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Experimental Analysis of Abrasive Diamond Tool Wear and their Cutting Force in Stone Machining Process

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Abstract: Stone machining with a diamond tool is a common procedure for producing both standard items and design shapes, such as tiles, slabs and so on. During the entire deep sawing process of a granite work piece with finite length cutting procedure in stone processing, force components acted on the saw-blade. The work is split into two parts: theoretical and practical. The theoretical section discusses the features of diamond blades, cutting process methodology, and stone mining and processing methods. The practical portion of the project focuses on the wear of diamond blades when cutting stone, notably granite. The overall weight of the cutting blade and the loss of tooth height as a function of time are used to determine blade wear for two cutting blades from different manufacturers. There is a linear relationship between the two measured values. The findings serve as the foundation for a cost-benefit analysis of both diamond wheels.
Keywords: Abrasive diamond tool, Stone machining, diamond tools, cutting thickness.

I. INTRODUCTION

Natural stone is perhaps the most ancient substance that our ancestors employed in prehistoric times. It was used not just as a building material, but as a foundation for making tools. Natural stone was used to make weapons, our forefathers ignited fires by cutting a hard stone for a flint, and the early foundations of culture were written or painted on stone. Natural stone, on the other hand, has a strong role today, when steel is the primary construction material and polymers are pushed ahead. It is still sought after in the building industry due to its hardness and endurance.

Natural stone's high hardness, on the other hand, places greater demands on machine tool qualities. As a result, diamond cutting discs are employed in the cutting process. Smaller blades are utilized for residential and hand-held grinding machines, whereas larger blades are used for formatting or block saws on an industrial level.

The work's practical aspect is the wear of diamond cutting tools when cutting natural stone. The goal of the practical component is to compare the wear rates of two different manufacturers' cutting discs when cutting so-called granite (granite) on a formatting saw. The wear of the discs is determined by two monitored criteria: the weight of the disc's dependence on time and the height of the segments' dependence on time.

II. LITERATURE REVIEW

1) Konstanty, (1991) [1] in the stone and building industries, diamond tools are indispensable. These sectors, like the diamond tool industry, have expanded as a result of significant advancements in abrasive materials, tool production, and joining techniques. The stone and building sectors have seen significant increases in productivity and cost reductions as a result of these and other reasons.
2) Pai et al (1988) [2] As a result, diamond tools have proven to be viable and practical alternatives to traditional tooling methods. Circular sawing is also one of the most efficient, versatile, and widely utilized ways for processing rock and other hard materials like concrete and asphalt.
3) Asche et al [3] presented their paper showed the empirical results of the influence of process parameters on tool wear.
4) Tonshoff et al [4] devised a model for stone cutting with disk-like diamond tools that is extensively utilized, despite the fact that it has not been thoroughly tested.
5) Di Ilio et al [5] presented their paper showed an analytical model for predicting maximal grain and matrix wear rates, as well as proof of the wear mechanism.

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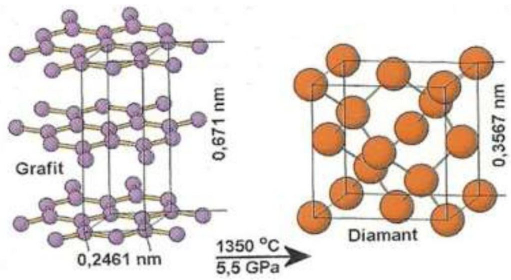
III. CHARACTERISTICS OF A DIAMOND

Diamond is often regarded as the hardest natural substance, with a melting temperature greater than 4,000° C, a high refractive index, and the ability to conduct heat but not electricity. The name "diamond" refers to a type of carbon that has been organized in a cubic lattice. There are several other allotropic carbon are described. Graphite and man-made fullerene are the most well-known of them [3]. Due to its look, the diamond is a one-of-a-kind jewellery material. However, diamond will be treated in this research largely as an industrial substance exploited for its distinctive physical qualities, particularly its extreme hardness. Natural diamond fragments, which are worthless in jewellery, are used in the business (about 80% of all natural diamonds found) (cut diamond dust, unsightly diamonds, etc.). For industrial diamond production, synthetically generated diamond (PKD abbreviation: - polycrystalline) is extremely important [3].The exposure of graphite to high temperature and pressure (Fig. 2) in the presence of a catalyst, which speeds up the reaction and allows carbon to crystallize to form diamond even at lower temperatures and pressures than in natural conditions [3], is the basis for the production of synthetic diamond.

