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Performance Evaluation of Blended Vegetable Oils as a Cutting Fluid under MQL in Turning

Putta Nageswara Rao[1], Suresh Babu Valeru[2], P. Vasanth Kumar[3], K. N. S Suman[4]
[1]Associate Professor, Mechanical Engineering Department, VVIT, Guntur, Andhra Pradesh, India
[2, 3]Research Scholar, Mechanical Engineering Department, Andhra University, Visakhapatnam, A.P, India
[4]Associate Professor, Department of Mechanical Engineering, Andhra University, Visakhapatnam, A.P, India

Abstract: Cutting fluids has been extensively uses over the years for the higher productivity and making good quality products. But, Cutting fluid related high costs and health problems are associated with exposure to operator and this lead to environmental pollution increasing. Therefore to maintain free pollution environmental sustainability in manufacturing various vegetable oils has been widely use in various machining process as a cutting fluid. Therefore in this work various vegetable oils were selected due to their wide usage. However compared to bare vegetable oils, vegetable based nanofluids are showed better performance due to their enhanced thermo-physical properties but, they are not suitable for economical machining. Hence, in this work the performance of the widely used three blended bare vegetable oils with their different combinations were evaluated under the turning of AISI 304 austenitic stainless steel by using Carbide tool through Minimum quantity lubrication (MQL) technique by the measurements of Surface roughness, maximum generated temperature at specified location and formation chips. All the measured parameters were in agreement, confirming that produces good surface finish, low temperature generated at specified location and better chip formation. It is suggested that considerable cost reduction by using blended vegetable oils as compared to commercial oils.
Keywords: Vegetable oils, Blending, MQL, Machining performance, Turning, Carbide Insert

I. INTRODUCTION

As a lubricant various vegetable oils were used widely in various machining processes from 21st centaury due to their environmental friendliness and good machining response [1-10]. However, many varieties of oils available in nature they were consisting of wide variety of fluid properties [11-12]. Therefore their performance as a cutting fluid in machining varies one over the other [12]. Generally machining performance under cutting fluid is depends on many properties among those properties thermal conductivity and viscosity are plays important role [13].Therefore to obtain required desirable properties many investigators were obtained through the addition of various nanoparticle concentrations in base fluid [14-16]. However those properties were obtained through various nanoparticles are very expensive, this can lead the cutting fluid will become more expensive. [17-18] Therefore many investigators improved the various properties by various methods [19-20] among which the blending of vegetable oil is most influenced and very easy method. Therefore in this work mostly used three oil were selected such as Soybean, Coconut, Sesame and they were blended with equal percentage ratio totally six combinations. The prepared oils were properly mixed with magnetic stirrer. These prepared blend oils performance was evaluated under turning by using MQL.

II. PREPARATION OF BLENDED OILS AND THEIR PROPERTIES

The vegetable oils soybean, coconut and sesame are selected for blending with desirable blending combinations which were prepared by magnetic stirrer with the duration of 10-15 minutes. From prepared samples it is observed that each combination was blended very well. The prepared samples were shown in Fig. 1

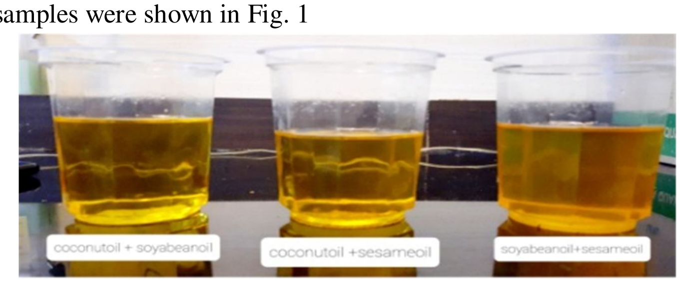

Fig.1 Blended oils with different combinations

After the preparation of blended oils, based on their bare vegetable oil properties. The blended oils properties were calculated by using mixture property rule. Those base oil properties [12] and calculated blended oil properties were tabulated through table I.

