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Effect of Pulse Parameters on Bead Geometry of Aluminium Alloy AA6063 using Pulse TIG Welding

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Abstract: Aluminium alloy 6063 has been considered one of the best materials commonly referred as Architectural alloy due to its properties like good surface finish and high corrosion resistance. It is used in various applications like architectural, extrusion, window, frames, irrigation tubing, and automobile industries. Many applications involve welding of the material and due to characteristics of the joining process there comes a change in the properties of the weld material which may defeat the sole purpose of the uses of the material. Thus it is required to indentify a welding process which affects least the characteristics of the AA 6063 and in the present case Pulse TIG welding has been adopted to study the effect on the bead geometry of the various pulse parameters. The effect of pulse parameters Pulse current, Base current, Pulse frequency and Pulse duty cycle on the bead geometry (weld penetration, bead width, reinforcement height) for bead on plate is studied.
Keywords: Pulsed TIG, Aluminium Alloy 6063, weld penetration, weld bead width, reinforcement height, weld bead geometry

I. INTRODUCTION

AA 6063 is an aluminium alloy with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminium Association. It has generally good mechanical properties and is heat treatable and weldable. GTA welding is an arc welding process in which a non-consumable Tungsten electrode used. The weld pool is protected from oxidation with the help of an inert gas. Mainly Argon gas is used, which is called as shielding gas. Filler material may or may not use for welding, if it is required than fed manually. Filler material is used in form of rods in TIG welding. If no filler material is available for welding than the base material can be used as the filler material. The setup of TIG welding consist of a constant voltage power source, connecting cables, a welding torch, a tungsten electrode, hoses of gas and water supply and an inert gas (argon) cylinder. Argon gas is used to protect the material form oxidation during welding and water is supplied to cool the welding torch. The major consumables of TIG welding are filler rod and shielding gas. (Chennaiah .MB, 2015) studied the effect of Pulsed TIG welding parameters on Microstructure and Micro Hardness of AA6061 joints. Aluminium is certified to the excellent corrosion resistance properties owing to the oxide layer, easy fabric capability and high strength together with mishmash of strength and formability. They study the effect of Pulsed TIG parameters on aluminium alloy weld characteristics such as microstructure and micro hardness. It was revealed that short pulse created finer grain than long pulse interval. It can be observed that low peak current produces finer aluminium grains than high peak current because pulsing of current between the base and peak current. (Balasubramanian .M, 2016) studied that prediction of optimum weld pool geometry of PCTIG welded titanium alloy using statistical design. Titanium is one of the most important non-ferrous metals. They studied the effect of pulse current TIG welding parameters on titanium alloy. It was revealed that Box-Behnken design could be efficiently be applied for modelling and optimization of weld pool geometry of pulse TIG welded titanium sheet and effect of peak current and pulse frequency has a positive effect. (Manti, Rajesh, 2008) studied that Microstructure and hardness of Al-Mg-Si weldments produced by pulse GTA welding. Pulse Tungsten Inert Gas (TIG) welding parameters on the microstructure, hardness of the weld joints of two Al (0.5-0.8%) Si (0.5-0.6%) Mg alloy (T4) produced by using three pulse frequencies (25, 33 and 50 Hz) and two duty cycles (40 and 50%). It has been observed that the mechanical properties (hardness and tensile strength) are sensitive to microstructure of weld metal, which is appreciably affected by the pulse parameters. Weld metal and HAZ were found stronger than the base metal. SEM study showed that the fracture of weldment was mostly brittle type. (Jayabalan .V, 2007) studied that effect of pulsed gas tungsten arc welding on corrosion behaviour of Ti – 6Al – 4V titanium alloy. Single pass GTAW of thin sections of Ti – 6Al – 4V was accomplished with pulsing current technique and was found to be superior to conventional continuous current process in terms of grain refinement in the fusion zone. They study the effect of pulsed current GTA welding parameters on titanium alloy weld characteristics such as grain size and hardness. (Kumar. A, 2009) Studied that effect of welding parameters on mechanical properties and optimization of pulsed TIG welding of Al-Mg-Si alloy. Al-Mg-Si alloys are extensively used