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A Comparative and Experimental Study of Parametric Influence on Drilling Process of Hybrid AMMC

Dr.S. Mahendran[1], Dr.S. Sukumar[2]
[1]*Assistant Professor in Dept. of Mechanical Engineering, University College of Engineering, BIT Campus, ANNA University, Tiruchirapalli.*
[2]*Teaching Fellow in, Dept. of Mechanical Engineering, University College of Engineering - Pattukottai Campus,*

Abstract: To aim for the highest quality product quality and a high metal removal rate, metal cutting is crucial. The primary obstacle to attaining optimal quality and high production is the short tool life. The hybrid aluminum metal matrix AA 6082, with reinforcement consisting of titanium dioxide (7.5%) and cenosphere (2.5%), was optimized using the Modified Taguchi optimization method for simultaneous minimization and maximization of surface roughness (Ra), machining time, and material removal rate. The surface finish was affected by different types of geometrical precision values of the CNC drilling process parameters in order to both minimize and maximize the responses. The experiments, including call for the machining of hybrid AMMC and the use of an HSS drill bit, will be performed using a CNC with different process parameters. The L16 orthogonal array will be used for the examinations, and each experiment will be run under a distinct set of circumstances, including feed, speed, and pecking. Using the TAGUCHI design, the optimal geometrical and machining parameters were determined from the experimental output responses, and significant influences were discovered for the corresponding specific output responses.
Keywords: AMMC, Drilling, Ra, CMM, DOE, Titanium Di Oxide.

I. INTRODUCTION OF MACHINING TECHNIQUES

One of the fundamental machining techniques for creating holes is drilling, which is mostly used in the manufacturing sectors such as the aerospace, medical, and automotive industries. Drilling is particularly important in sectors where mechanical fastener assembly is involved. According to reports, around 55,000 holes are bored in an AIR BUS A350 aircraft throughout its single unit manufacture (3). Metal drilling is becoming more and more necessary in order to produce smaller, more highly functioning goods.

II. INTRODUCTION OF MATRIX AA 6082

AL 6082 has a smooth exterior that is very resistant to corrosion, is well suited for welding, and is simple to anodize. An alloy with medium strength and exceptional resistance to corrosion is aluminum 6082. Of the alloys in the 6000 class, it possesses the highest strength. One term for alloy 6082 is structural alloy. The most popular alloy for machining in plate form is 6082. Despite being a relatively new alloy, 6082 has replaced 6061 in many applications due to its better strength. A significant amount of manganese is added to the alloy to control the grain structure, making the alloy stronger**.**

A. Hybrid Metal Matrix

Materials created by fusing two or more distinct types of fibers together inside a single matrix are known as hybrid composites. Titanium dioxide and cenosphere have been employed as reinforcing particles in this study project.

B. Titanium DI Oxide (TiO2)

Titanium dioxide, also known as titanium oxide or titania, it is the naturally occurring oxide of titanium, chemical formula TiO_2. When used as a pigment, it is called titanium white, Pigment White, or CI 77891. The melting point and density of titanium dioxide is 1843°C and 4.23 g/cm3. Titanium dioxide has an elastic modulus of 228 GPa and tensile strength of 367 Mpa. The grain size of titanium dioxide is 25 µm.

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C. Cenosphere
Boilers that burn coal are widely used to generate steam, which is used to generate power. A typical boiler involves injecting pulverized coal into a furnace. The process of burning coal in a boiler produces fly ash. A portion of the enhanced fly ash can be used commercially for a variety of uses, including reinforced plastics, lightweight aggregate, pavement foundation materials, cement manufacturing, stabilization of sewage sludge, and concrete and related goods. The residual fly ash must usually be disposed of by land filling since it has hardly any commercial value. Depending on the composition of coal the composition of fly ash varies. Consequently, material requirements have been devised for this waste material to be employed in particular applications. The specific demonstrates that the majority of these waste particles are composed of silicon dioxide, iron oxide, and aluminum oxide. There are various kinds of architectures seen in the fly ash particle. There are some powerful particles in fly ash. Fly ash contains various empty particles known as cenospheres..