Table I
Thermo-Physical Properties Of Blended Vegetable Oils

S. No.	Vegetable Oil	Specific heat (kJ/kg.K) at 40°C	Flash point (°C)	Thermal conductivity at 40°C (W/m.K)	Kinematic viscosity at 40°C (mm^2/s)	Density (g/cm^3)	OS (°C)	TS (°C)
1	Soybean	1.957	254	0.158	29	0.914	274	302
2	Coconut oil	2.201	266	0.154	27	0.918	241	257
3	Sesame	2.131	260	0.145	36	0.918	236	244
4	50%Soybean +50%Coconut	2.079	260	0.156	28	0.916	257.5	279.5
5	50% Sesame +50%Coconut	2.166	263	0.1495	31.5	0.918	238.5	250.5
6	50%Soybean + 50%Sesame	2.044	257	0.1515	32.5	0.916	255	273

III. EXPERIMENTAL CONDITIONS

The performance of prepared blended vegetable oils were evaluated by turning of AISI 304 steel with 100 mm length on a conventional lathe by a standard carbide insert under different machining conditions with MQL.

All these parameters selected as based on Lathe specifications for machining of AISI 304 steel with carbide insert. Which are shown in table II and experimental setup shown in Fig 2.

Table II
Experimental Conditions

Machine tool	:	Conventional Lathe Machine		
Work materials	:	AISI 304 Steel, Diameter 30mm*100mmLength		
Cutting tool	:	Carbide Insert		
Cutting Conditions	:	Speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)
Low	:	350	0.1	0.5
Medium	:	530	0.2	1
High	:	800	0.3	1.5
MQL conditions	:	Nozzle distance -25mm Flow rate:180ml/h Pressure :60kg/cm^2		

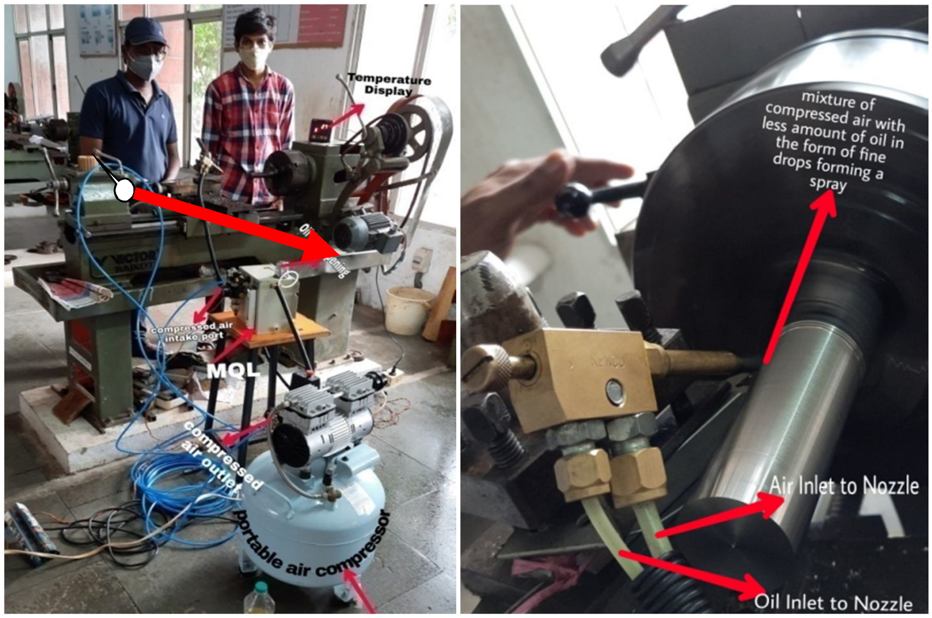

Fig. 2 Machining setup under MQL

During the machining for the measurement of temperature a hole of 1.6 mm diameter is made through the insert holder nearer to the insert rake face (~0.3mm below rake face) it is diagonally 4 mm away from the tip of the tool. In this hole, one end of the K- type thermocouple probe of 1.5 mm diameter is fitted the other is connected temperature digital display unit. The hole was made through the electro discharge machine and thermocouple setup shown in Fig. 3.

