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Experimental Investigation to Increase the Efficiency of the Air Compressor by Changing the Coolants in Inter Cooler

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Abstract: The compressed air usage is increasing fastly now days. But the efficiency of compressor is low due to the many reasons like location, elevation, length of pipe lines, inter cooler performance, even atmosphere conditions also effects the efficiency of the compressor, which increases the power consumption of the compressor. The inter cooling is the best method to reduce the coolant. In this study we are extending the investigating by changing the temperature of the water and mixing of the different types of the coolants in water at different proportions. The selection of the coolants is depends upon their properties like miscibility, self ignition temperature, boiling point and exploding range. For this investigation ethylene glycol and glycerol as coolants and a two stage reciprocating air compressor fitted with shell and tube heat exchanger is selected. This investigation shows the good arguments between the water, glycerol and ethylene glycol.
Keywords: Coolants, intercooler, Isothermal efficiency, volumetric efficiency, reciprocating air compressor.

I. INTRODUCTION

Air compressors account for significant amount of electricity used in Indian industries. Air compressors are used in a variety of industries to supply process requirements, to operate pneumatic tools and equipment, and to meet instrumentation needs. Only 10 – 30% of energy reaches the point of end-use, and balance 70 – 90% of energy of the power of the prime mover being converted to unusable heat energy and to a lesser extent lost in form of friction, misuse and noise.

A. For Efficient Operation of Compressor

1) Location Of Compressors: The location of air compressor and the quality of air drawn by the compressors will have a significant influence on the amount of energy consumed. Compressor performance as a breathing machine improves with cool, clean, dry air at intake.

2) Cool Air Intake: As a thumb rule, “Every 4°C rise in inlet air temperature results in a higher energy consumption by 1% to achieve equivalent output”. Hence, cool air intake leads to a more efficient compression.

3*) Dust Free Air Intake:* Dust in the suction air causes excessive wear of moving parts and results in malfunctioning of the vales due to abrasion. Suitable air filters should be provided at the suction side. Air filters should have high dust separation capacity, low-pressure drops and robust design to avoid frequent cleaning and replacement.

4) Dry Air Intake: Atmospheric air always contains some amount of water vapour, depending on the relative humidity, being high in wet weather. The moisture level will also be high if air is drawn from a damp area – for example locating compressor close to cooling tower, or dryer exhaust is to be avoided.
The moisture-carrying capacity of air increases with a rise in temperature and decreases with increase in pressure.

5) Elevation: The altitude of a place has a direct impact on the volumetric efficiency of the compressor. It is evident that compressors located at higher altitudes consume more power to achieve a particular delivery pressure than those at sea level, as the compression ratio is higher.

6) Cooling Water Circuit: Most if the industrial compressors are water-cooled, wherein the heat of compression is removed by circulating cold water to cylinder heads, inter-coolers and after-coolers. The resulting warm water is cooled in a cooling tower and circulated back to compressors. The compressed air system performance depends upon the effectiveness of inter-coolers, after coolers, which in turn are dependent on cooling water flow and temperature.

7) Efficacy Of Inter And After Coolers: Efficacy is an indicator of heat exchange performance-how well intercoolers and after coolers are performing.
Inter-coolers are provided between successive stages of a multi-stage compressor to reduce the work of compression (power requirements) – by reducing the specific volume through cooling the air – apart from moisture separation. The efficiency of a compressor is increased by supplying the different types of coolants mixed with water at different proportions.

B) Experimental Procedure

For this a two stage reciprocating compressor with inter cooler is selected. First we supply the normal water, next 15°C water is supplied, after that glycerol is supplied with different proportions of mixing water is supplied and finally ethylene glycol is supplied with different proportions in water is supplied to the inter cooler and for every coolant the observations are tabulated and calculations are done by using following analytical procedure and results are discussed in results section.

1) Specifications of Compressor:

Type = Two stage double cylinder with external and internal cooler.

