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Optimization of Materials EN31, SAE8620 and EN9 using Genetic Algorithm

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Abstract: The study presents the influence of various process parameters such as machining force, surface roughness, cutting force, material removal rate for three different steel materials EN31, SAE8620 and EN9. The analysis shows that feed rate directly affects the hardness, nose radius/ depth cut or cutting speed effectively. Surface roughness is affected mostly by the feed rate. Genetic algorithm is used as an optimization approach to optimize for both rough as well as finished material. For machine surface analysis XRD process is performed, which is followed by the SEM analysis. Higher heat is observed while cutting material with high speed. White layer depth is increased as the tool nose radius increases, same effect is observed for larger feed.
Keywords: Hard Turning, Genetic algorithm, ANOVA, EN31, SAE8620 and EN9.

I. INTRODUCTION

Hard turning is a process of machining materials in the hardened state using a single point cutting tool. This was possible with the advent of new cutting tool, which is made up of Cubic Boron Nitride (CBN) and ceramics. Producing a finished product requires a large number of operations, and if certain operations are ignored or replaced by other processes, the output product finishing times can be minimized and productivity increased [1].

Conventional techniques used to hardened materials include rough turning, heat treatment and grinding processes. Through hard turning process, one can eliminates the series of operations required to produce a part, thereby reducing cycle time and thus increasing productivity [2].

A number of researches have been conducted to examine the performance of CBN material. These include, cutting force, tool wear, and surface roughness as a major parameters that must be taken into consideration while applying machining process specifically in hardened state [3]. Among all parameters cutting force is one of the most essential factors that can be used to control machining process. It is the backbone of the machining process by which one can get an idea of necessary power, tool dimension and other tool body. On the other hand, in hard turning, cutting force was affected by enumerate factors like as time of cutting, its condition, and hardness of tool [4].

Taguchi's design of experiments approach provides a simple, an efficient and a systematic approach to the design of experiments to optimize performance quality as well as cost [5]. The experimental results were examined using the Design of Experiments (DOE) technique by the method of Taguchi [6].

Designs and methods such as factorial designs, response surface methods (RSM), and Taguchi methods are now widely used to replace time-consuming and costly one-factor-at-a-time experimental approaches. In this research the comparison of three different materials that are SAE8620, EN9, and EN31 have been considered [7].

II. EXPERIMENTAL STUDY

The research was focused on to studying the influence of different machining variables on the parameters of machine such as force, surface roughness etc.

The factor, which is responsible to influence the factor, is identified using Taguchi and ANOVA methods [8]. The factors that were considered during the experiment were nose radius, depth of cut, cutting speed, feed, radial force, tangential force, feed force, and machining force respectively. The values of these factors were varied by changing the setting of machine used. Three commonly used die steels (i) SAE 8620 (ii) EN 9 and (iii) EN 32 were used as for experiment during the research.

The factors which affect the response parameters (forces and surface roughness) with three levels were identified using cause and effect relationship. The aim of experiment is suchthatallthefactorsusedinpastworkcanbeutilizedinthisexperiment.The various parameters were decided according to machine settings and the availability of materials. There are no interactions between the factors to be studied.

Table 1
Factors and there levels

Factors	Levels		
	Level 1	Level2	Level3
Hardness(HRC)	50	55	60
Material	EN31	SAE8620	EN9
Noseradius(mm)-Depthofcut(mm)	0.4-0.075	0.4-0.15	0.8-0.15
Speed(m/min)	75	110	150
Feed(mm/rev)	0.03	0.06	0.1

The third factor combination of nose radius and depth of cut will decide to help of Taguchi's design. The factors which do not have a direct relationship between them can be combined so combination of nose radius and depth of cut can be made.

Every factor had three levels. The least required degrees of freedom in an experiment is the summation of all the degrees of freedom of various factors. For each factors there are three levels.