III. WORK PIECE PREPARATION THROUGH CASTING PROCESS
Crucible casting is used for the preparation of the hybrid aluminum metal matrix composite work material Titanium dii oxide7.5%, cenosphere 2.5% and Mg 1% of average particle size 120 mesh and 140 mesh respectively are used as the reinforcements for casting. The cast specimen of 30 mm diameter and 300 mm length after casting it had been cutting using power hacksaw in to circular plates of 15 mm thickness of 16 numbers.

A. Drilling Process
Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips (swarf) from the hole as it is drilled.

B. High Speed Steel End Mill Bit (HSS)
Te reason HSS tools got their moniker is that they were designed to cut faster. The highest alloyed tool steels are HSS, which were developed in 1900. First developed, the tungsten (T series) usually has 12–18% tungsten, together with 4% chromium and 1%–5% vanadium.

C. CNC Turning Machine Set Up

Figure 1 CNC turning center

IV. DESIGN OF EXPERIMENT (DOE)
When it comes to cutting down on the cycle time needed to develop new products or processes, experiment design is a potent tool for enhancing process performance or product design. A design experiment is a test, or set of tests, in which a process's input variable (parameter) is changed in order to observe and detect changes in the output response that correlate to those changes. The process outcome is examined to determine the ideal value or parameters that have the biggest impact on the process. The objectives of the experiment could be as follows

A. Analysis Of Variance (ANNOVA)

In social science research, the Analysis of Variance (ANOVA) is a potent and often used statistical technique. It is an application to determine the impact of certain elements. ANOVA is a group of statistical models and related techniques in statistics that divide the observed variance into components because of various explanatory variables.

B. Taguchi Technique

Essentially, the first fishermen created experimental design techniques. However, the procedures for designing experiments are too complicated and difficult to use. Additionally, as the number of process parameters rises, more tests must be conducted. To address this issue, the Taguchi technique makes use of a unique orthogonal array design to examine the whole parameter space using a limited number of experiments. After that, the experimental data are converted into a signal-to-noise (S/N) ratio in order to quantify the quality attributes that deviate from the intended values. When analyzing the S/N ratio, three kinds of quality attributes are often considered: the lower the better, the higher the better, and the nominally better.

V. DESIGN OF EXPERIMENT

Table 1 Process parameters and their levels of drilling process

Sl.no	SPEED	FEED	PECKING	EPA
1	500	0.02	2	55
2	600	0.04	3	75
3	700	0.06	4	95
4	800	0.08	5	118

A. An Orthogonal Array L16 Formation (INTERACTION)

Table 2 An orthogonal array L16 formation (interaction) .

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	EPA
1	500	0.02	2	55
2	500	0.04	3	75
3	500	0.06	4	95
4	500	0.08	5	118
5	600	0.02	3	95
6	600	0.04	2	118
7	600	0.06	5	55
8	600	0.08	4	75
9	700	0.02	4	118
10	700	0.04	5	95
11	700	0.06	2	75
12	700	0.08	3	55
13	800	0.02	5	75
14	800	0.04	4	55
15	800	0.06	3	118
16	**800**	**0.08**	**2**	**95**

B. Experimental Data Analysis And Optimization

Table 3 Experimental data and output response analysis

EXP	RA	DIA ERR	RE ERR	CYL ERR	MT

1	0.883	8.242	0.009	0.018	137
2	1.497	8.226	0.008	0.019	74
3	2.009	8.160	0.008	0.016	53
4	2.056	8.114	0.008	0.018	42
5	1.516	8.185	0.006	0.015	116
6	4.246	8.126	0.009	0.017	63
7	2.263	8.171	0.008	0.019	45
8	2.714	8.165	0.009	0.019	37
9	1.969	8.104	0.011	0.020	101
10	2.498	8.156	0.008	0.017	55
11	2.294	8.183	0.010	0.019	41
12	1.578	8.156	0.011	0.020	33
13	2.445	8.253	0.009	0.017	89
14	1.731	8.256	0.008	0.019	50
15	3.771	8.096	0.010	0.020	37
16	1.690	8.151	0.008	0.019	30

C. Conclusion Of Drilling Responses

By observing the output responses value the roughness average is minimum obtained 0.883 µmm on first parameter specimen and exact geometrical precision is obtained on fifth specimen value of Roundness Error is 0.006mm & Cylindrical error-0.015mm during the drilling operation.