in defence and aerospace applications. The purpose of this research is to improve the dilution of the base metal into the weld in pulsed TIG welding process by using Taguchi method. (Kumar Sanjeev, 2010) studied that experimental investigation on pulsed TIG welding of aluminium plate. They studied the opportunity for welding of higher thickness aluminium plate and studied that why DC current power source is not using for welding of aluminium plates. It was revealed that tensile fracture has been found due to major amount of porosity by using DC power source. Microstructure also shows the presence of porosity by using DC power source. It has been experiential that shear strength vary with change of pulse current due to be short of refined grain structure of weldments. The welded joints have been found fracture due to presence of porosity. (Kumar Pawan, 2012) studied that pulse parameters optimization of GTAW process for mechanical properties of Ti-6Al-4V alloy using Taguchi method. Titanium is best engineering metal for industrial applications because of high toughness, excellent corrosion resistance and good fatigue property. They studied that effect of each welding process parameter on mechanical properties. It has been observed that pulse current had the major contribution for optimizing the mechanical properties of the welded joint of titanium alloy because of argon-helium mixture produce deep penetration. (Chkravarthy M.P. 2013) studied that process parameters optimization for pulsed TIG welding of 70/30 Cu-Ni Alloy using Taguchi technique. They evaluate the effect of process parameters such as pulse frequency, peak current, base current and welding speed by using taguchi method. It has been found that pulse frequency has maximum contribution as compared to peak current and welding speed. (Raveendra.A, 2013) studied that effect of pulsed current on welding characteristics of aluminium alloy 5052 using Gas Tungsten Arc Welding. They evaluate the welding of Aluminium alloy 5052 with two different thickness material at different frequencies with pulsed and non- pulsed current and see the effect of pulsed current on the quality of weldments. It has been observed that porosity found with increase the thickness of material and also increasing the pulse frequencies. (Ravindar .B, 2013) studied that influence of process parameters on aluminium alloy 5083 in Pulsed Gas Tungsten Arc Welding. They have been evaluated the effect of welding parameters such as welding current, gas flow rate and also important two different filer diameter on aluminium alloy 5083. They has been found that in basic current phase, low temperature causes a decrease the volume of molten pool due to welding current varies between high value (pulse current) and low value (basic current). The hardness value of the weld zone changes distance from weld centre due to changing the microstructure. (Tadamalle A.P. 2013) studied that Influence of laser welding process parameters on weld pool geometry and duty cycle. They studied that to examine the influence of welding speed and power on weld pool geometry and welding parameters such as duty cycle, energy density and bead diameter on Austenitic 304L stainless steel. They found that the bead width and depth of penetration decreases with increase the welding speed. Depth of penetration is more affected as compare to bead width due to increase the welding speed. (Parveen.P, 2005) studied that meeting challenges in welding of aluminium alloys through pulse gas metal arc welding. They studied the difficulties in joining of newer variety of aluminium alloy with pulse gas metal arc welding. They has been found that use of pulse gas metal arc welding the heat input reduced and solving the joining of aluminium alloy because the current is flow in pulses not continuously. (Kumar Ravi B.V.R, 2014) studied that Evaluation of mechanical properties of AA6082-T6 Aluminium alloy using Pulse & Non-Pulse current GTAW process. They studied that the mechanical properties like ultimate tensile strength (UTS), yields strength and % of elongation using Pulse and Non-Pulse GTAW process with different pulse frequencies and to find the weld joint efficiency. They has been revealed that no pores and no cracks in the weldments and produce more tensile strength by using Pulse current GTAW as compare to Non-Pulse current GTAW. The 4mm thick AA6082 produce more % of elongation as compared to low thickness of AA6082 alloy. (Kumar T.Senthil, 2007) studied that Effect of pulsed current TIG welding parameters on Pitting corrosion behaviour of AA6061 Aluminium alloy. They studied that the effect of pulse current on Corrosion properties of AA6061 alloy. They found that peak current increases as well as pulse frequency increased then pitting corrosion resistance increased. If the base current increased pitting corrosion resistance decreased.