III. EXPERIMENTAL SETUP

Taguchi method is used to perform experiment. Some conditions have to be maintained to retain the orthogonality among different factors. In this research five factors were varied for three different levels as shown in Table 1. The degree of freedom calculated for the given experiment was recorded as 2. The task was completed using MINITAB (statistical software) [9], and the experiment were performed on CNC machine. Force components were recorded using dynamometer.

Table 2
Table for machining forces

HardnessHRC	Material	Noseradius - depthof cut(mm)	Cuttingspeedm/min	Feedmm/rev	Radialforce (N)	Tangentialforce(N)	Feedforce (N)	MachiningForce(N)
50	EN 31	0.4-0.075	75	0.03	17.317	8.291	2.327	19.339
50	EN 31	0.4-0.075	75	0.06	23.128	9.8856	2.358	25.262
50	EN 31	0.4-0.075	75	0.1	40	17.1	5.641	43.866
50	SAE8620	0.4-0.15	110	0.03	8.158	6.144	0.362	10.219
50	SAE8620	0.4-0.15	110	0.06	15.623	5.797	0.4409	16.669
50	SAE8620	0.4-0.15	110	0.1	50.367	22.93	5.705	55.634
50	EN9	0.8-0.15	150	0.03	6.649	3.3	1.378	7.549
50	EN9	0.8-0.15	150	0.06	50.294	23.25	4.614	55.599
50	EN9	0.8-0.15	150	0.1	21.65	1	2.172	21.781
55	EN 31	0.4-0.15	150	0.03	18.44	6.573	2.0165	19.680
55	EN 31	0.4-0.15	150	0.06	20.063	10.3279	1.65	22.623
55	EN 31	0.4-0.15	150	0.1	65.966	20.209	12.8	70.170
55	SAE8620	0.8-0.15	75	0.03	54.774	26.531	5.506	61.110
55	SAE8620	0.8-0.15	75	0.06	45.3	20.859	5.93	50.223
55	SAE8620	0.8-0.15	75	0.1	48.806	21.279	2.8375	53.318
55	EN9	0.4-0.075	110	0.03	5.011	3.769	0.8	6.321
55	EN9	0.4-0.075	110	0.06	10.184	5.011	1.6536	11.469
55	EN9	0.4-0.075	110	0.1	20.379	7.4784	2.7625	21.882
60	EN 31	0.8-0.15	110	0.03	20.94	8.5315	2.0746	22.706
60	EN 31	0.8-0.15	110	0.06	54.836	25.392	4.633	60.607
60	EN 31	0.8-0.15	110	0.1	80.23	5.567	9.132	80.939
60	SAE8620	0.4-0.075	150	0.03	25.019	10.383	3.678	27.336
60	SAE8620	0.4-0.075	150	0.06	21.937	5.495	1.4955	22.664
60	SAE8620	0.4-0.075	150	0.1	34.24	15.22	3.058	37.594
60	EN9	0.4-0.15	75	0.03	45.6	23.338	4.5	51.422
60	EN9	0.4-0.15	75	0.06	63.677	28.018	6.56	69.877
60	EN9	0.4-0.15	75	0.1	85.302	38.375	9.454	94.012

Table 3
Analysis of variance for means of Forces

Source	Degree of freedom	Sum of squares	Variance	Fvalue	Significance
Hardness	2	2627.3	1313.66	5.63	Significant
Material	2	58.9	29.46	0.13	Not-Significant
Noseradius-depthof cut	2	2856.1	1428.03	6.12	Significant

Table 4
Response table for means for forces

Level	Hardness	Material	Depthof cut-Noseradius	Cuttingspeed	Feed
1	28.44	40.58	23.97	52.05	25.08
2	35.20	37.20	45.59	31.83	37.22
3	51.91	37.77	45.98	31.67	53.24
Delta	23.47	3.38	22.01	20.38	28.17
Rank	Second	Fifth	Third	Four	First

According to the test conditions listed in Table 2, three work pieces have been prepared for hard turning before the tests were started. SAE 8620 was carburized to a hardness of 50, 55, and 60 HRC and tempered at 250 ° C and 400 ° C to achieve the desired hardness. EN 9 are induced and tempered by the machine itself, holding the part for a while. EN 31 is directly fastened and then tempered. To remove the parts are crushed in a decentralized grinder with a diameter of 26 mm. The shaft was sized as 400 mm, and the diameter of it was measured before and after the turning process. The maintenance plot for force was given in Fig. 1.