Motor = 3 H.P AC motor

Max working pressure = 10kgf/cm^2

Cylinder bore = L.P cylinder = 70 mm dia

H.P cylinder = 50 mm dia

Stroke = 85 mm

Electrical input = 3 phase, 440V , 20A with neutral & earth connections

Torque arm distance R = 0.2 mts

Orfice diameter d=25mm.

II. LITERATURE REVIEW

Liquid piston gas compression concept was proposed by James D. Van de Ven et al was to improve the efficiency of gas compression and expansion. Because a liquid can coform to an irregular chamber volume, the surface area to volume ratio in the gas chamber can be maximized using a liquid piston. This creates near-isotheramal operation, which minimizes energy lost to heat generation. A liquid piston eliminates gas leakage and replaces sliding seal friction with viscous friction. The liquid canalso be used as a mediuim to carry heat into and out of the compression chamber.
B.G.Shivaprasad stated that the heat transfer carried out in reciprocating compressor which was leading to loss of volumetric efficiency. Regenerative heating of the gas in the absence of any heat source, is considered to be one of the primary contributors to suction gas heating. The experiments conducted to measure the cylinder wall heat transfer rate in order to verify earlier imperial models used for prediction, and to assess the capacityloss resulting from regenerative heating. The results from the experiments indicated a significant contribution to capacity loss by suction gas heating.
The measurements were done in a two stage, single cylinder, double acting air compressor running at approximately 900 rpm. The suction pressure was atmospheric and the discharge pressure was 110 psig. Al measurements were mainly confined to head end of the first stage cylinder.
An energy analysis was presented by T. Armaghani et al was based on the first and the second laws of thermodynamics to study in cylinder properties of the air in a typical reciprocating compressorat each crank angle. The simulation used to calculate the pressure

and temperature field existing in realistic compressor chambers for various engine speeds. The results show a good agreement with previous studies where applicable.

Jeng-Min Huang et al studied to examine the flow mixing characteristics subject to slot injection and hole-injection of an intercooler applicable to a two-stage refrigerant compressor. The effect of injected angle and velocity is also investigated. The result indicates that the temperature distribution of a hole-injection is more uniform at a vertically injected arrangement. Larger injection angles generate bigger flow separation zones which results in velocity non-uniformity, whereas smaller injection angles give rise to a less velocity non-uniformity. As the injection velocity rises, both the temperature and velocity non-uniformity of the slot-injection type increase significantly whereas the injection velocity has negligible influence on the relevant uniformity for a hole injection type.
David Kim et al detail and analyse Rutgers' compressed air system, ultimately finding ways for Rutgers to save money by using less energy. To do this first find the factors affect a compressed air system's performance and efficiency.
P. Grolier evaluates the performance of reciprocating compressors. An analyitical formula of the volumetric efficiency was presented. This formula, based on both theoretical and empirical approach, takes account of the most important factors, which occur during the working process of the compressor and the affect the refrigeration performance. An accurate determination of the clearance volume of the compressor and a good knowledge of the temperature of the suction gas in the cylinder are required, to get agood agreement between calculationand experiment.
J. A. McGovern et al presented "an energy method for compressor performance analysis". They had identified and quantify defects in the use of a compressor's shaft power. This information can be used as the basis for compressor design improvements.
The defects are attributed to friction, irreversible heat transfer, fluid throttling, and irreversiable fluid mixing. They are described, on a common basis, as energy destruction rates and their locations are identified. This method can be used with any type of positive displacement compressor.