II. EXPERIMENTAL PROCEDURE

A.Selection of Material

AA6063 is an aluminium alloy with magnesium and silicon as the alloying elements. The composition of AA6063 alloy is maintained by The Aluminium Association. AA6063 was taken for Pulse TIG welding in the form of rectangular plate and had the following dimensions - Length = 150mm Width = 75mm and Thickness of plate = 6mm. The composition of AA6063 is in Table 1.

Table 1Chemical composition of AA6063 alloy

Elements	Mg	Al	Zn	Si	Mn	Cu	Fe	Al
Wt. %	0.68	8.25	0.1	0.046	0.1	0.1	0.035	(bal)

B. Selection of Filler wire

Alloy 4043 is one of the oldest and most widely used welding and brazing alloys. AA4043 can be classed as a general purpose type filler alloy. The silicon addition result in improved fluidity (wetting action) to make the alloy. The alloy is less sensitive to weld cracking and produces brighter, almost smut free welds. Chemical composition of filler wire AA4043 in Table 2.

Table 2 Chemical composition of AA4043 alloy

Weight %	Al	Si	Fe	Cu	Ti	Zn	Mn	Mg	Others
Alloy 4043	Bal	4.5 – 6.0	0.60 max	0.30 max	0.15 max	0.10 max	0.15 max	0.20 max	0.05 max

C. Pulse TIG welding process

Based on trails and literature surveys, pulse parameters have been selected for the present study. The pulse parameters for Pulse TIG welding are given in Table 3. Pulsed current GTAW welding parameters that may affect the quality of Pulsed GTAW joints Pulsed GTAW welding process parameters like pulse frequency, pulse current, base current and pulse duty cycle play a major role in deciding the weld quality in this experiment. In the present experimentation, four levels process parameters i.e. pulse frequency (P.F), pulse current (P.C), base current (B.C) and pulse duty cycle (P.D) were considered. Aluminum alloy (6063) was using 6 mm thick plate to fix the working range of Pulsed GTAW welding process parameters.

Table 3 Pulse parameters

Pulse Current (Amp)	Base Current (Amp)	Pulse Frequency (Hz)	Pulse Duty Cycle (%)	Diameter of Electrode (mm)	Diameter of Filler wire (mm)
90	50	02	30	3.2	2.4
120	80	05	60	3.2	2.4

D. Experimental layout

The design matrix developed to conduct the eight trail runs of (2^{4-1}) = 8 fractional factorial design. The confounding patterns were expressed as 4 = 1*2*3 on the top of the forth column in the design matrix. (-1) indicates the minimum value of the pulse parameters and (+1) indicates the maximum value of pulse parameters.

Where,

P.C = Pulse current, B.C = Base current, P.F = Pulse Frequency, P.D = Pulse Duty Cycle

Table 4 Experimental Layout

Experiment No.	P.C	B.C	P.F	P.D
	1	2	3	4 = 1*2*3
1.	+1	+1	+1	+1
2.	-1	+1	+1	-1
3.	+1	-1	+1	-1
4.	-1	-1	+1	+1
5.	+1	+1	-1	-1
6.	-1	+1	-1	+1
7.	+1	-1	-1	+1
8.	-1	-1	-1	-1

E. Preparation of base Plate

Twenty four (8+8+8) numbers Al alloy 6063 plates of size 120 x 75 x 6 mm were cut from given length. The plates were cleaned mechanically so as to remove oxide layer before welding.

Figure 1 Preparation of base plate

Eight base plates marked as 1 to 8 was taken for laying weld beads using two levels half factorial design with four parameters (Pulse current, Base current, Pulse frequency and Pulse duty cycle) as given in Table 3. These aluminium alloy 6063 plates have dimensions 120x75x6 mm each.