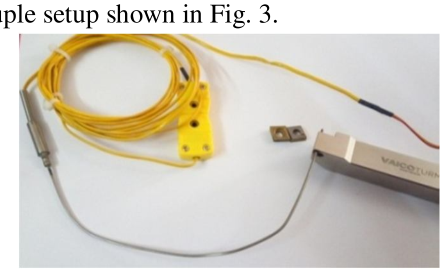

Fig. 3 Thermocouple sensor with tool

After conducting the experiments, machined specimen's surface roughness was measured by a Talysurf using a sampling length of 4 mm with 5 trails and average value is taken and finally the chip morphology studies were carried out under all cutting conditions for the selected combinations of blended vegetable oils.

IV. RESULTS AND DISCUSSIONS

To observe the performance of three blended vegetable oils under different cutting conditions in MQL environment. The obtained results discussed in the following sections.

A. Variation Analysis of Cutting Temperature

Machining with high speed, feed rate and depth of cut inherently generate more amount of heat as well as high cutting zone temperature. The magnitude of this cutting temperature increases, though in different degree, with the increase of speed, feed rate and depth of cut, as a result, production levels is constrained by rise in temperature. In the present work maximum temperature generated during machining at 4mm away of tool tip was measured under MQL with the help of thermocouple sensor.

In this work, a tool-work thermocouple with proper calibration was used to determine the maximum generated temperature at 4 mm away of tool tip during turning of AISI 304 steel at various cutting conditions. The obtain results were tabulated in table 3 with digital photographs and the results are plotted against different cutting conditions in MQL for the three blended vegetable oils as shown in Fig. 4.

Table III
Generated Maximum Temperature (0C) from 4 MM Away of Tool Tip for Blended Vegetable Oils

S.No.	Cutting conditions	Digital Photographs of Generated Temperature at 4mm away from the Tool tip along the rake face diagonal (^{0}C)		
		50% Sesame + 50% Coconut	50%Soybean + 50%Coconut	50%Soybean + 50%Sesame
1	Low			
2	Medium			
3	High			

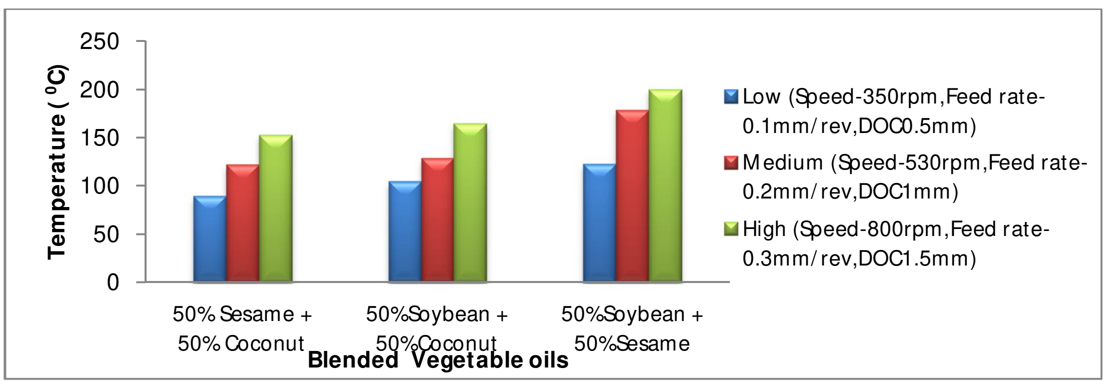

Fig. 4 Generated maximum temperature (^{0}C) from 4 mm away of tool tip VS under different Speeds (rpm) and Depth of cuts

The maximum generated temperature at 4 mm away from the tool tip along the rake face is evaluated at different cutting conditions for three blended vegetable oils under MQL. The Fig. 4 clearly shows that the maximum generated temperature for 50% Sesame + 50% Coconut blend is very less as compared to blends of 50%Soybean + 50%Coconut and 50%Soybean + 50%Sesame for all the selected cutting conditions. With the increase in cutting conditions, maximum generated temperature has been increased as usual, due to increase in energy input generated temperature increases with the increase in specific energy consumption and material removal rate i.e. with the increase of cutting speed, feed rate and depth of cuts. The maximum generated temperature at specified distance i.e. 4mm away from the tool tip for the blend 50% Sesame + 50% Coconut is found to be very less and at Low cutting condition is 16.6%, 36.6%, at medium cutting condition is 5.7%, 46.7% and at high cutting condition is 7.8%, 30.7% as compared to 50%Soybean + 50%Coconut and 50%Soybean + 50%Sesame blends respectively. This is due to impinging of fine droplets of mist into the region of chip-tool interface which dissipates the heat effectively and it provides better lubrication between chip –tool interface in turn avoids formation of Build up edge even at higher cutting conditions for the blend of 50% Sesame + 50% Coconut.