III. ANALYTICAL METHODOLOGY

$$\text{Volumetric Efficiency} = \eta_{vol} = (V_a/V_s)*100$$

$$\text{H.P. Elect} = \frac{n}{E.M\ constant} * \frac{1000}{736} * \frac{3600}{t}$$

$$\text{Discharge} = Q = 0.62*A*\sqrt{2*9.81*H_a}$$

$$\text{Actual air swep } V_a = \frac{Q*60}{R.P.M\ of\ compressor} m^3/sec$$

$$\text{Actual work done } W = W_{L.P} + W_{H.P}$$

$$W_{L.P} = n/n\text{-}1\{P_1V_1[(P_2/P_1)^{n-1/n}-1]\}\text{joules/cycle}$$

$$W_{H.P} = n/n\text{-}1\{P_2V_2[(P_3/P_1)^{n-1/n}-1]\}\text{ joules/cycle}$$

$$\text{Indicated power (I.P)= actual work done in joules/cycle*N/60}$$

$$\text{Isothermal work}(W_{iso}) = P_1V_1\{\log_e[P_3/P_1]\}\text{ joules/cycle}$$

$$\text{Iso-thermal power = isothermal work in joule *N/60}$$

$$\text{Iso-thermal efficiency}(\eta_{iso\text{-}thermal}) = \text{(isothermal power/indicated power)*100}$$

TABLE 1
OBSERVATION TABLE FOR 40% ETHYLENE GLYCOL WITH 60% WATER

s.no	Pressure after first stage P_1	Pressure after second stage P_2	Energy meter reading		R.P.M of compressor N	Temperature			
			No.of rev	time		T_1	T_2	T_3	T_4
1	1	2	1	11.2	431	32	89	74	49
2	1	4	1	11	429	32	92	79	56
3	1	6	1	10.7	429	32	94	76	59
4	1	8	1	10.5	427	32	106	84	63

TABLE 2
CALCULATIONS TABLE

s.no	Electrical input H.P	Indicated power in watts	Isothermal power in watts	Volumetric efficiency η_v	Isothermal efficiency η_{iso}
1	2.18	197.54	76.28	63.22	38.61
2	2.22	524.88	168.24	63.66	32.05
3	2.28	747.39	236.67	63.66	31.66
4	2.34	992.13	240.59	64.09	24.25