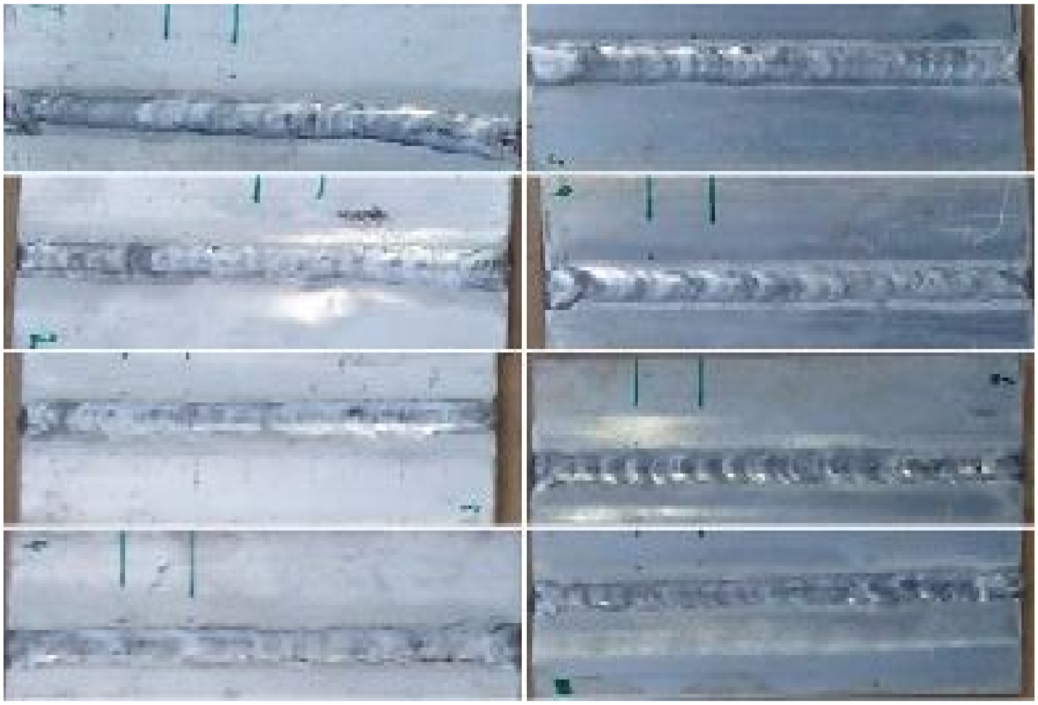

Figure 2 Aluminium alloy 6063 plates after welding process

F. Preparation of Specimens for Testing

Specimen for testing is taken from the middle of the work piece by power hacksaw. These specimens should be polished for accurate testing. The polishing has been done with emery papers of different grit size namely from P - 100 grit paper up to P - 3000 grit paper. After polishing was over the test pieces were etched with compound made by using combination of 25ml methanol, 25ml hydrochloric acid, 25ml nitric acid and 1 drop of hydrofluoric acid.

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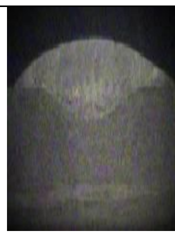
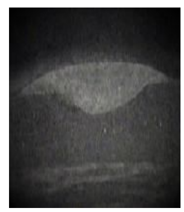
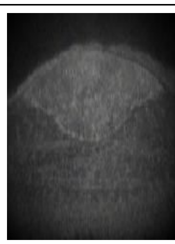
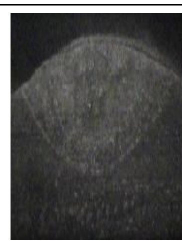
Table 5 Bead Profile Projector and Specimens for Testing

G. Images of Bead profile

In the present work the bead profile was observed under profile projector at 10X magnification which is available at metallurgical laboratory of SLIET Longowal. The magnified view was captured on to the monitor for further analysis. The images of specimen after testing are shown in Table 5. The images show the penetration value, bead width value and reinforcement value.

Table 6 Testing Bead Profile

 Fig.1	 Fig.2	 Fig.3	 Fig.4
 Fig.5	 Fig.6	 Fig.7	 Fig.8

III. RESULT AND DISCUSSION

Based on all experiment performed, the result has to be evaluated and the effect of pulse parameters on bead geometry has to be found out.

A. Effect of pulse parameters on Penetration

In the present study, effect of pulse current on bead geometry on AA6063 is when pulse current is increased from 90 Amp to 120 Amp, the penetration achieves steeply higher value of weld bead penetration during experiment. The increase in penetration is due to increase in heat input. The fact that the increase in pulse current results the concentrating arc increase the intensity of arc, resulting increased digging power of the arc and hence increases the penetration. As well as increasing the base current 50Amp to 80Amp penetration also increased because of increase the heat input. When the pulse frequency increase 2Hz to 5Hz, increase the penetration and increasing the pulse duty cycle from 30% to 60% penetration also increase because of pulse on time when pulse on time increasing penetration also increasing. The effect of pulse parameters on penetration is shown in figure 3.