VI. RA (ANALYSIS OF RESULT)

Table: 4 RA and S/N RATIO Values for the Experiments

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	EPA°	RA µm	SN-RATIO
1	500	0.02	2	55	0.883	1.0808
2	500	0.04	3	75	1.497	-3.5044
3	500	0.06	4	95	2.009	-6.0596
4	500	0.08	5	118	2.056	-6.2605
5	600	0.02	3	95	1.516	-3.6140
6	600	0.04	2	118	4.246	-12.5596
7	600	0.06	5	55	2.263	-7.0937
8	600	0.08	4	75	2.714	-8.6722
9	700	0.02	4	118	1.969	-5.8849
10	700	0.04	5	95	2.498	-7.9518
11	700	0.06	2	75	2.294	-7.2119
12	700	0.08	3	55	1.578	-3.9621
13	800	0.02	5	75	2.445	-7.7656
14	800	0.04	4	55	1.731	-4.7659
15	800	0.06	3	118	3.771	-11.5291
16	800	0.08	2	95	1.690	-4.5577

A. Ra-Responsible & Anova For Each Level Of The Process Parameter

Table: 5 Response Table for Signal to Noise (RA-Smaller is better)

Level	SPEED	FEED	PECKING	EPA
1	-3.686	-4.046	-5.812	-3.685

2	-7.985	-7.195	-5.652	-6.789
3	-6.253	-7.974	-6.346	-5.546
4	-7.155	-5.863	-7.268	-9.059
Delta	4.299	3.928	1.615	5.373
Rank	2	3	4	1

Table: 6 Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
SPEED	3	2.5546	0.85154	1.53	0.367	24
FEED	3	2.0661	0.68870	1.24	0.432	19
PECKING	3	0.1612	0.05375	0.10	0.957	1
EPA	3	4.3033	1.43444	2.58	0.229	40
Error	3	1.6687	0.55623			16
Total	15	10.7540				100

VII. DIAMETER ERRORS (ANALYSIS OF RESULT)

Table: 7 Diameter Error (Analysis of Result)

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	EPA°	DIA ERR	SN-RAIO
1	500	0.02	2	55	8.242	-18.3207
2	500	0.04	3	75	8.226	-18.3038
3	500	0.06	4	95	8.160	-18.2338
4	500	0.08	5	118	8.114	-18.1847
5	600	0.02	3	95	8.185	-18.2604
6	600	0.04	2	118	8.126	-18.1975
7	600	0.06	5	55	8.171	-18.2455
8	600	0.08	4	75	8.165	-18.2391
9	700	0.02	4	118	8.104	-18.1740
10	700	0.04	5	95	8.156	-18.2295
11	700	0.06	2	75	8.183	-18.2583
12	700	0.08	3	55	8.156	-18.2295
13	800	0.02	5	75	8.253	-18.3322
14	800	0.04	4	55	8.256	-18.3354
15	800	0.06	3	118	8.096	-18.1654
16	800	0.08	2	95	8.151	-18.2242

A. Dia-Errors Responsible & Anova For Each Level Of The Process Parameter

Table: 8 Response Table for Signal to Noise (Diameter Error-Smaller is better)

Level	SPEED	FEED	PECKING	EPA
1	-18.26	-18.27	-18.25	-18.28
2	-18.24	-18.27	-18.24	-18.28
3	-18.22	-18.23	-18.25	-18.24
4	-18.26	-18.22	-18.25	-18.18
Delta	0.04	0.05	0.01	0.10