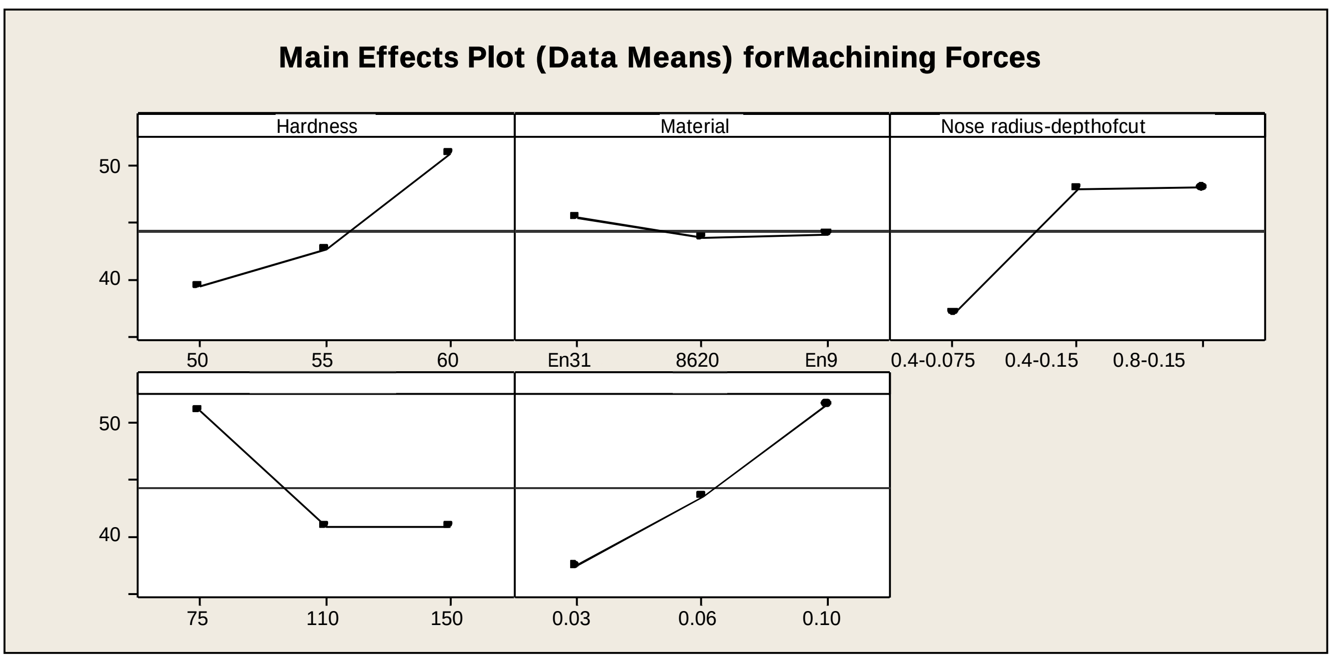

Fig. 1 maintenance plot for force

IV. RESULT AND DISCUSSION

After converting the parts according to the test conditions listed in Table 2, the processing power, surface roughness, and dimensional deviation were measured for each test. The results for these parameters are given in Table 5. The influence of these parameters was analyzed using ANOVA method. On the other hand, the plot of significant factor has also been developed to indicate the significant of factors to show the deviation in response [10]. The response obtained after applying Genetic algorithm as evolutionary approach or an optimization approach was presented in Table