IV. RESULTS AND GRAPHS

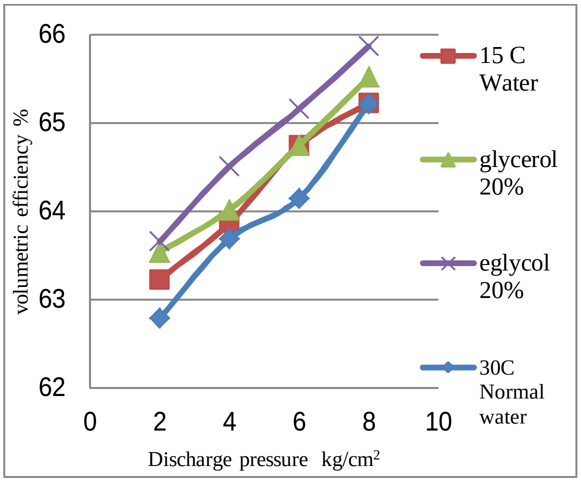

Fig 1 discharge pressure vs volumetric efficiency at 20% ethylene glycol

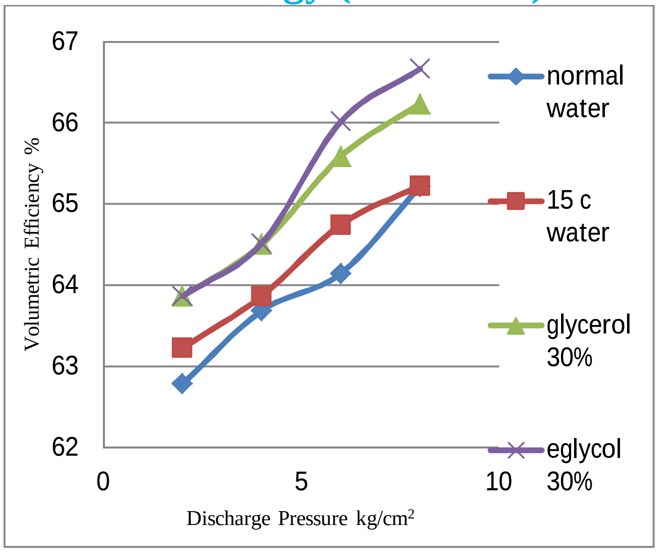

Fig 2 discharge pressure vs volumetric efficiency at 30% ethtlene glycol

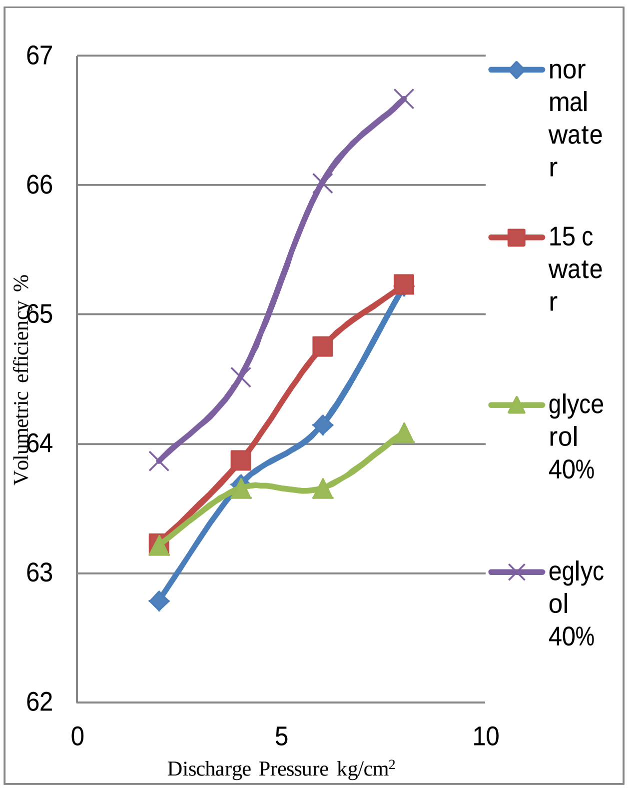

Fig 3 discharge pressure vs volumetric efficiency at 40%ethylene glycol

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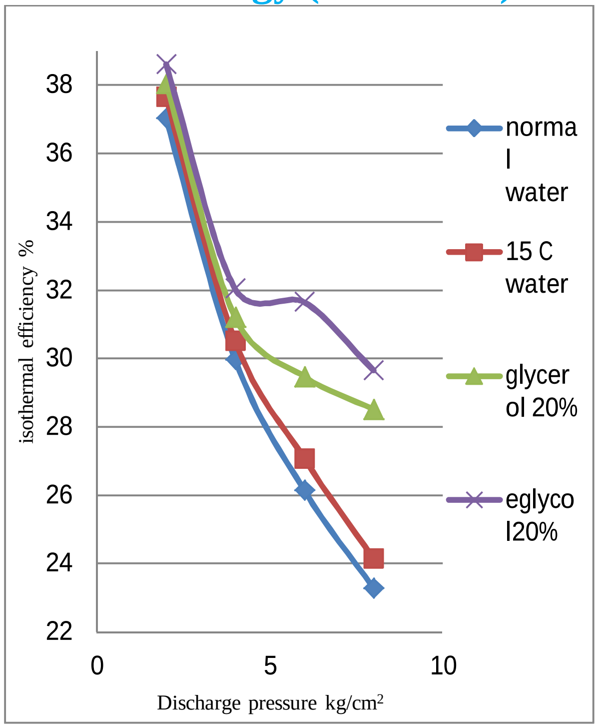