Fig 1: Change of hexagonal lattice (graphite) to cubic lattice (diamond).



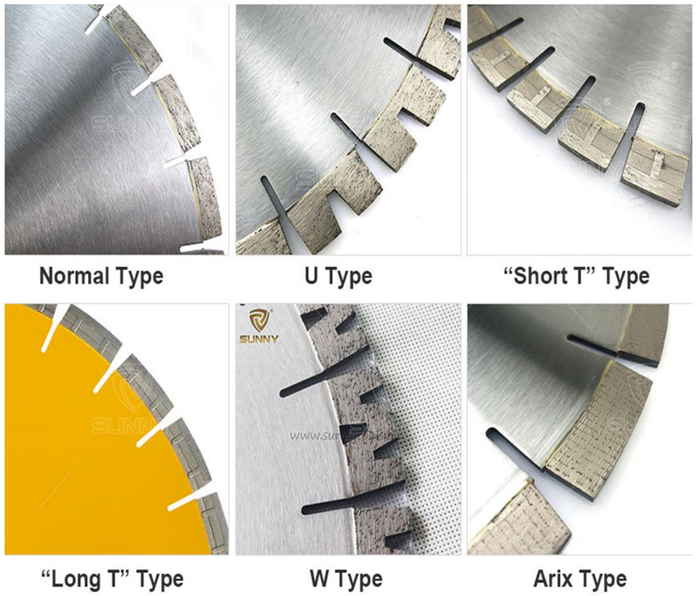
Because of its low thermal stability, diamond cannot be utilized to machine ferrous materials. When machining ferrous materials, high tool heating is attained, and the diamond begins to transition to the form of graphite at a temperature of 650 ° C, resulting in rapid diamond crystal diffusion between the wheel and the material to be cut. Above all, the great hardness of polycrystalline diamond is a mechanical quality that is desirable in certain applications. The Mohs hardness scale, shown in tab, describes the hardness of minerals [3].

A. Diamond Cutting Discs

Cutting discs made of diamonds Diamond cutting discs are popular because of their speed, versatility, cost-effectiveness, ease of use, and great precision. The discs are made up of (see Fig. 4). The diamond segment and the steel core are the two major components. The diamond segment is made up of very small diamond crystals (150-1000 m) scattered in a binder, most commonly metal, but occasionally resin or ceramic matrix. The segments are soldered, laser-welded, or sintered to the body and are always broader than their carrier, reducing frictional

Fig 2: Figure Shows Value at Mohs Graduated

Fig 3: Different Segment Types of Granite Cutting Blade



Mineral	Value at Mohs Graduated	Observed behavior of minerals:
Talc	1	The groove in it is stimulated by a light push of the nail
Gypsum	2	The groove in it is stimulated by a strong push of the nail
Calcite	3	The groove in it is stimulated by pushing a copper coin
Fluorite	4	The groove in it is stimulated by a light push of a knife
Apatite	5	The groove in it is stimulated by a strong push of a knife
Orthoclass	6	Strong push to ignite the groove in the glass
Silica	7	Light push to ignite the groove in the glass Very
Topaz	8	light push to ignite the groove in the glass
Corundum	9	It can be used to cut glass. It is
Diamond	10	Commonly used for cutting glass

B. Production Of Diamond Cutting Discs

The diamond wheel is manufactured in three phases. To begin, a steel core/carrier is created. Diamond segments are typically made individually and then fastened to the steel core using one of the procedures [8].

The fabrication of steel bodies is the initial step in the production of diamond cutting discs. Steel cores come in a variety of steel kinds, depending on whether the segments are soldered, laser baked, or sintered to the core. The steels used to make cores have been hardened and tempered. The clamping hole in the disc's centre is sharpened to ensure optimum roundness while maintaining exceptionally tight tolerances. Special grinders can grind the wheel with an accuracy of 0.01 mm, allowing the thickness of the wheel core to be changed [2].