Table 5
Output generated by Genetic Algorithm

S.no	Hardness X(1)	Speed X(2)	FeedX (3)	MaterialX(4)	NoseRadius-depthofcut X(5)	surface finishz(1)	Dimensional DeviationZ(3)	MachiningForces Z(4)	Materialremovalrate Z(2)
1	60	147	0.03	EN31	0.4-0.075	0.22	10.67	17.63	396
2	53	106	0.03	SAE8620	0.4-0.075	0.41	11.02	13.22	149
3	53	110	0.03	SAE8620	0.4-0.075	0.42	10.73	11.91	203
4	54	115	0.04	SAE8620	0.4-0.075	0.43	10.65	14.90	304
5	60	150	0.05	EN31	0.8-0.15	0.44	6.77	46.57	1226
6	51	133	0.04	SAE8620	0.4-0.075	0.5	9.81	3.44	441
7	50	139	0.03	SAE8620	0.4-0.075	0.51	9.49	-0.87	487
8	50	146	0.03	SAE8620	0.4-0.075	0.53	9.27	-4.09	537
9	50	148	0.03	SAE8620	0.4-0.075	0.53	9.19	-5.61	541
10	50	147	0.04	SAE8620	0.4-0.075	0.55	9.05	-3.16	607
11	50	142	0.04	SAE8620	0.4-0.075	0.59	9.26	-0.59	611
12	50	144	0.04	SAE8620	0.4-0.075	0.59	9.22	-1.89	617
13	60	150	0.07	EN31	0.8-0.15	0.61	6.43	56.49	1571
14	53	122	0.05	SAE8620	0.4-0.075	0.61	9.50	19.99	670
15	52	124	0.06	SAE8620	0.4-0.075	0.65	9.48	17.96	689
16	51	138	0.05	SAE8620	0.4-0.075	0.66	8.56	8.80	753
17	51	137	0.05	SAE8620	0.4-0.075	0.67	8.59	9.60	765
18	50	150	0.04	EN9	0.4-0.075	0.71	8.34	-5.61	613
19	50	143	0.05	SAE8620	0.4-0.075	0.72	7.95	9.67	908
20	52	115	0.07	EN9	0.4-0.15	0.85	8.03	30.62	965
21	53	112	0.07	SAE8620	0.4-0.15	0.86	7.93	36.45	1016
22	54	125	0.08	SAE8620	0.8-0.15	0.88	6.72	45.61	1377
23	53	109	0.07	SAE8620	0.4-0.15	0.89	7.63	38.49	1019
24	52	106	0.08	SAE8620	0.4-0.15	0.89	8.00	38.51	1031
25	54	118	0.08	SAE8620	0.8-0.15	0.90	6.44	49.90	1369
26	54	121	0.08	SAE8620	0.4-0.15	0.91	7.29	41.24	1253
27	55	125	0.10	SAE8620	0.8-0.15	0.95	6.50	56.83	1634
28	53	127	0.08	EN9	0.4-0.15	0.96	6.67	38.81	1348

29	52	137	0.08	EN9	0.8-0.15	0.97	5.62	34.96	1444
30	54	140	0.10	SAE8620	0.8-0.15	0.99	5.45	53.59	1829
31	53	125	0.09	SAE8620	0.8-0.15	1.00	6.20	49.53	1572
32	54	141	0.10	SAE8620	0.8-0.15	1.02	5.25	51.90	1851
33	53	118	0.09	EN9	0.4-0.15	1.04	6.36	48.74	1465
34	51	146	0.08	EN9	0.8-0.15	1.06	4.71	37.15	1693
35	51	138	0.1	EN9	0.8-0.15	1.13	5.30	42.02	1733
36	51	138	0.1	EN9	0.8-0.15	1.13	5.29	42.11	1735
37	50	150	0.1	EN9	0.4-0.075	1.16	6.97	22.14	1544
38	51	138	0.1	EN9	0.8-0.15	1.16	5.22	43.67	1790
39	51	148	0.1	EN9	0.8-0.15	1.19	4.24	43.49	1962
40	50	150	0.1	EN9	0.8-0.15	1.20	4.96	34.58	1850
41	50	150	0.1	EN9	0.8-0.15	1.22	4.40	38.04	1935
42	50	150	0.1	EN9	0.8-0.15	1.22	4.22	39.12	1962