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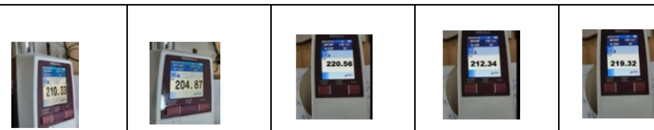
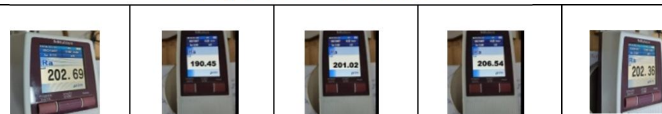
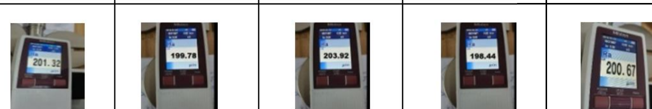
B. Variation Analysis of Surface Roughness

Surface roughness is a widely used index of product quality and in most cases a technical requirement for mechanical products. In this work after machining surface roughness has been measured by a Talysurf, taking the average of 5 Trails for each workpiece as shown in table IV. Variation of surface roughness at different Cutting conditions (Low, Medium and High) has been plotted shown in Fig. 5.

Table IV. Surface Roughness Of Blended Vegetable Oils

S.No	Cutting conditions	Surface Roughness Trail-1 (μIn.)	Trail-2 (μIn.)	Trail-3 (μIn.)	Trail-4 (μIn.)	Trail-5 (μIn.)	Average R_A (μm)
50% Sesame +50% Coconut							
1	Low						5.4224936
2	Medium						5.1609752
3	High						4.2784268
50%Soybean + 50%Coconut							
4	Low						5.0955448
5	Medium						5.3622448
6	High						5.2571396
50%Soybean + 50%Sesame							
7	Low						5.2576476
8	Medium						5.5051452
9	High						5.1009804