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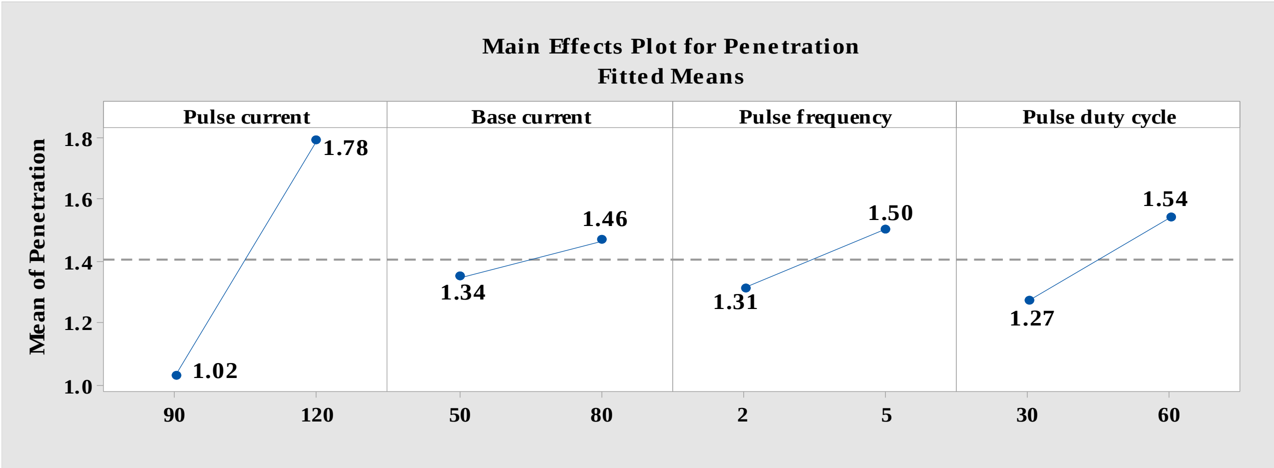

Figure 3 Effect of pulse parameters on Penetration

B. Effect of pulse Parameters on Bead Width

In the present study, effect of pulse current on bead geometry on AA6063 is when pulse current is increased from 90 Amp to 120 Amp, bead width increases with increase the pulse current and achieves higher value of penetration due increasing the heat input, the penetration also increases. When the base current increased 50Amp to 80Amp bead width increases due increases the molten pool with increasing the heat input. When pulse frequency increase 2Hz to 5Hz, bead width also decrease because of rapid droplets of arc. When the pulse duty cycle means pulse on time increase from 30% to 60% bead width value is increase innocently. The effect of pulse parameters on bead width shown in figure 4.