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The segments are made up of free or ceramic-bound crystals ranging in size from 150 to 1000 m. (Fig. 7). Binder A diamond with a small diameter that has disintegrated into a metallic resin is made up of very fine dust particles (0.5 to 2 m). Cobalt, copper, nickel, and iron are common elements used to make metal binders. With the help of "shakers," the mixture is fully stirred, ensuring the free dispersion of diamond particles in the binder. A solid section is created from the mixture using laser sintering or another sintering method [2].
The final step in the fabrication of diamond blades is to join the section to the blade's steel core. The following methods [8] are used to connect the section to the steel core (Fig. 8):

1) *Soldering:* The process operates on the idea of melting solder between the steel core and the segment at a temperature of 600 to 800 ° C. Because high temperatures aren't necessary to melt the solder, this technique of connection isn't employed with manual grinders, where the wheel may heat up to a greater temperature. Soldering is mostly utilized in quarries for large-diameter saws that are cooled by water. On big diameter discs, there are a lot of segments, but the heat load isn't as high [8].
2) *Laser:* Laser technology works by melting a thin layer of steel core and segment and then embedding them. As a result, the segment is immediately imbedded in the steel core, and its attachment is not affected by temperature fluctuations as it is with soldering. As a result, the cut material does not need to be cooled with water. The drawback is that portion of the cutting segment is required for the connection during attachment and the blade thus loses part of its cutting edge that could otherwise be used for cutting, resulting in increased blade production costs [8].
3) *Sintering:* As previously indicated, sintering is accomplished by producing a segment that may then be soldered to the core. Sintering, on the other hand, can serve as the connection's function. The fabrication of a steel core with microscopic teeth cut around its circumference is the essence of this technology for connecting the segment to the core. After that, the steel core is placed in a mould, and the sintering reaction mixture is injected into the mould at the suitable spots (teeth in the core). After that, the mould is closed and a junction is created using high-pressure pressing. The link is not affected by extreme temperatures [8].

IV. EXPERIMENTAL SETUP

The loss of solid material caused by the relative movement of the blade and the material being cut when they come into contact is referred to as wear. Diamond cutting disc wear is influenced by a number of elements, the most important of which are the diamond blade type, the saw's operating settings, and the characteristics of the material to be cut. Abrasive wear, or mechanical loss of the cutting segment owing to the diffusion of diamond crystals on the material being cut, is the most prevalent type of wheel wear. depicts a detailed view of a worn and unworn diamond wheel segment Figure 1.

Fig 5: On the left is a worn diamond tool element, on the right not worn

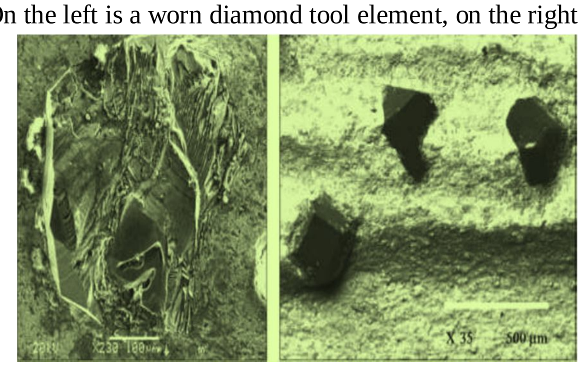

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Fig 6: Figure shows the testing on granite

Blade wear is a fundamental determinant of its life and influences the cutting method chosen for a certain type of rock. Significant cost savings in the cutting process can be gained by selecting the proper blade. Cutting conditions must always be adjusted to prevent excessive sludge thickening in the cut, which leads to rapid die wear and, as a result, premature blade wear.

V. RESULTS AND DISCUSSION

"When cutting with a diamond blade, the goal is to find the right balance of feed rate, circumferential speed, and cut depth. An appropriate rotation of the total cutting force is obtained with the correct setup of the cutting conditions. Large vibrations occur when the direction of the total force applied on the disc deviates too far from its geometric centre (the disk's stiffest point), resulting in rapid wear".