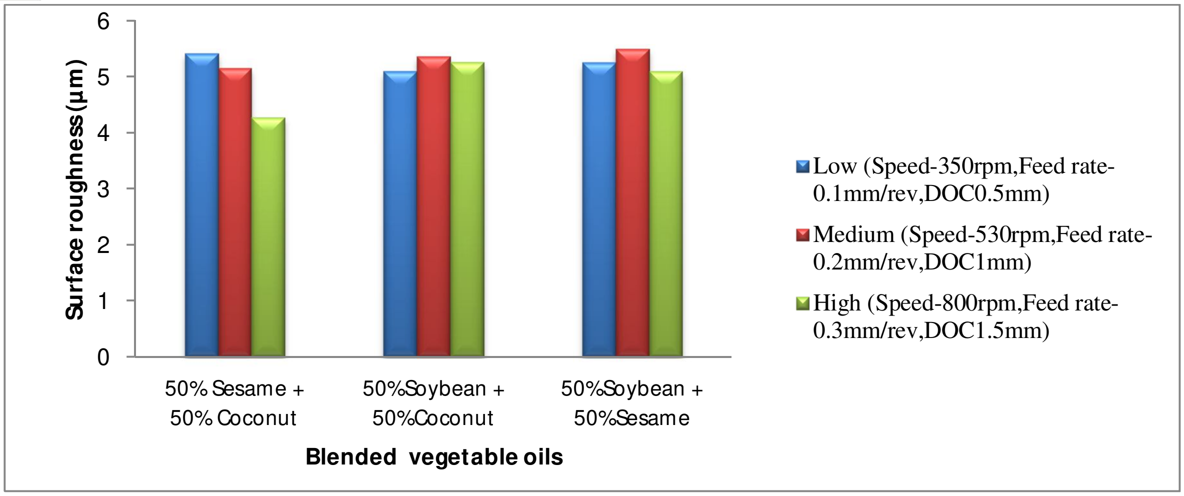


Fig.5 Surface roughness of blended vegetable oils

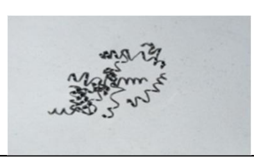
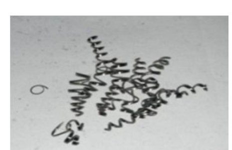
Variation of surface roughness at different cutting conditions (Low, Medium and High) has been plotted shown in Fig. 6. it was observed that the blend of 50% Sesame + 50% coconut is having less surface finish compared to other blend combinations for all cutting conditions due to the increase in the Conventional heat transfer which inturn causes reduction in friction between chip and tool interface. However it is also attributed to mainly the reduction of friction accomplished by the lubricating effect of the MQL jet. The MQL jet with its velocity was able to reach the tool tip where it performed its lubricating and cooling effects and minimized friction to a remarkable amount. As cutting speed and depth of cut increases the surface finish is decreased as usual trend is followed for the blend 50% Sesame + 50% Coconut [21]. It is also observed that at higher cutting condition as the machining process continues, the sprayed cutting fluid on workpiece forms a thin layer which reduces further rise of temperature causing good surface finish. This improvement might be due to reduction in wear and also due to the fact of prevention of built-up-edge formation.

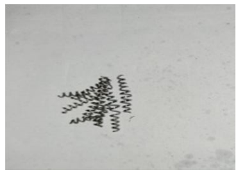
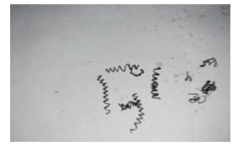
C. *Chip formation analysis*

From the table V it was observed that chips produced for the blend 50% Sesame + 50% Coconut oil at low cutting condition is very long ribbon coiled chips (continuous chips) due to continuous plastic deformation and it was observed inside part of the chip shows steps due to intermittent slip and outside is smooth, where as for medium cutting condition shorter coiled chips are formed for higher cutting conditions Serrated Chips (semi-continuous) are generated which posses a saw tooth profile due to the alternating high shear strain followed by a low shear strain. It is clearly observed that effectiveness of MQL is suitable for the blend of 50% Sesame + 50% Coconut oil.

The chip formation for other blends is unfavorable at medium and high cutting conditions as shown in the table V. Which are similar to dry cutting condition due to the fact that these two blends are having less heat carrying capacity as compared to the blend 50% Sesame + 50% Coconut oil.

Table V
CHIP FORMATION UNDER DIFFERENT CUTTING CONDITIONS AND BLENDED VEGETABLE OILS

S.No.	Cutting conditions	Digital Photographs of Chips		
		50% Sesame + 50% Coconut	50%Soybean + 50%Coconut	50%Soybean + 50%Sesame
1	Low			

2	Medium			
3	High			

V. CONCLUSIONS

In this work the effect of blending of selected vegetable oils for each 50% composition under minimum quantity lubrication on machining performance in turning of AISI 304 steel is investigated in terms of maximum generated temperature, surface finish and chip morphology has been examined at low, medium and high cutting conditions.

A. The maximum generated temperature at specified distance i.e. 4mm away from the tool tip for the blend 50% Sesame + 50% Coconut is found to be very less and for Low cutting condition is 16.6% , 36.6%, for medium is 5.7% , 46.7% and for high is 7.8% , 30.7% as compared to 50%Soybean + 50%Coconut and 50%Soybean + 50%Sesame blends respectively.

B. It was observed that for the blend of 50% Sesame + 50% Coconut is having good surface finish as compared to other blend combinations for all cutting conditions due to the increase in the Conventional heat transfer.

C. chips produced for the blend 50% Sesame + 50% Coconut oil at low cutting condition is very long ribbon coiled chips (continuous chips) where as for medium higher cutting conditions favorable Chips are produced

D. MQL provided proper lubrication that minimizes the friction resulting in retention of tool sharpness for a longer period which leads lower surface roughness values were obtained.