Using the genetic algorithm approach, 42 solutions were obtained and 6 best solutions were selected from this table under the conditions. However, the criteria for choosing the best solution in this table depend on the user. The first six results revealed a surface finishing process. The results obtained were the best, so they can be selected. In addition, after seven experiments, the surface finish began to deteriorate, and the forces obtained were negative, which is not possible. Thus, seven or twelve speeches cannot be accepted. Other optimal combinations depend on the type of demand. If tool wear needs to be minimized, the selected joint may be the one that consumes the least force. If productivity needs to be increased, we can select the optimal condition for a higher material extraction rate. If both forces are minimized, the best quality must be obtained, not that we must choose the first combination. The measurement deviation was less than 10 microns, and this is acceptable in all cases according to the tolerance range for shafts 6.

A. Metallurgical Analysis

In this analysis, a study was performed to understand the phase transitions using XRDmachine. The formation of the white layer was studied using a Leica microscope and SEM was used to find the rotation pattern generated by the ground sample and the hard-rotated sample. The following samples, shown in Table 6.1, were selected for their analysis of etallurgy [11].

To study the surface of hard part turned material three samples were selected at different hardness and different materials. The fourth sample of SAE 8620 on which finish grinding was done using cylindrical grinder. It was observed that feed marks were generated on the surface of hard turned component. A uniform pattern was generated on the surface shown in Fig. 2 - 7.

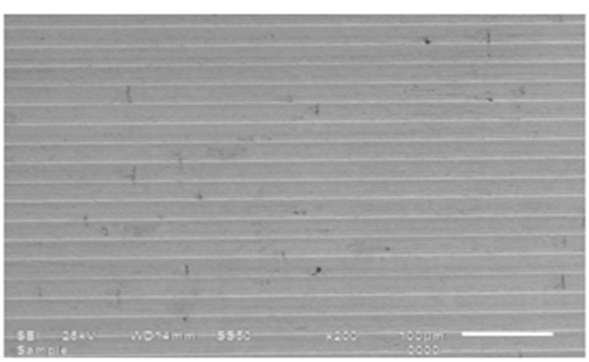

Fig. 2: SEMimageat200 X for sample number34

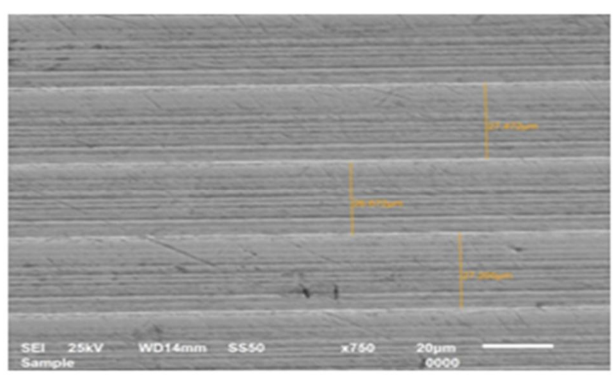

Fig. 3: SEM image at750X for sample number34

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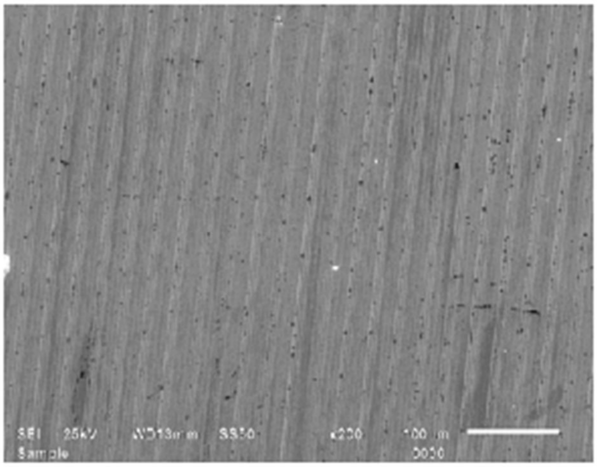

