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Performance Analysis of Welded Joint Made by MIG Welding Process on EN-24 Steel Work Pieces for Micro Hardness

Vimal Kishor Kumawat[1], Jogendra Choudhary[2]
[1]M.Tech Student, [2]Assistant Prof. Rajasthan Institute of Engineering and Technology, Jaipur

Abstract: In industry welded joints are most significant part for making engineering items. Welded joints are made by different procedure like TIG, MIG, and spot opposition welding, bend welding process and so on. For present research analysis about MIG welding process is chosen for examination the welded joints. Three procedure parameters are chosen for this examination which is feed rate, gas stream rate and gap among test pieces. The structure of test technique is chosen for making the trial table. The strategy is BB reaction surface technique.

In this strategy low focus and abnormal states are chosen. All out 30 tests are created utilizing this DOE approach. A reaction parameter micro hardness is estimated for this examination think about. Model condition age utilizing sufficiency check is additionally direct in this examination contemplate.

Keywords: MIG, process parameters, welding time box-bhenken design, ANOVA analysis.

I. INTRODUCTION

Welding is a process of joining at least two pieces of the equivalent or different materials which are liquefied together by the utilization of warmth or pressure or both and with or without adding filler material to get solid structures.

A. Welding Process

Welding process is divided into two sections which are following

1) Plastic Welding
2) Fusion Welding

B. Plastic Welding Process-Theory

Plastic Welding Process is generally called Pressure Welding Process. The process in which two metal pieces are braced together by the utilization of external forces making a temperature underneath the conditioning motivation behind the base material without the extension of filler material is known as Pressure Welding Process. In this process, the metal pieces experience a plastic state as a result of warming besides, by the utilization of an outside pressure. Thusly, the joining of metal pieces is conveyed as a result of the utilization of temperature, time and pressure blend without dissolving the base material. The metals joined using this process can keep up their original properties as base metals, in light of the way that no dissolving happens in the base metals in the midst of Pressure Welding Process.

C. Fusion Welding Process

Combination Welding Process is otherwise called Non-Pressure Welding Process. In this process, the metals are joined by warming the material to the liquid state and after that cooling it to harden. In Fusion Welding Process, no outer pressure is connected. The combination happens just by the use of different sources. The protecting gases, for example, argon, helium, nitrogen and so on shield the liquid metal from the encompassing environment by giving legitimate protecting. Essentially, filler material is likewise added to accomplish completely filled joints.

The fundamental target of present research paper is to perform practicable research examination on process parameters of MIG welding on EN-08 object material which isn't in the warmth treated condition. The impact of process parameters of MIG on reaction parameters are additionally explored in present research work. The individual examination of present research work is following:

A.Perform investigation on MIG for shifting the feed rate of filler material for various dimensions to check the attainability of MIG reactions like hardness, joint structure, quality and so on.

B.Perform examination on MIG for various dimensions of inactive gas stream conditions to check the distinctive reactions
Play out the investigation for changing the hole among two diverse test pieces, which have same article material to discover the quality of joined item. This investigation is significantly more progressed and new for this exploration result.

II. EXPERIMENTAL SETUP

In present research study the MIG machine used for field experiments are present in figure 1. The machine is installed at college foundry shop at RIET, Jaipur.

Figure-1: Experimental Setup of MIG welding machine

As seen in figure, the machine setup show the feeder system as well as the torch used for welding process. Pilot experiments are conduct to verify the machine process parameters and the outcome of pilot experiments are show in figure 2. The pilot experiment is conduct to find the effect of changing the process parameters like feed rate, gas flow rate and effect of gap for welded joints.

Figure-2: Pilot experiments analysis for MIG process

III. MATERIAL SPECIFICATION

In present work one material is chosen for welding tests, the determination of material is rely upon writing audit and neighborhood accessibility of material and machine working conditions. The material is mechanical evaluation of steel (EN-24). EN-24 is utilized as a rule applications like house hold items made of sheets, car body making, farming items, development equipment's and so forth. Concoction and mechanical properties of EN-24 is available in table 1 and table 2 separately.