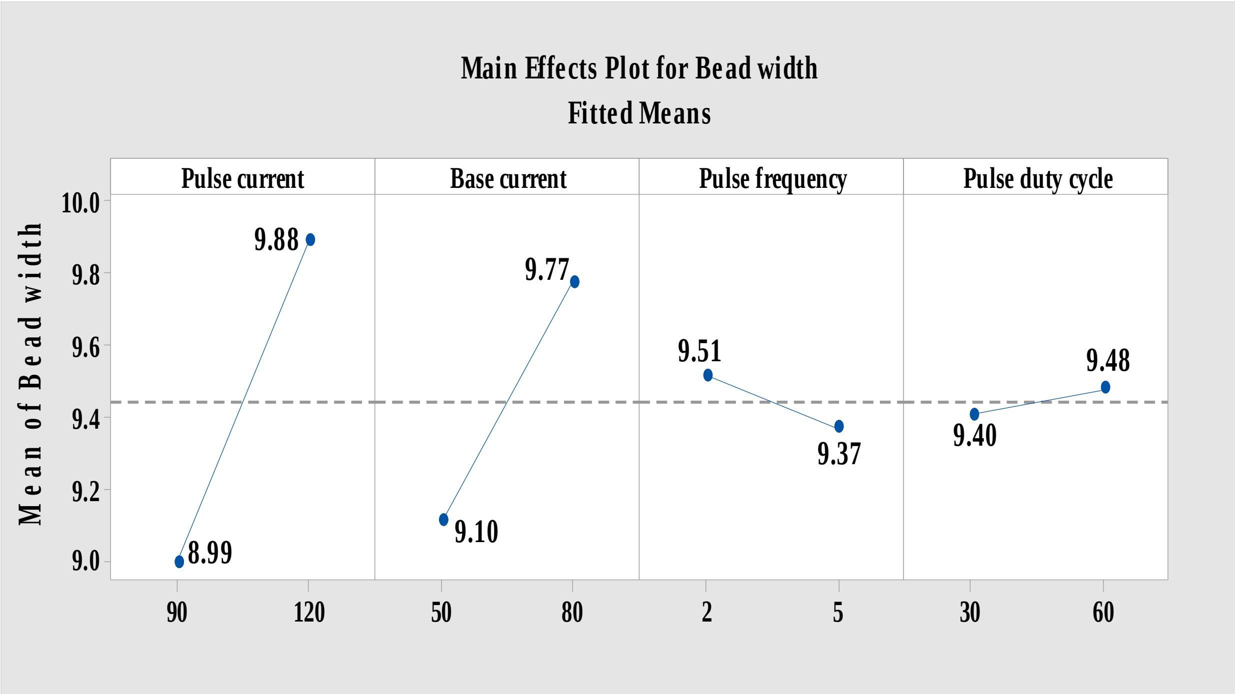

Figure 4 Effect of pulse parameters on Bead Width

C. Effect of pulse Parameters on Reinforcement Height

In the present study, effect of pulse current on bead geometry on AA6063 is when pulse current is increased from 90 Amp to 120 Amp, decrease the reinforcement height as well as increase the base current from 50Amp to 80Amp reinforcement height steeply increases and achieves higher value of reinforcement height. When increasing the pulse frequency from 2Hz to 5Hz reinforcement height is increases in small amount. When increase the pulse duty cycle from 30% to 60% reinforcement height increases. The effect of pulse parameters on reinforcement height is shown in figure 5.

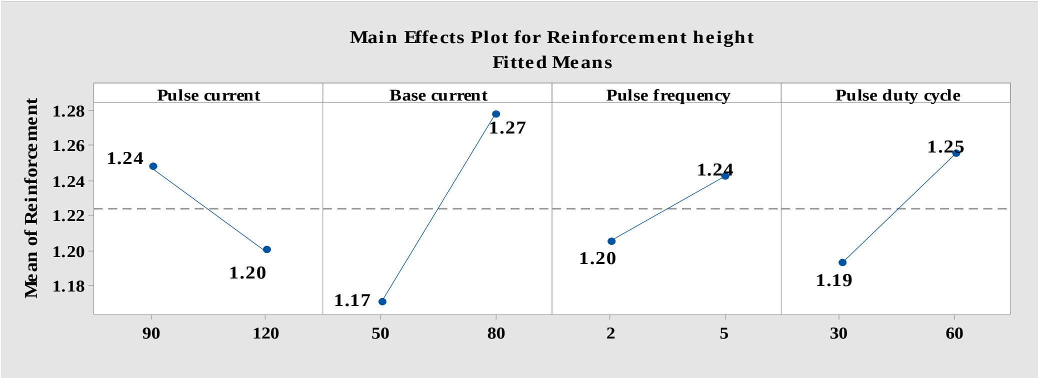

Figure 5 Effect of pulse parameters on Reinforcement Height

IV. CONCLUSIONS

Two level half factorial designs is found to be effective tool for quantifying the main and interaction effect of variable on bead geometry. Model is problem specific; however technique can be applied effectively. Proposed model is adequate to predict bead geometry with confidence level of 95%. Penetration increases drastically using filler wire, significantly increases with pulse current and increases with pulse frequency and also increased by pulse duty cycle. Weld bead width increase significantly with pulse current as compared to base current, decreases with increase pulse frequency but increases with increase in pulse duty cycle. Reinforcement height increase with base current as compared to pulse current, decreases with increase pulse frequency but increases with increase in pulse duty cycle. It is economic to use AA4043 filler wire with pulse parametric values: pulse current 90-120 A, base current 50-80Amp, pulse frequency 02-05Hz and pulse duty cycle 30-60%. The effect of pulse parameters on reinforcement height is in figure 3.