Fig. 4: SEMimageat200 Xforsamplenumber37

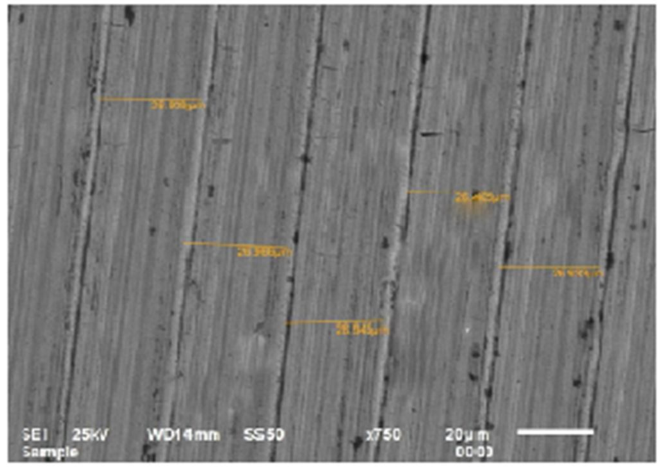

Fig. 5:SEMimageat750 Xforsamplenumber34

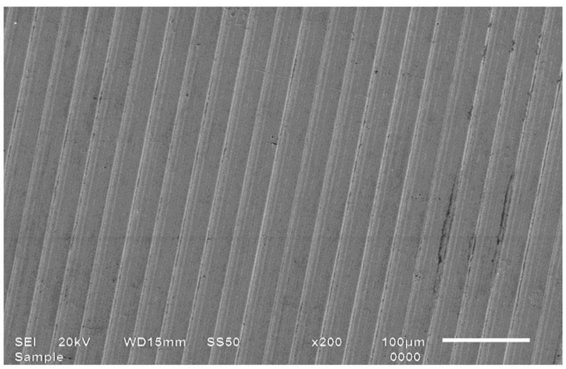

Fig. 6:SEMimageat200Xforsamplenumber47

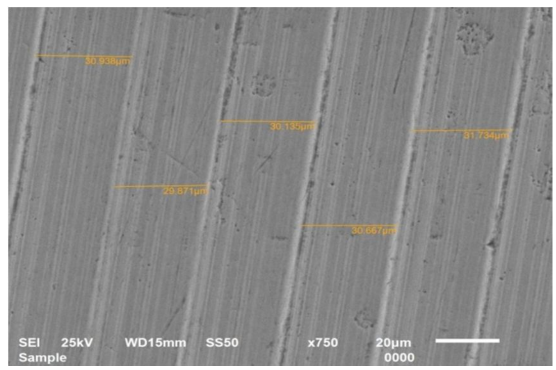

Fig. 7:SEMimageat750Xforsamplenumber47

V. CONCLUSION

In the experiment Taguchi‟s L_{27} design was used to study the effect of various factors like hardness, type of material used, speed of cutting, feed and also the simultaneous effect of factors like nose radius and depth of the cut. From the experiment following results were obtained. It was observed from the dynamometer interpretations that radial force, tangential force were much less than the radial force and the least one was the feed force. At feed rate of 0.03 mm/rev, forces were minimum. With the increment in the feed, the forces also showed an increase. The cutting velocity of 75 m /min it was detected that full force was appliedthere. The working array of ceramic inserts ranges between 100-200/min which shows that the ceramic inserts must be used within the specific given range to get the best results. There was no significant growth in the forces between 110/min to 150/min. The rise in the forces was mainly determined by the hardness of the material. Material type has negligible effect on the forces. Nose radius of 0.8 mm had very minor rise in the forces. Only depth of cut inclined the machining forces. As the depth of cut improved the machining forces got better. X-ray diffraction showed a large variation the phases. The main phase set up obtained in every material after the hard turning process was Chromium. White layer does not get spoiled by engraving. The likely reason for the white layer creation was because of Heat affected zone or owing to slaking. The distance between the two crests was equal to that of the feed value. The compressive nature of the Micro strain that settled in the surface was mainly due to the development of the white layer.