Table-1: Chemical Composition Of En-24 (In % Composition)

Material	C	Mn	Si	Cr	Ni	P	Fe
EN-24	0.35	0.60	0.25	0.85	1.8	0.035	Balance

Table-2: Mechanical Properties Of En-24 (Ansi-4340)

Material	Tensile Strength (N/mm2)	Yield Strength (N/mm2)	% Elongation	Impact (Izod J)	Hardness HB
EN-24	900	700	13	55	250

IV. FACTOR AND LEVELS

Three factors are selected for current research study and present in this section, the factors are selected on the basis of pilot experiments which is preformed and present in this chapter. These parameters are present in table 3 with levels.

Table-3: Factor And Levels

Factor	Unit	Min (-1)	Center (0)	Max (+1)
Feed rate	Inch/sec	4	5	6
Gas Flow	Psi	3	3.5	4
Gap	Mm	0	1	2

The experiment table is generated using Box-bhenken design method and the experiment table generated using MINITAB software is present in table 1 for this research study.

V. RESULT AND DISCUSSION

The present research work is focused to improve process parameters effect, on welding quality made with MIG welding machine. In present research work design of experiment method is used for experiment table generation and the factor and levels are present in table 3 for this research work. The adequacy check for micro hardness is present in table 4.

As discussed in following section the various test are conduct to analysis the regression modeling of equation through adequacy check is performed for micro hardness and the results are present in table 4.

Table 4 Adequate Model For Micro Hardness (Mh)

Sequential Model Sum of Squares Test						
Source	SS	Df	MS	F-Value	P-value	
Linear	144.87	3	48.29	2.66	0.069	
Linear + Square	372.29	6	62.04	5.85	0.001	
Linear +2-way	320.62	6	53.43	4.16	0.006	
Full Quad	548.04	9	60.89	17.88	0.000	Selected
Lack of Fit Test						
Source	SS	df	MS	F-Value	P-value	
Linear	422.79	9	46.97	16.47	0.000	
Linear + Square	195.37	6	32.56	11.41	0.000	
Linear +2-way	247.04	6	41.17	14.43	0.000	
Full Quad	19.62	3	6.54	2.29	0.115	Selected
Error Test						
Source	SS	df	MS	Contribution (%)		
Linear	471.29	26	18.27	76.49		
Linear + Square	243.87	23	10.60	39.58		
Linear +2-way	295.54	23	12.85	47.96		
Full Quad	68.12	20	3.40	10.06		Selected
Model Summary Test						
Source	St. Dev.	R^2	Adj-R^2	PRESS	Pre-R^2	
Linear	4.25	23.51	14.69	637	0.00	
Linear + Square	3.25	60.42	50.10	428	30.38	
Linear +2-way	3.58	52.04	39.52	505	18.02	
Full Quad	1.84	88.94	83.97	159	74.15	Selected

As seen in table 4, the full quad mode equation is selected for further analysis means optimization of response analysis. As seen in SS test, P value is in range of 0.05 for all options but in lack of fit test only one equation show p value more than 0.05 which is full quad model equation, in Error test Full quad show lower contribution when compare with other model equation options.

A. Analysis of Variance table for all Modeling Options for MH

In previous section the adequacy check is performed for micro hardness (MH) for all possible modeling equations option available in MINITAB software, in this section the ANOVA tables with model summary is present for all these modeling options. The ANOVA table for all these model equations are present in table 5 to table 8 for linear, square, interaction and full quad model options. In each table model summary is also present for selective model equation.

Table- 5: Anova Analysis For Linear Model For Mh

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	3	144.875	23.51%	144.875	48.292	2.66	0.069
Linear	3	144.875	23.51%	144.875	48.292	2.66	0.069
Feed Rate	1	0.25	0.04%	0.25	0.25	0.01	0.907
Gass Flow Rate	1	126.563	20.54%	126.563	126.563	6.98	0.014
Gap	1	18.062	2.93%	18.062	18.062	1	0.327
Error	26	471.292	76.49%	471.292	18.127		
Lack-of-Fit	9	422.792	68.62%	422.792	46.977	16.47	0
Pure Error	17	48.5	7.87%	48.5	2.853		
Total	29	616.167	100				

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
4.25	23.51	14.69	637	0.00

As seen in table 5, very few factors has significant levels (If any factor is treated as significant otherwise its P value is lower or equal to 0.05) major factors of linear model are non-significant for this analysis.