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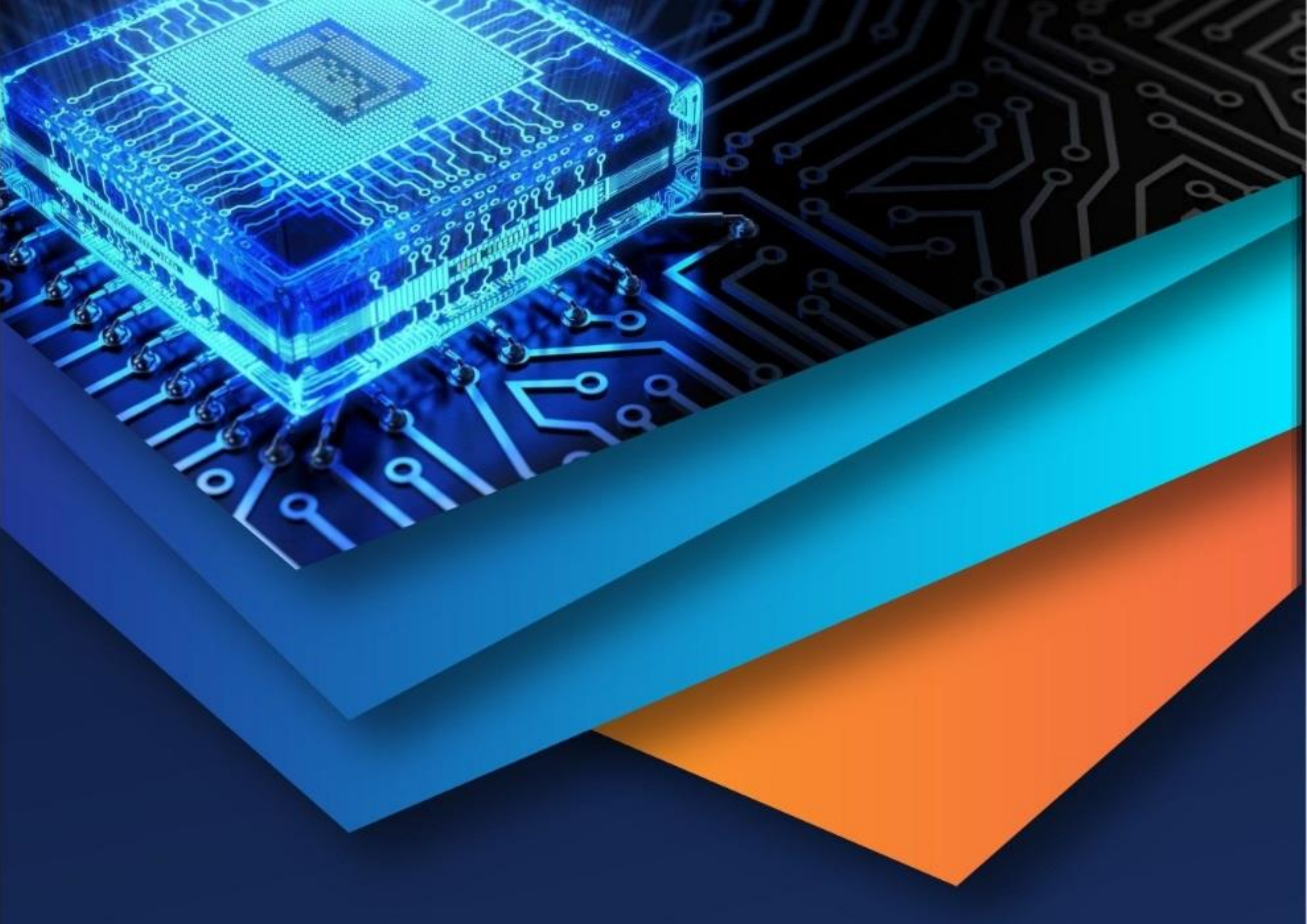

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