E. The blends 50%Soybean + 50%Coconut and 50%Soybean + 50%Sesame are not effective under MQL condition may be due to the 50% composition or poor thermo-physical properties

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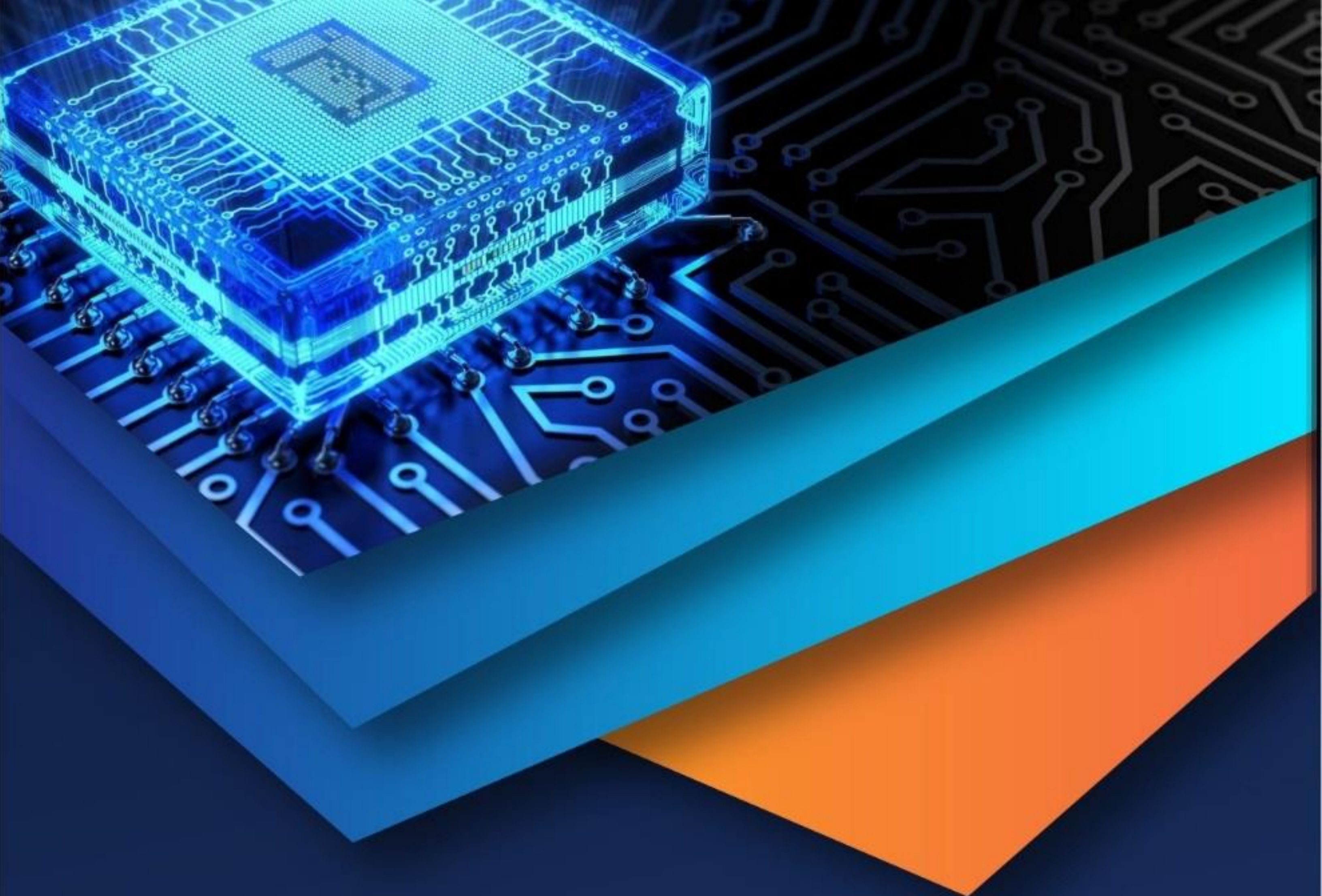

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