Table -6: Anova Analysis For Linear And Square Model For Mh

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	6	372.292	60.42%	372.292	62.049	5.85	0.001
Linear	3	144.875	23.51%	144.875	48.292	4.55	0.012
Feed Rate	1	0.25	0.04%	0.25	0.25	0.02	0.879
Gass Flow	1	126.563	20.54%	126.563	126.563	11.94	0.002
Gap	1	18.062	2.93%	18.063	18.063	1.7	0.205
Square	3	227.417	36.91%	227.417	75.806	7.15	0.001
Feed Rate	1	21.488	3.49%	29.538	29.538	2.79	0.109
Gass Flow	1	11.967	1.94%	5.654	5.654	0.53	0.473
Gap*Gap	1	193.962	31.48%	193.962	193.962	18.29	0.000
Error	23	243.875	39.58%	243.875	10.603		
Lack-of-Fit	6	195.375	31.71%	195.375	32.563	11.41	0.000
Pure Error	17	48.5	7.87%	48.5	2.853		
Total	29	616.167	100.00%				

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
3.25	60.42	50.10	428	30.38

As seen in table 6, most of the factors have significant levels (If any factor is treated as significant otherwise its P value is lower or equal to 0.05) some factors (feed rate, square of gas flow rate) like linear model are non-significant for this analysis.

Table -7: Anova Analysis For Linear And 2-Way Model For Mh

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	6	320.625	52.04%	320.625	53.438	4.16	0.006
Linear	3	144.875	23.51%	144.875	48.292	3.76	0.025
Feed Rate	1	0.25	0.04%	0.25	0.25	0.02	0.89
Gass Flow Rate	1	126.563	20.54%	126.562	126.562	9.85	0.005
Gap	1	18.062	2.93%	18.063	18.063	1.41	0.248
2-Way Interaction	3	175.75	28.52%	175.75	58.583	4.56	0.012
Feed Rate*Gass Flow Rate	1	153.125	24.85%	153.125	153.125	11.92	0.002
Feed Rate*Gap	1	10.125	1.64%	10.125	10.125	0.79	0.384
Gass Flow Rate*Gap	1	12.5	2.03%	12.5	12.5	0.97	0.334
Error	23	295.542	47.96%	295.542	12.85		
Lack-of-Fit	6	247.042	40.09%	247.042	41.174	14.43	0
Pure Error	17	48.5	7.87%	48.5	2.853		
Total	29	616.167	100.00%				

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
3.58	52.04	39.52	505	18.02

As seen in table 7, most of the factors have significant levels (If any factor is treated as significant otherwise its P value is lower or equal to 0.05) some factors (feed rate, 2-way of gas flow rate) like linear model are non-significant for this analysis.

Table -8: Anova Analyses For Full Quad Model For Mh

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	9	548.042	88.94%	548.042	60.894	17.88	0.000
Linear	3	144.875	23.51%	144.875	48.292	14.18	0.000
Feed Rate	1	0.25	0.04%	0.25	0.25	0.07	0.789
Gass Flow Rate	1	126.563	20.54%	126.563	126.563	37.16	0.000
Gap	1	18.062	2.93%	18.062	18.062	5.3	0.032
Square	3	227.417	36.91%	227.417	75.806	22.25	0.000
Feed Rate*Feed Rate	1	21.488	3.49%	29.538	29.538	8.67	0.008
Gass Flow Rate*Gass Flow Rate	1	11.967	1.94%	5.654	5.654	1.66	0.212
Gap*Gap	1	193.962	31.48%	193.962	193.962	56.94	0.000
2-Way Interaction	3	175.75	28.52%	175.75	58.583	17.2	0.000
Feed Rate*Gass Flow Rate	1	153.125	24.85%	153.125	153.125	44.95	0.000
Feed Rate*Gap	1	10.125	1.64%	10.125	10.125	2.97	0.100
Gass Flow Rate*Gap	1	12.5	2.03%	12.5	12.5	3.67	0.070

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Error	20	68.125	11.06%	68.125	3.406		
Lack-of-Fit	3	19.625	3.19%	19.625	6.542	2.29	0.115
Pure Error	17	48.5	7.87%	48.5	2.853		
Total	29	616.167	100.00%				

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
1.84	88.94	83.97	159	74.15

As seen in table 8, most of the factors have significant levels (If any factor is treated as significant otherwise its P value is lower or equal to 0.05) some factors are non-significant for this analysis.

