 do appear from time to time. However, circumstances in which the examining portion is both 1 and close to 0 are more frequently encountered. As far as parameters go, the main results are shown. For linked records, direct gauges of these parameters may be available.

IV. METHODOLOGY

Following the completion of the linked writing study, we discovered that the most important characteristics for this undertaking were voltage, current, wire feed rate, and gas stream rate. As a result, these four variables were used as treatment variables in the model.

Variables in Treatment:

I. Voltage.

II. Current.

III. Wire feed rate.

IV. Gas stream rate.

According to the structure, the number of levels to include in the inquiry was chosen for each aspect. According to the definition, each of these level quantities was to be such. It's a factorial study with 2n (2*2*2). The number of variables is denoted by the letter n. If the entire division procedure had been used, the number treatment mixes would have been 8. The most notable esteem and the least estimation of the components in the center of and at which the outcome was satisfactory were the dimensions for each element. Preliminary runs yielded these characteristics. The most significant esteem has been spoken to by '+', while the least esteem has been spoken to by '-', as shown in Table 4. The last runs were led, and the response, such as elasticity and hardness, was assessed and noted down against each blend according to the plan framework.

The computation was done according to the accompanying model.

Table 4: Model showing the treatment of the variable.

S.No.	Gas Flow Rate (G) X1	Wire Feed Rate(W) X2	Voltage (V) X3
1.	+	+	+
2.	-	-	-
3.	+	+	-
4.	+	-	+
5.	-	+	+
6.	-	+	-
7.	+	-	-
8.	-	-	+

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.

V. EXPERIMENTATION

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

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 design matrix can be found in Table 1. During the experimentation period, Table 5 the following welding conditions remained constant:

I. Welding process-MIG with NANO CORE of aluminium 4043 wire,
II. Electrode diameter-1.6 mm.
III. Shielding gas- Argon gas.
IV. Thickness of the plate – 6 mm.
V. Torch angle – 65^0.
VI. Electrode polarity – DCEP.
VII. Type of weld – Surfacing.

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 Figure 1 and Figure 2. The welding condition required to be varied for 8 plates are taken from the design matrix. The run were 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: Data collected

S.No.	Bead height in (mm)	Bead Width in (mm)	Bead Penetration in (mm)	Bead Hardness in (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	**0.231**	**0.8525**	**0.3625**	**34.15**

Fig.1: sample image a

Selection of Model:

A model methods 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.

Fig.2: sample image b

Assuming Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8 as the optimal value of response as compared to the treatment combinations 1,2,3,4,5,6,7,8 (as indicated by the serial number in the matrix design). The following equation depicts the relationship between main effects, interaction effects, and response.

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

Here, Y represents the optimal weld deposit area, Yi (I =1,2,3----8) represents the response of the i^{th} treatment combination, B_0 represents the mean of all responses, Bj (j = 1,2,3) represents the coefficient of the j th main factor (j = 1 for voltage, 2 for wire feed rate, 3 for gas flow rate), and Bjk (j, k = 1,2,3) represents the coefficient of interaction factor-

$B_0 = \sum Yi / 8$

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

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

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

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

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

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

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

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

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

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

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

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

- **For Hardness:**

Presently according to the condition referenced in the part 5 estimations of various impacts can be determined as underneath Figure 3:

$B_0 = 34.15$

$B_1 = -0.125$

$B_2 = 0.125$

$B_3 = 0.375$

$B_{12} = -1.25$

$B_{13} = -2.875$

$B_{23} = 1.00$

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

$Hd = 34.15-0.125X_1+0.125X_2+0.375X_3-1.25X_1X_22.875X_1X_3+X_2X_3$

- **For Bead height:**

As per the equation mentioned in the part 5 values of effects on bead height can be intended as below Figure 4:

$B_0 = 0.231$

$B_1 = 0.021$

$B_2 = 0.212$

$B_3 = 0.213$

$B_{12} = 0.168$

$B_{13} = -0.006$

$B_{23} = 0.026$

The relations for bead height are shown in the equation:

$H = 0.231+0.021X_1+0.212X_2+0.213X_3+0168X_1X_20.006X_1X_3+ 0.026X_2X_3$

- **For Bead Width:**

As per the equation mentioned in the part 5 values of effects on bead width can stay as below Figure 5:

$B_0 = 0.8525$

$B_1 = 0.0125$

$B_2 = -0.030$

$B_3 = 0.000$

$B_{12} = -0.027$

$B_{13} = -0.027$

$B_{23} = 0.0025$

The relations for bead width are shown in the equation:

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

- **For Bead Penetration:**

As per the equation mentioned in the part 5 values of effects on bead penetration can be calculated as below Figure 6:

$B_0 = 0.3625$

$B_1 = 0.0275$

$B_2 = 0.1625$

$B_3 = 0.01$

$B_{12} = -0.015$

$B_{13} = -0.015$

$B_{23} = -0.087$

The relations for bead penetration are shown in the equation:

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

VI. RESULT AND ANALYSIS

The effect of the various parameters on hardness, bead geometry and all parameter were also calculated, and the graphs were plotted by the computer.

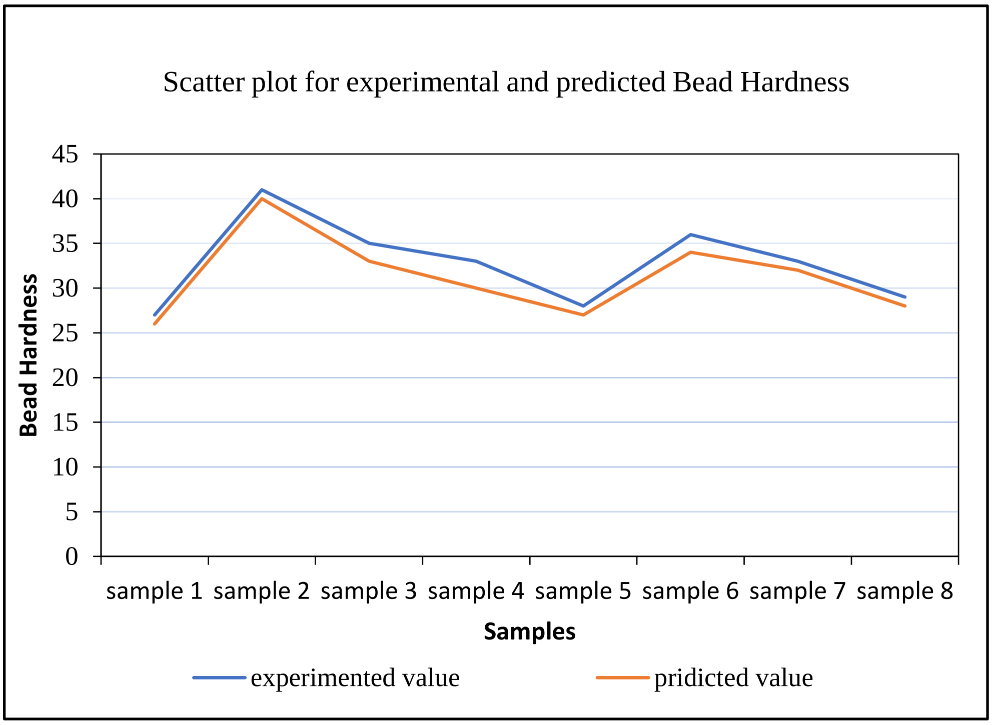

Fig.3: Scatter plot for experimental and predicted Bead Hardness

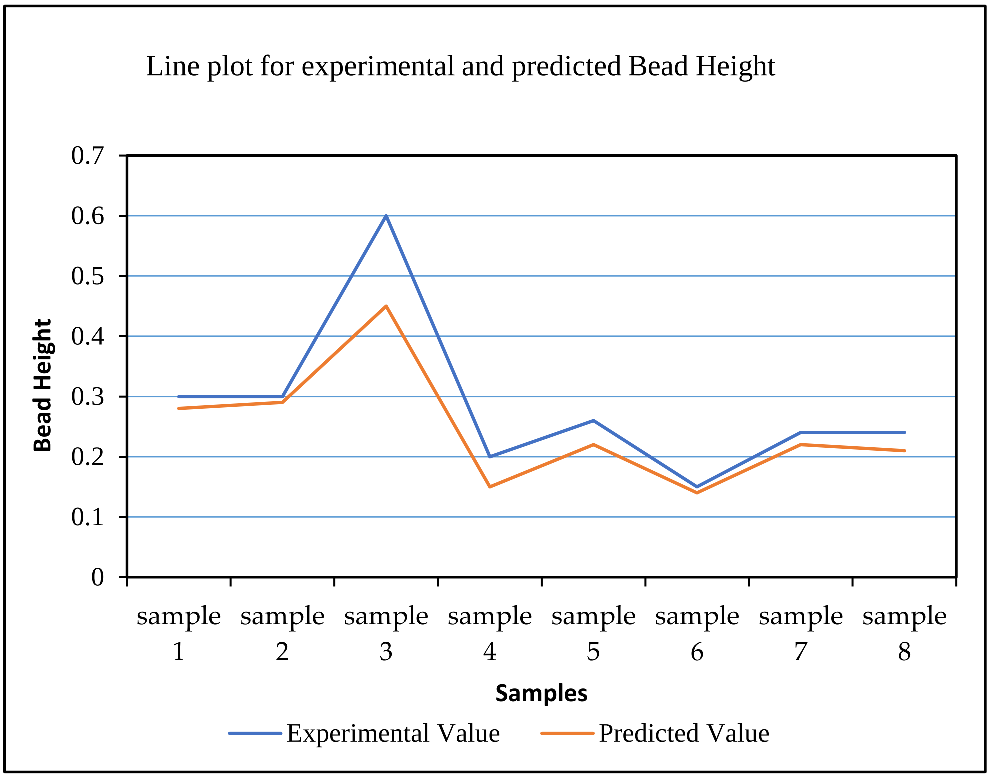

Fig.4: Line plot for experimental and predicted Bead Height

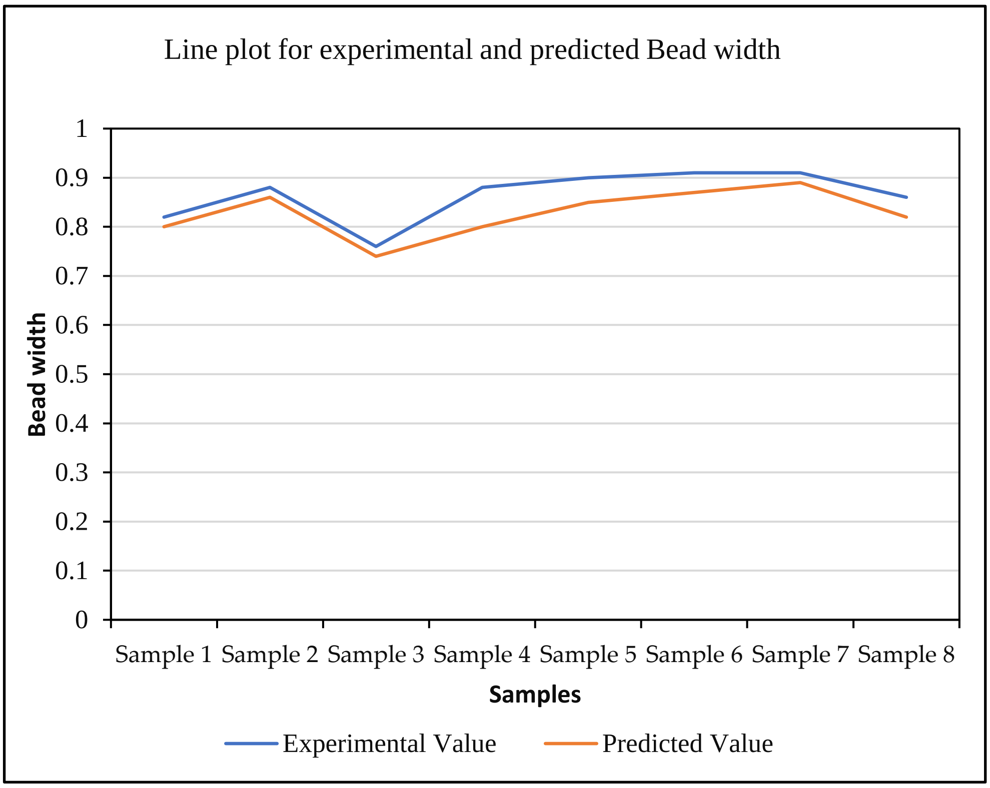

Fig.5: Line plot for experimental and predicted Bead width

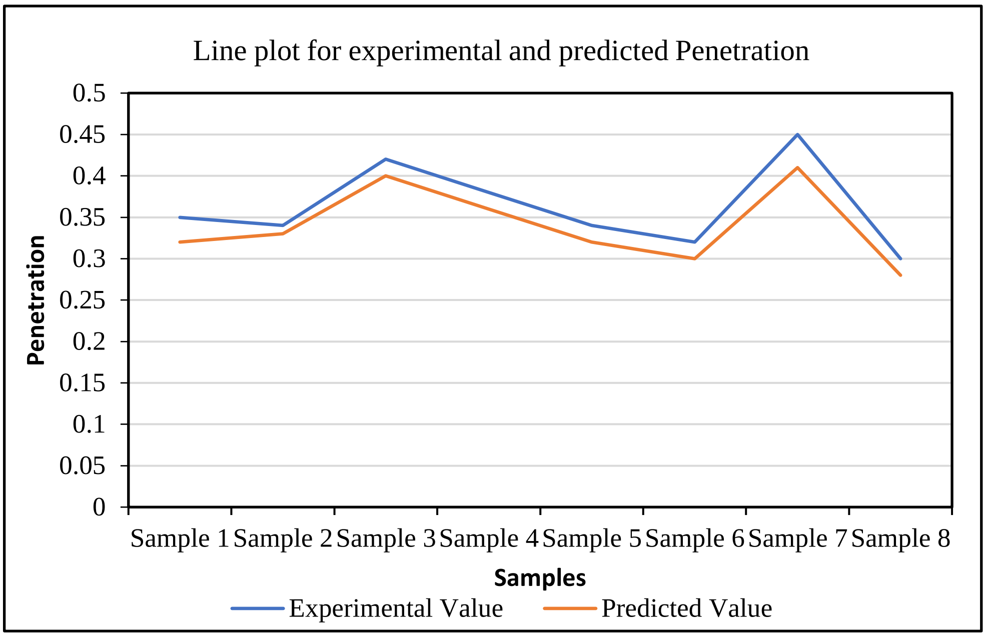

Fig.6: Line plot for experimental and predicted Penetration

VII. CONCLUSION

We can conclude following points based on effects in Table 5.

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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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

[1] H.J. Park, D.C. Kim, M.J. Kang, S. Rhee [1] VOLUME 27 ISSUE 1 March 2008. Received 15.01.2008; published in revised form 01.03.2008.

[2] B.F. Jogi*, N.S. Tupe, M.B. Todkar, R.S. Pawade and P.K. Brahmankar] Proc. of The Third Intl. Conf. on Advances in Mechanical and Robotics Engineering - AMRE 2015 Copyright © Institute of Research Engineers and Doctors, USA.

[3] Md Khalid Mumtaz, Dr. Shahnawaz Alam, 'Study and Analysis of Spot Welding of Dissimilar Material 1008 Low

Carbon Steel-5052 Aluminum Alloy", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 8 Issue Oct 2020, pp. 502-516 | ISSN: 2321-9653.

[4] Amit Kohli and Hari Singh (2011), "Optimization of Processing Parameters in Induction Hardening Using Response Surface Methodology", Sadhana, Vol. 36, Part 2, April, pp. 141-152, Indian Academy of Sciences.