Rank	3	2	4	1

Table: 9 Analysis of Variance of Circle

SOURCE	DF	SEQ SS	ADJ MS	F	P	%of Contribution
SPEED	3	0.004282	0.001427	3.67	0.157	11
FEED	3	0.007866	0.002622	6.74	0.076	20
PECKING	3	0.000212	0.000071	0.18	0.902	1
EPA	3	0.025219	0.008406	21.60	0.016	65
Error	3	0.001168	0.000389			3
Total	15	0.038746				100

VIII. ROUNDNESS ERRORS (ANALYSIS OF RESULT)

Table: 10 S/N RATIO Values for the Roundness Error

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	EPA°	ROUNDNE SS ERROR	S-N RATIO
1	500	0.02	2	55	0.009	40.9151
2	500	0.04	3	75	0.008	41.9382
3	500	0.06	4	95	0.008	41.9382
4	500	0.08	5	118	0.008	41.9382
5	600	0.02	3	95	0.006	44.4370
6	600	0.04	2	118	0.009	40.9151
7	600	0.06	5	55	0.008	41.9382
8	600	0.08	4	75	0.009	40.9151
9	700	0.02	4	118	0.011	39.1721
10	700	0.04	5	95	0.008	41.9382
11	700	0.06	2	75	0.010	40.0000
12	700	0.08	3	55	0.011	39.1721
13	800	0.02	5	75	0.009	40.9151
14	800	0.04	4	55	0.008	41.9382
15	800	0.06	3	118	0.010	40.0000
16	800	0.08	2	95	0.008	41.9382

A. Roundness Error Responsible & Anova For Each Level Of The Process Parameter

Table: 11 Response Table for Signal to Noise (-Smaller is better)

Level	SPEED	FEED	PECKING	EPA
1	41.68	41.36	40.94	40.99
2	42.05	41.68	41.39	40.94
3	40.07	40.97	40.99	42.56
4	41.20	40.99	41.68	40.51
Delta	1.98	0.71	0.74	2.06
Rank	2	4	3	1

Table: 12 Analysis of Variance- Roundness

Source	DF	Seq SS	Adj MS	F	P	% of contribution
SPEED	3	0.000009	0.000003	2.71	0.217	37
FEED	3	0.000002	0.000001	0.43	0.748	8
PECKING	3	0.000002	0.000000	0.43	0.748	8
EPA	3	0.000009	0.000003	2.57	0.229	35
Error	3	0.000003	0.000001			12
Total	15	0.000025				100

IX. CYLINDRICITY ERROR (ANALYSIS OF RESULT)

Table: 13 S/N RATIO Values for the Cylindricity Error

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	EPA°	CYL ERR	SN-RAIO
1	500	0.02	2	55	0.018	34.8945
2	500	0.04	3	75	0.019	34.4249
3	500	0.06	4	95	0.016	35.9176
4	500	0.08	5	118	0.018	34.8945
5	600	0.02	3	95	0.015	36.4782
6	600	0.04	2	118	0.017	35.3910
7	600	0.06	5	55	0.019	34.4249
8	600	0.08	4	75	0.019	34.4249
9	700	0.02	4	118	0.020	33.9794
10	700	0.04	5	95	0.017	35.3910
11	700	0.06	2	75	0.019	34.4249
12	700	0.08	3	55	0.020	33.9794
13	800	0.02	5	75	0.017	35.3910
14	800	0.04	4	55	0.019	34.4249
15	800	0.06	3	118	0.020	33.9794
16	800	0.08	2	95	0.019	34.4249

A. *Cylindricity – Responsible & Anova For Each Level Of The Process Parameter*

Table: 14 Response Table for Signal to Noise Cylindricity Error – (Smaller is better)

LEVEL	SPEED	FEED	PECKING	TOOL
1	35.03	35.19	34.78	34.43
2	35.18	34.91	34.72	34.67
3	34.44	34.69	34.69	35.55
4	34.56	34.43	35.03	34.56
Delta	0.74	0.75	0.34	1.12
Rank	3	2	4	1