B. Residual Plot Analysis for all Model Equation Options for MH (Micro Hardness)

Residual plot is generated among original response value measured during experiments and predicted value of response during regression model equation development. The results for residual plots for these response variables (micro hardness) are discussed in this section. The results of residual plots are show in figure 5.6 to figure 5.9 for linear, square, 2-way interaction and full quad model equation.

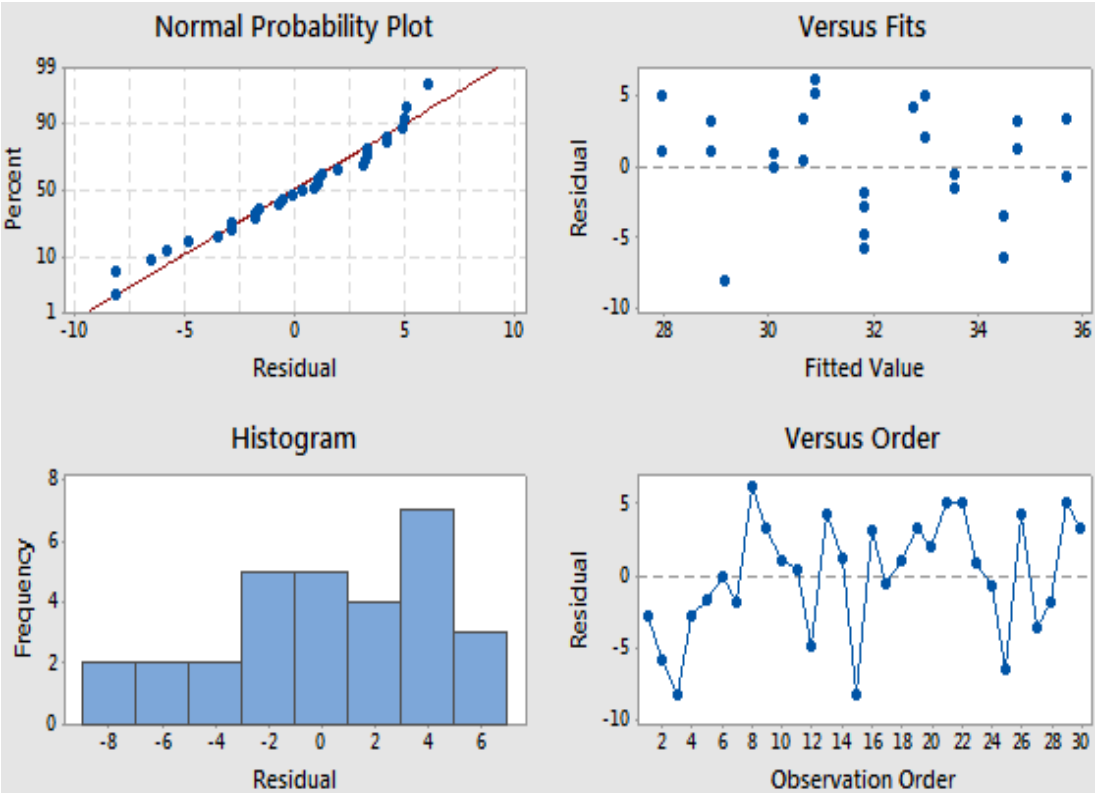

Figure 3 Residual Plot for MH for Linear model

Figure 3 show the residual plots for linear model for MH (Micro Hardness), as seen in normal distribution plot, it is clear show that residual is very high when compare with theoretical best value (zero). Figure 4 show the residual plots for linear and square model for MH (Micro Hardness), as seen in normal distribution plot, it is clear show that residual is very high when compare with theoretical best value (zero).