Fig 4 discharge pressure vs isothermal efficiency at 20% of ethylene glycol

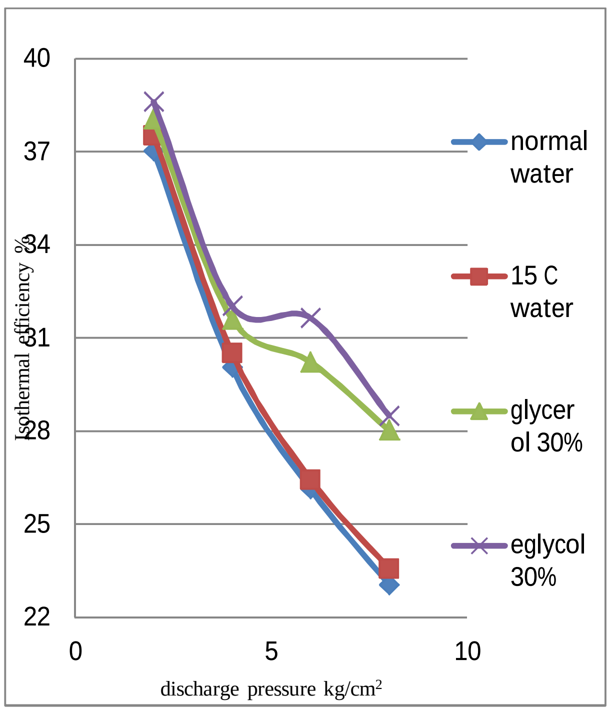

Fig 5 discharge pressure Vs isothermal efficiency at 30% of ethylene glycol

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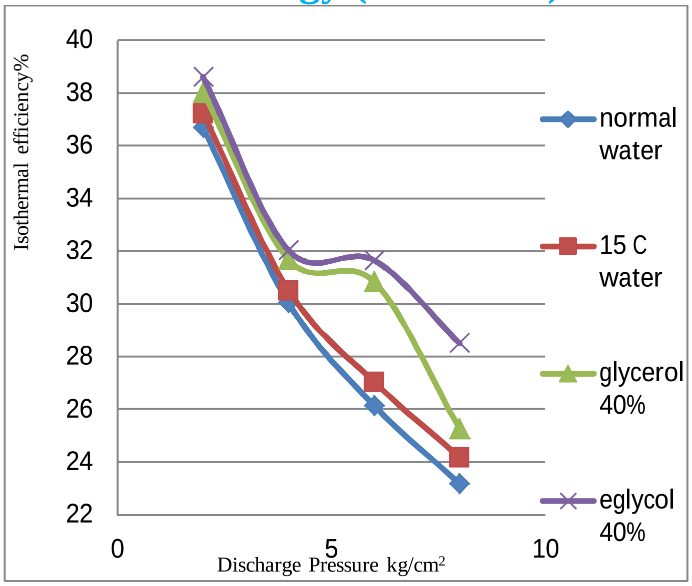

Fig 6 discharge pressure Vs isothermal efficiency at 40% of ethylene glycol

The fig 1, 2 and 3 shows the results of volumetric efficiency with water, 15 of water, glycerol, and ethylene glycol relating to the discharge pressure. the results shows that there is an improvement in the volumetric efficiency. With respect to the discharge pressure maximum volumetric efficiency is obtained by ethylene glycol mixed with water is 66.67%.where in the case of water inter cooling efficiency is 62.79% which is minimum. The figure 4, 5, and 6 shows the results of the isothermal efficiency efficiency with water, 15 of water, glycerol, and ethylene glycol relating to the discharge pressure. the results shows that there is an improvement in the isothermal efficiency. With respect to the discharge pressure maximum isothermal efficiency is obtained by ethylene glycol mixed with water is 37.62%.where in the case of water inter cooling efficiency is 38.64 % which is minimum.

V. CONCLUSION

From the different intercooling processes carried out in two stage reciprocating air compressor, it can be concluded that the isothermal work required to compress the air has been reduce. So the power required to drive the reciprocating compressor has also reduced by 1-2% with respect to normal intercooling. From all the results of intercooling processes, it can be concluded that the radiator coolant intercooling and mixture of ethylene glycol with water intercooling result in better volumetric efficiency ascomparedto other type of intercooling. It is possible that when costs of different coolants are not considered, in operation of two stages reciprocating air compressor can be used.