[5] Pranesh B. Bamankar Asst. Professor Arvind Gavali College of Engg. Satara, Amol Chavan Student Arvind Gavali College of Engg. Satara and Tushar Phadtare Student Arvind Gavali College of Engg. Satara. October 2015, Volume 3, Issue 10, ISSN 2349-4476.

[6] Jigar Shah1, Gaurav Patel2, Jatin Makwana3. 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939.

[7] Effect of arc voltage, welding current and welding speed on fatigue life, impact energy and bead penetration of AA6061 joints produced by robotic MIG welding by H.R. Ghazvinloo1, A. Honarbakhsh-Raouf1 and N. Shadfar.

[8] A Review on Optimization of MIG Welding Parameters using Taguchi"s DOE Method by Satyaduttsinh P. Chavda1, Jaysh V. Desai, Tushar M. Patel.

[9] Anurag Tewari & Ekta Rawat 2017, 'A Review Paper on Optimization of Process Parameter of Resistance Spot Welding', International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 5, pp. 24-27 | ISSN: 2321-9653.

[10] Manoj Singla, Dharminder Singh, Dharmpal Deepak Parametric Optimization of Gas Metal Arc Welding Processes by Using Factorial Design Approach, Printed Jmmce.org in the USA Vol. 9, No.4, pp.353-363, 2010.

[11] Aravinthan Arumugam & MohdAmizi Nor 2015, 'Spot Welding Parameter Optimization to Improve Weld Characteristics for Dissimilar Metals', International Journal of Scientific & Technology Research, vol. 4, pp. 75-80.

[12] Optimization of Mig welding process parameters to predict maximum yield strength in AISI 1040 by AjitHooda, AshwaniDhingra and Satpal Sharma.

[13] Chan B, Pacey J, Bibby M. (1999) „Modeling gas metal arc weld geometry using artificial neural network technology". Journal Of Canadian Metallurgical Quarterly.

[14] G. Haragopal, P V R Ravindra Reddy, G Chandra Mohan Reddy and J V Subrahmanyam, "Parametric design for MIG welding of Al-65032 alloy using Taguchi Technique", Journal of Scientific and Industrial Research.

[15] AmitKohli and Hari Singh (2011) "Optimization of Processing Parameters in Induction Hardening Using Response Surface Methodology", Sadhana

[16] Faseeulla Khan M D, Dwivedi D K and Satpal Sharma (2012), "Development of Response Surface Model for Tensile Shear Strength of Weld-Bonds of Aluminium Alloy 6061 T651", Materials.

[17] Feramuz Karcı, Ramazan Kaçar & Süleyman Gündüz 2009, 'The effect of process parameter on the properties of spot welded cold deformed AIS5052 grade austenitic stainless steel' Journal of Materials Processing Technology, vol. 209, pp. 4011-4019.

[18] Florea, RS, Bammann, DJ, Yeldell, A, Solanki, KN & Hammi, Y 2013, 'Welding parameters influence on fatigue life and microstructure in resistance spot welding of 6061-T6 aluminum alloy', Materials and Design ELSEVIER, vol. 45, pp. 456–465.

[19] Hamid Eisazadeh, Mohsen Hamedi & Ayob Halvaee 2010, 'New parametric study of nugget size in resistance spot welding process using finite element method', Materials and Design, vol. 31, pp. 149– 157.

[20] Hao, M, Osman, KA, Boomer, DR & Newton, CJ 1996, 'Developments in Characterization of Resistance Spot Welding of Aluminum', Supplement to The Welding Journal by the American Welding Society and the Welding Research Council, pp. 1-8.

[21] Hatsuhiko Oikawa Tatsuya Sakiyama, Tadashi Ishikawa, Gen Murayama & Yasuo Takahashi 2007, 'Resistance Spot Weldability of High Strength Steel (HSS) Sheets for Automobiles', Nippon Steel Technical Report, no. 95.

[22] Hayriye Ertek Emre & Ramazan kacar 2016, 'Resistance Spot Weldability of Galvanize Coated and Uncoated TRIP Steels', Metals 2016, 6, 299; DOI:10.3390/met6120299 www.mdpi.com/journal/ metals.