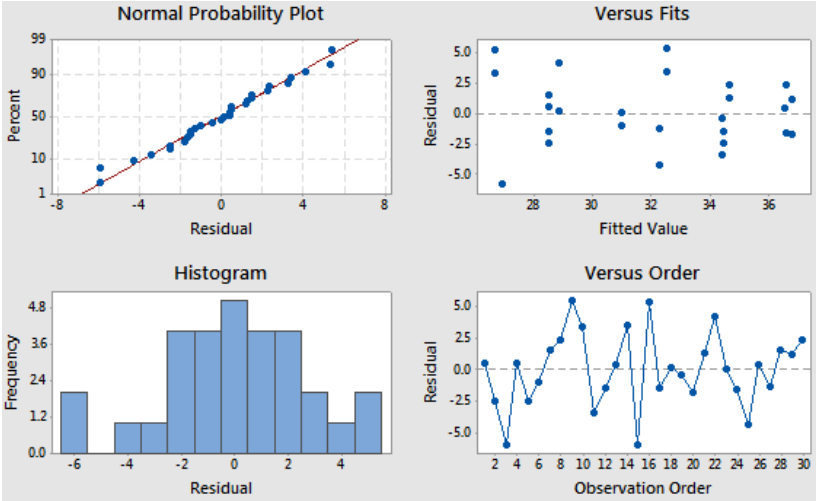

Figure 4 Residual Plot for MH for Square model

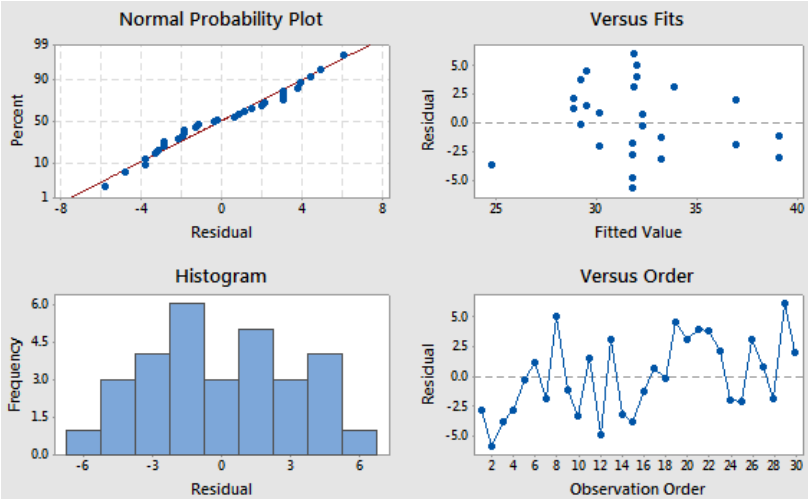

Figure 5 Residual Plot for MH for 2-way Interaction model

Figure 5 show the residual plots for linear and square model for MH (Micro Hardness), as seen in normal distribution plot, it is clear show that residual is very high when compare with theoretical best value (zero).

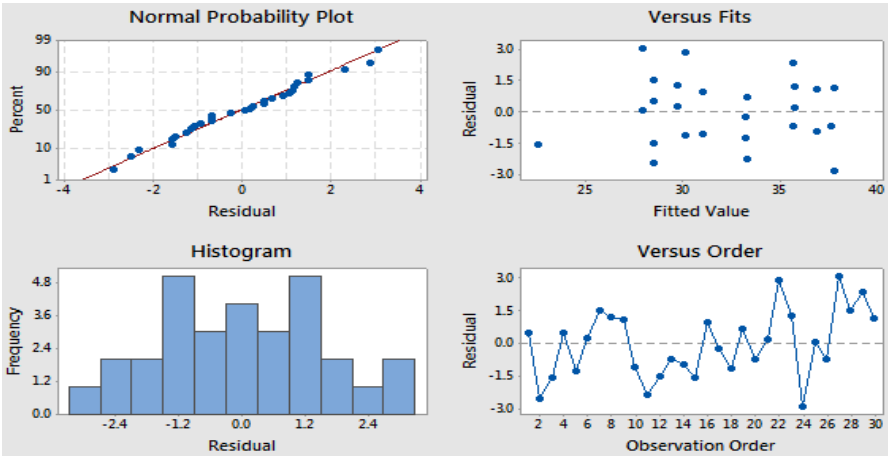

Figure 6 Residual Plot for MH for Full Quad model

Model equation for Micro Hardness (MH)

MH = 175.6 - 49.37 Feed Rate - 16.1 Gass Flow Rate - 12.31 Gap + 2.000 Feed Rate*Feed Rate - 3.50 Gass Flow Rate*Gass Flow Rate + 5.125 Gap*Gap + 8.75 Feed Rate*Gass Flow Rate - 1.125 Feed Rate*Gap + 2.50 Gass Flow Rate*Gap

VI. CONCLUSION

A. The main conclusion of this study is present in this section and the conclusions are following and present hereBox-Behnken Design (BBD) is applied for three factors feed rate, gas flow rate and gap for three levels for MIG study. Total 30 experiments are designed using this DOE technique. one response welding time is selected as output parameters for MIG research work.