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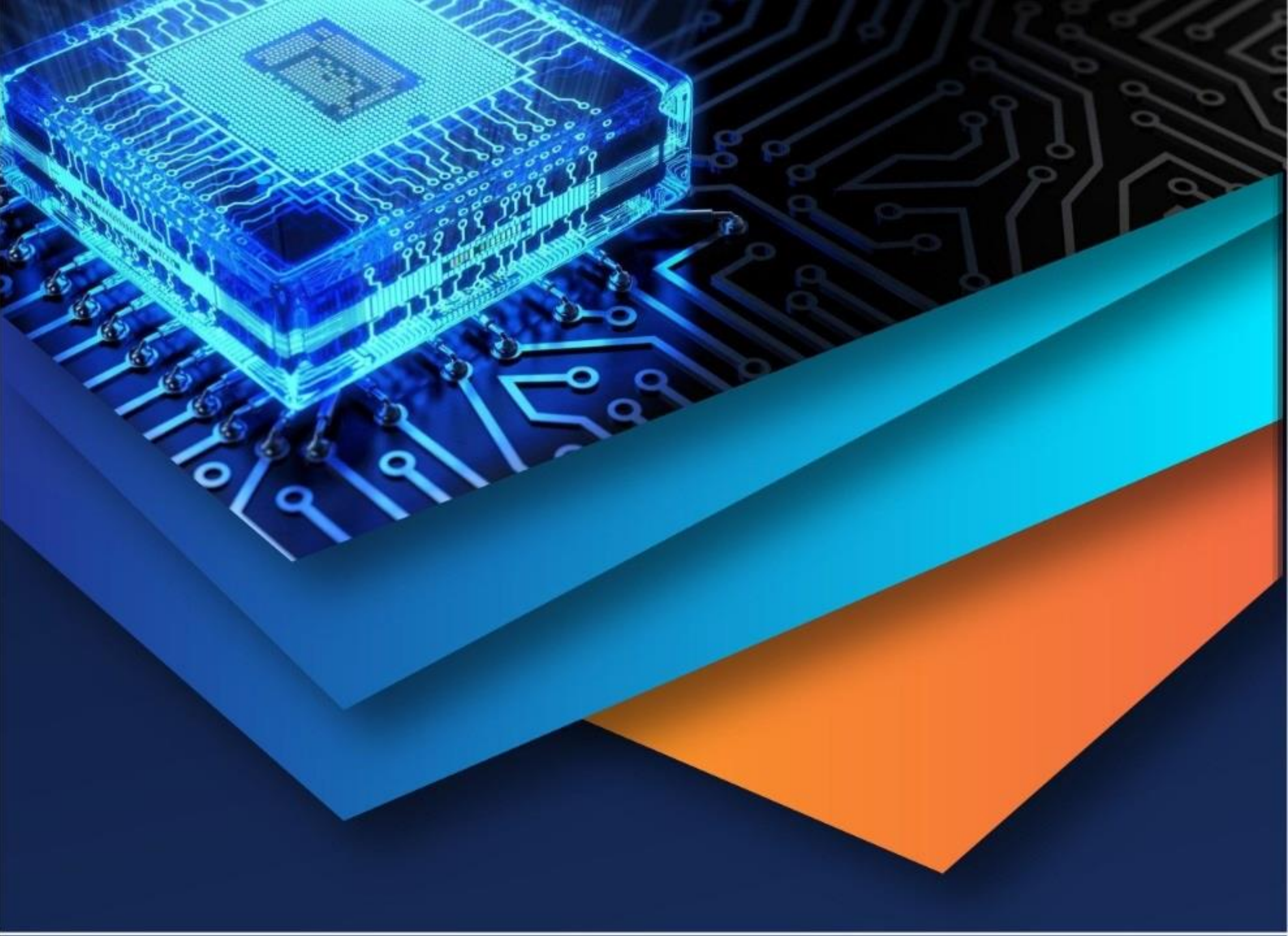

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