The cutting force's rotation is also determined by whether the cutting is done in a sequential or non-sequential manner. The difference in the total force's rotation can be seen in, where the angle represents the total force's angle of deviation. The angle of departure of the total force from the vertical axis is clear from, where the angle is the angle of deviation of the total force from the vertical axis. The figure clearly shows that non-consecutive cutting causes larger vibrations and thus lower system stability.

Fig 7: Figure shows the cutting operation of marble stone with two different diamond tool blades with same segments.

Tab. 2 Operating parameters and parameters of the discs used.

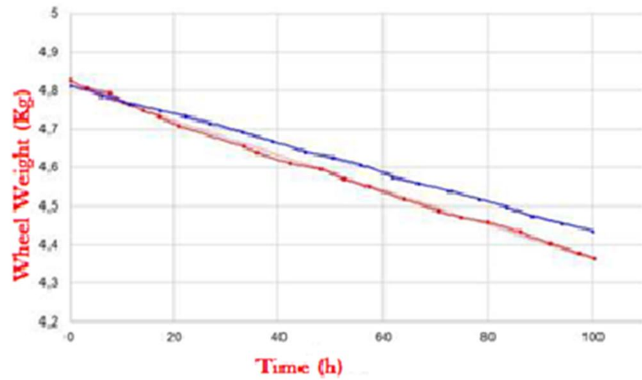
	Size	Value	Note
Cutting conditions	Speed feed	3.2	--
	Perimeter speed	37.96	$V_p = \pi$ d n/60
	Depth cut	8	--
Complementary parameters Cutting conditions	Speed	1450	n = 24.17[1/width]
	Angular speed	151,844	$\omega = 2 \cdot \pi \cdot n$
Parameters of disc	Diameter wheels	500	Both discs
	Number of teeth	60	Both discs
	Width segments	3.8	Both discs
	Measured initial mass wheels	4,827 4,814	DISC-I DISC-II
	Measured initial height segments	4,827 19,581	DISC-I DISC-II

At the start of each measurement cycle, the machine saw was halted and its operational time was deducted. The disc was withdrawn from the spindle once it had completed its rotation, and the height of the teeth and the total weight of the disc were measured. The wheel was adequately dried to the value in order to reduce the weight measuring error.

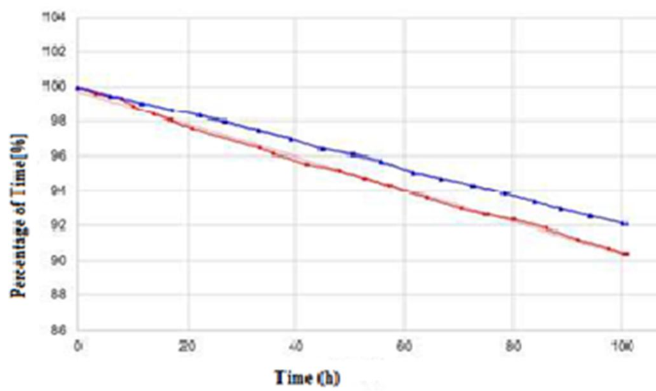
Due to clinging water drops on the cutting disc, the weight was not skewed. Because of the amount of solder utilized in the tooth root, the height of the teeth varied slightly for each individual tooth. As a result, the height was always measured every 5 to 10 teeth at various positions around the circle of the disc, and an average value was determined.

Fig 9: Example of tooth height measurement.

After determining the time, weight, and height of the teeth, the blade was reinstalled on the spindle, and the saw was turned on for the next cutting interval.

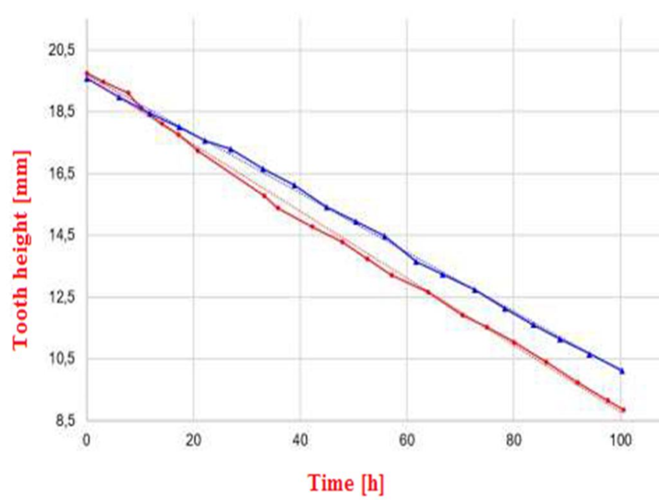


Graph 1: Dependence of wheel weight on time.