Table: 15 Analysis of Variance for Cylindricity Error

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
SPEED	3	0.000006	0.000002	0.87	0.545	18

FEED	3	0.000005	0.000002	0.67	0.626	15
PECKING	3	0.000001	0.000000	0.20	0.890	3
EPA	3	0.000013	0.000004	1.67	0.343	43
Error	3	0.000007	0.000002			21
Total	15	0.000033				100

X. MACHINING TIME (ANALYSIS OF RESULT)

Table: 16 S/N RATIO Values for the Machining Timing

NO	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	TOOL COATED	MT SEC	SN-RAIO
1	500	0.02	2	55	137	-42.7344
2	500	0.04	3	75	74	-37.3846
3	500	0.06	4	95	53	-34.4855
4	500	0.08	5	118	42	-32.4650
5	600	0.02	3	95	116	-41.2892
6	600	0.04	2	118	63	-35.9868
7	600	0.06	5	55	45	-33.0643
8	600	0.08	4	75	37	-31.3640
9	700	0.02	4	118	101	-40.0864
10	700	0.04	5	95	55	-34.8073
11	700	0.06	2	75	41	-32.2557
12	700	0.08	3	55	33	-30.3703
13	800	0.02	5	75	89	-38.9878
14	800	0.04	4	55	50	-33.9794
15	800	0.06	3	118	37	-31.3640
16	800	0.08	2	95	30	-29.5424

A. Machining Time Responsible & Anova For Each Level Of The Process Parameter

Table:17 Response Table for Signal to Noise Machining Timing-(Smaller is better)

LEVEL	SPEED	FEED	PECKING	EPA
1	-36.77	-40.77	-35.13	-35.04
2	-35.43	-35.54	-35.10	-35.00
3	-34.38	-32.79	-34.98	-35.03
4	-33.47	-30.94	-34.83	-34.98
Delta	3.30	9.84	0.30	0.06
Rank	2	1	3	4

Table: 18 Analysis of Variance for Machining Timing

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
SPEED	3	1397.7	465.90	14.02	0.029	9
FEED	3	13612.7	4537.56	136.55	0.001	88
PECKING	3	245.2	81.73	2.46	0.240	2
EPA	3	92.2	30.73	0.92	0.525	1
Error	3	99.7	33.23			0
Total	15	15447.4				100

XI. RESULT&CONCLUSION

A. Taguchi Result

The below mentioned taguchi result along with % of contribution found through ANOVA were illustrated.

Optimal control factor for drilling process

1) Surface roughness- A2 (RPM -600) B3 (Feed -0.06 mm/Rev) C4 (Pecking-5mm) D1 (EPA55°)
2) Diameter Error- A3 (RPM -700) B2 (Feed -0.04 mm/Rev) C4(PECKING -5mm) D1 (EPA55°)
3) Roundness Error- A2 (RPM -600) B4 (Feed -0.08 mm/Rev) C3 (Pecking-4mm) D1 (EPA55°)
4) Cylindricity Error- A3 (RPM -700) B2 (Feed -0.04 mm/Rev) C4 (Pecking -5mm) D1 (EPA55°)
5) Machining Timing- A2 (RPM -600) B1 (Feed -0.02 mm/Rev) C3 (Pecking-4mm) D4 (EPA118°)

B. Percentage Contribution Of Process Parameter

1) Surface roughness –EPA-40%
2) Diameter Error – EPA- 65%
3) Roundness error – Speed -37%
4) Cylindricity Error - EPA -43%
5) Machining Timing - Feed-88%

C. Conclusion

The objective of this research is to use an HSS drill bit to drill a hybrid AMMC 6082 and determine how drilling settings affect the geometric precision and surface roughness. Pecking, spindle speed, and feed rate were the variables, and geometrical and machining data were the responses. The model for this experiment was developed using the Taguchi Design, and an ANOVA was used to analyze the results. By looking at the output answers value, the first parameter specimen's roughness average is found to be as low as 0.883 µmm, and the fifth specimen yields the exact geometrical precision of 0.006 mm for roundness error and 0.015 mm for cylindrical error during the drilling process.