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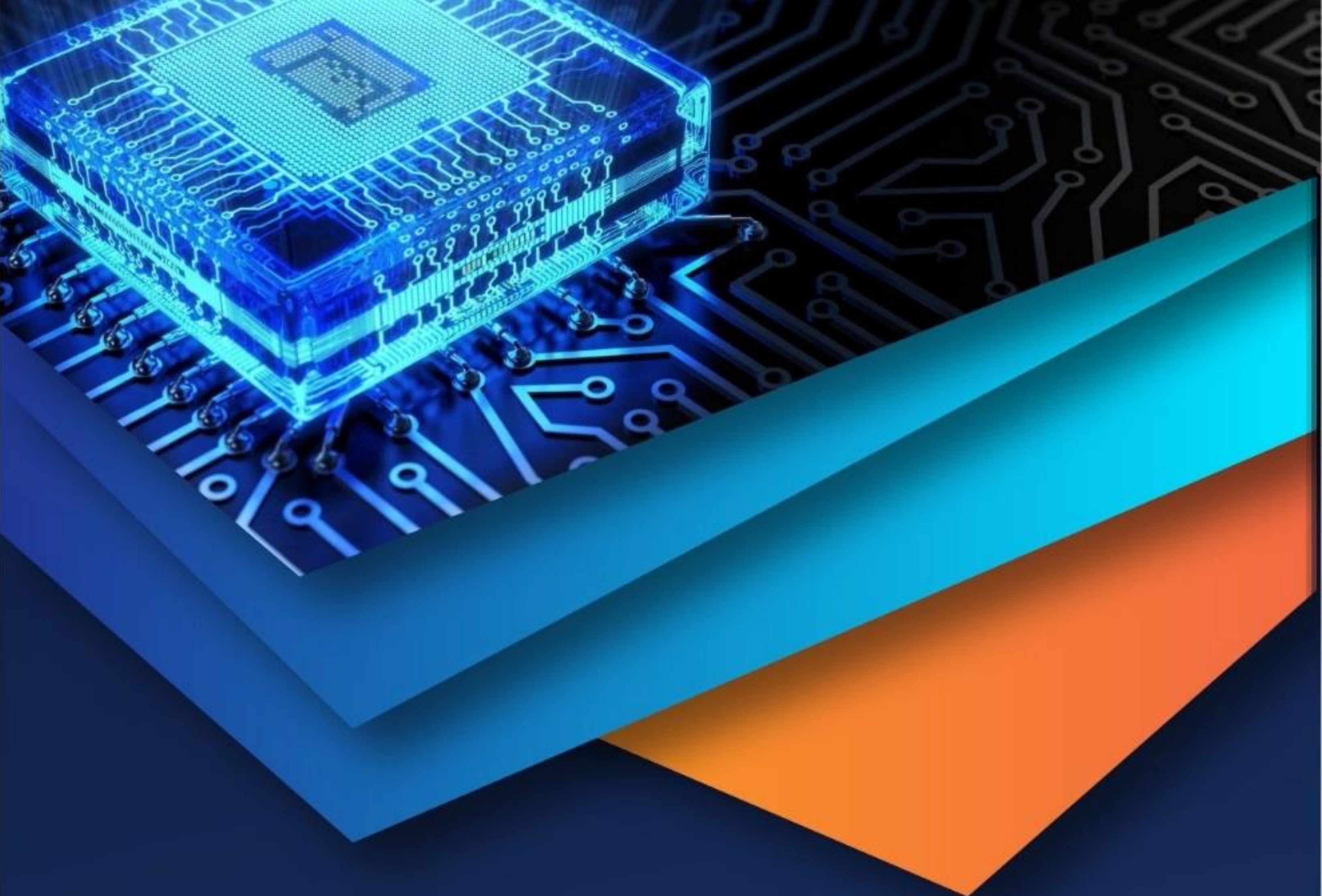

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