Graph 2: Dependence of wheel weight expressed as a percentage of time

Both discs' graphs demonstrate linear dependencies. This demonstrates that diamond particles are distributed evenly across the segments of both discs. Individual weight measurement variations correspond to individual tooth height measurement deviations. Losses are used to express the total quantities of ground segment components, as shown in the table. The losses were calculated using the tables of measured data that are included.



Graph 3: Dependence of tooth height on time.

Tab. 4 Losses of weight and height of teeth for the total monitoring time of the discs

	Tool Disc-I	Tool Disc-II
Cutting time [h]	100	100
Total weight loss wheels [kg]	0.463	0.379
Total weight loss discs expressed In percent [%]	9.59	7.87
Total height loss teeth [mm]	10.87	9,456
Total height loss teeth expressed In percent [%]	55	48

VI. CONCLUSION

Cutting tools with diamonds are required for cutting natural stone, the features of which are also detailed in the theoretical section of this work. Diamond circular saws should be detailed if possible. In addition, the work includes a full kinematic description and analysis of the force between the work piece and the diamond blade throughout the cutting process, as well as the effects of cutting parameters on wheel wear.

The practical section examines the wear of the diamond segment when cutting granite with a circular saw, with the goal of comparing the wear of two cutting discs from different manufacturers. Throughout the experiment, the same cutting circumstances (depth of cut, circumferential speed, and feed rate) were used as in the company's typical operations. The weight loss of the diamond wheel and the height of the diamond segments as function of granite cutting time were used to determine wear.

The practical part's output is to estimate the linear relationship between diamond segment loss and cutting time. The wear lines for the two discs have different guidelines values, indicating that the disc from the manufacturer diamond tool has a higher wear rate.

REFERNCES

[1] Grote, Karl-Heinrich; Antonsson, Erik K.Springer handbook of mechanical engineering. Springer Science & Business Media, 2009.
[2] Campbell, James Wilbert, et al. Sintering process for diamond and diamond growth. U.S. Patent No. 6,270,548, 2001.
[3] Jerro HD, Pamg SS, Yang C, Mirshams RA (1999) Kinematics analysis of the chipping process using the circular diamond saw blade. Transactions of ASME: Journal of Manufacturing Science and Engineering 121:257–264.
[4] KONSTANTY, Janusz. Theoretical analysis of stone sawing with diamonds. Journal of materials processing technology, 2002, 123.1: 146-154.
[5] Ersoy A, Buyuksagic S, Atici U (2005) Wear characteristics of circular diamond saws in the cutting of different hard abrasive rocks. Wear 258:1422–1436
[6] Hwang TW, Malkin S (1999) Grinding mechanisms and energy balance for ceramics. Transactions of the ASME: Journal of Manufacturing Science and Engineering 121:623– 631
[7] Tönshoff HK, Peters J, Inasaki I, Paul T (1992) Modelling and simulation of grinding processes. Annals of the CIRP 41/2:677–688
[8] Chen X, Rowe WB, Allanson DR, Mills B (1999) A grinding power model for selection of dressing and grinding conditions. Transactions of the ASME: Journal of Manufacturing Science and Engineering 121:632–637.
[9] Wang CY, Clausen R (2002) Marble cutting with single point cutting tool and diamond segments. International Journal of Machine Tools & Manufacture 42:1045–1054.
[10] Tönshoff HK, Warnecke G (1982) Research on stone sawing, Advances in Ultrahard Materials Applications Technology, P. Daniel, Hornbeam, ed. England, Vol. 1, pp. 36–29.
[11] Pai DM, Ratterman E, Shaw MC (1989) Grinding swarf. Wear 131:329–339.
[12] X.P. Xu, Y. Li and S. Malkin: Transactions of the ASME: Journal of Manufacturing Science and Engineering Vol. 123 (2001), p.13.
[13] Malkin: Grinding Technology-Theory and Application of Machining with Abrasives (England: Ellis Horwood Limited, 1989).