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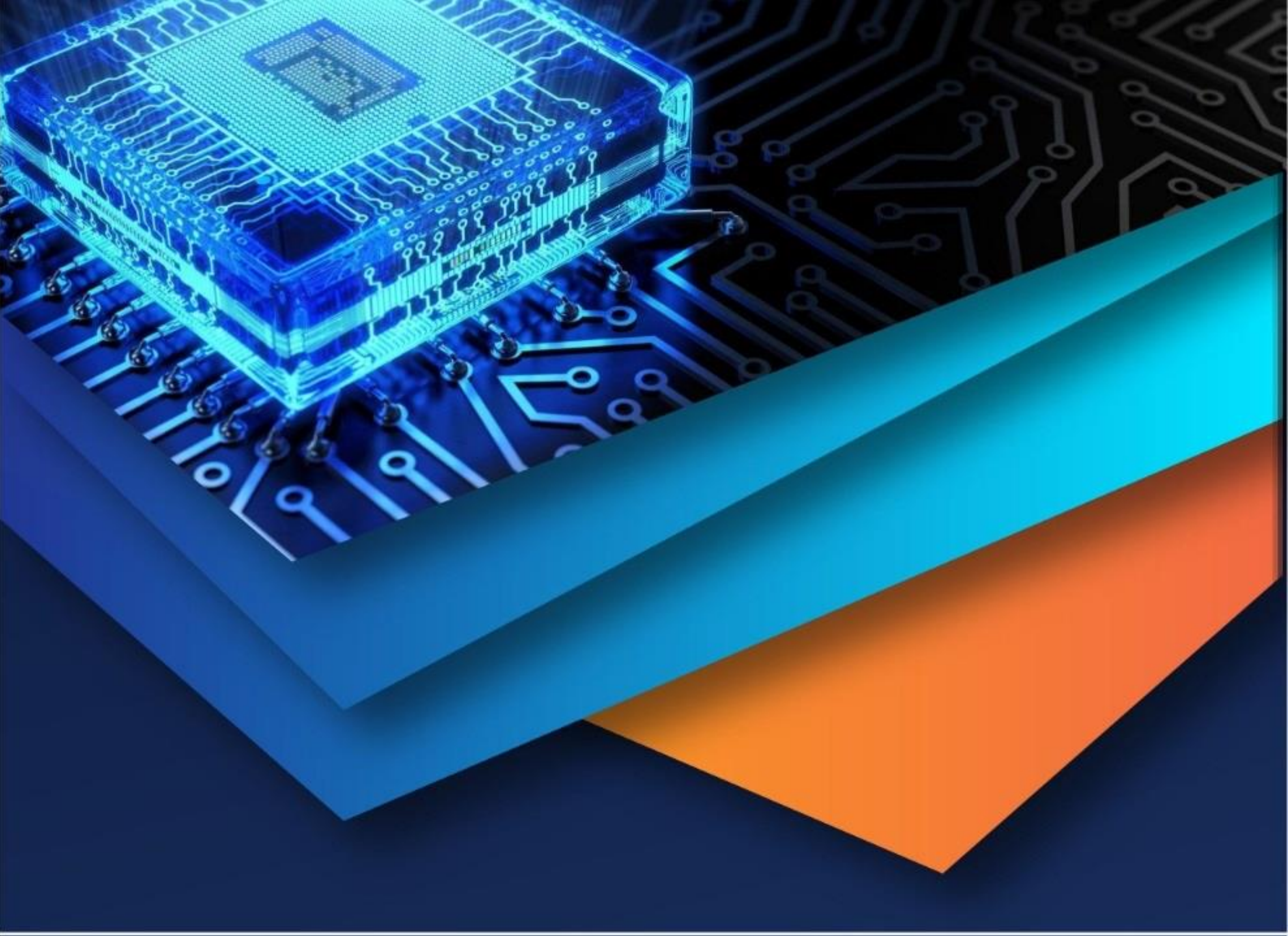

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