B. Adequacy check analysis is performed for welding time response variables using Analysis of Variance (ANOVA) tests. The final regression model equation for micro hardness (MH) is full quad model equation

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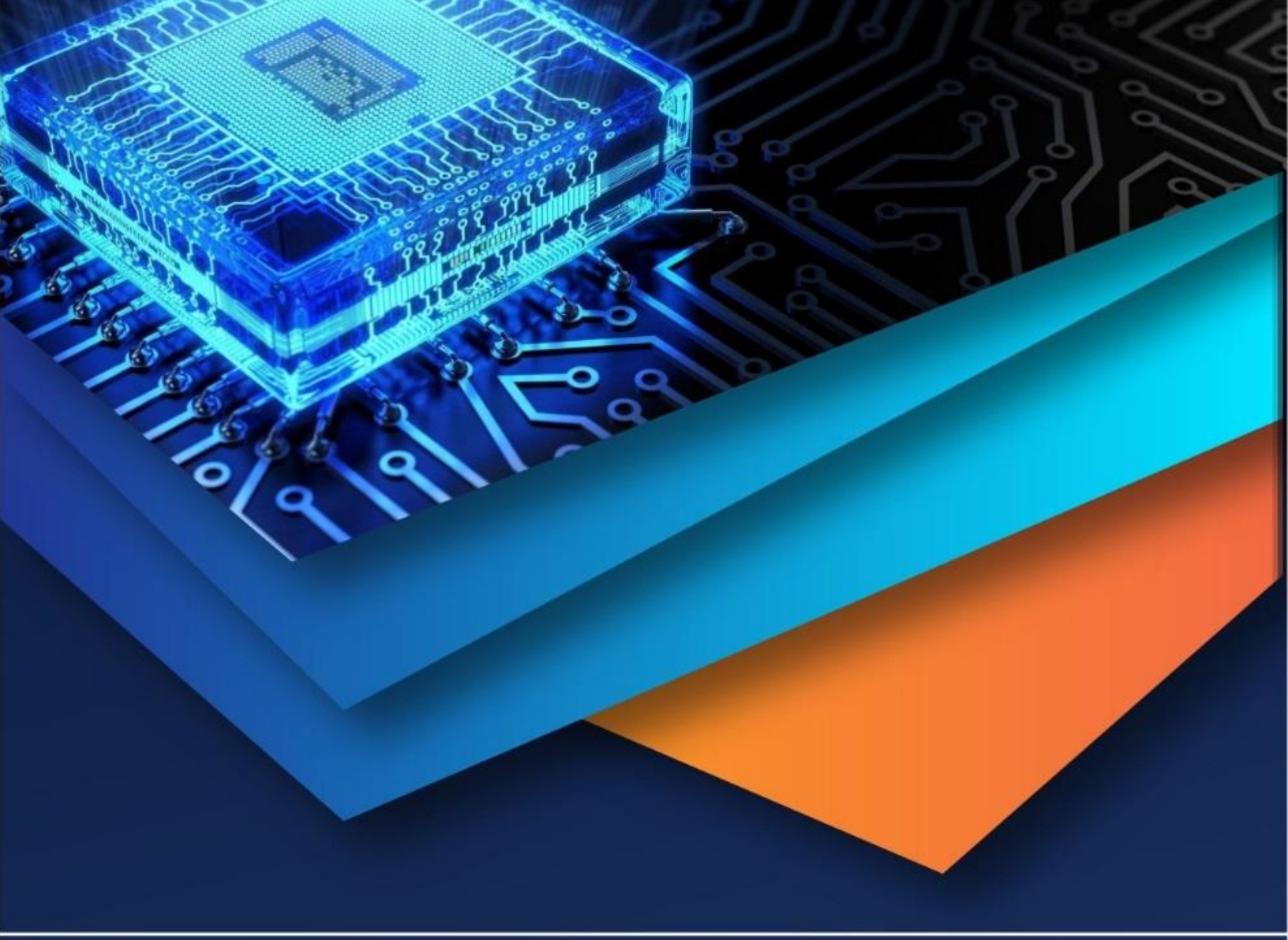

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