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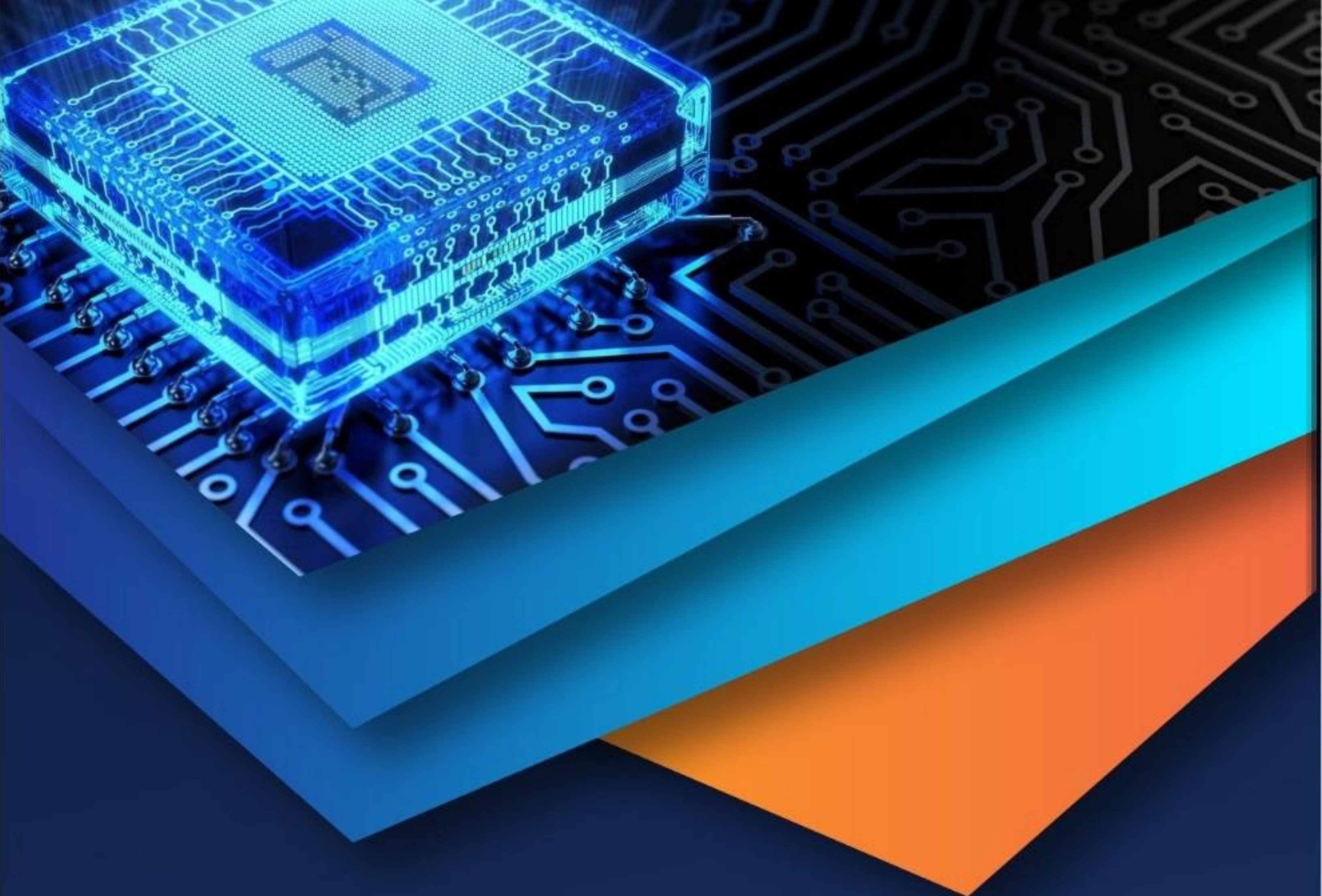

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