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Performance Analysis of Four Stroke Diesel Engine Working with Acetylene and Diesel

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***Abstract*: Limited reserve of fossil fuel and increasing pollution make it necessary to search for alternative fuels which can reduce dependency on petroleum based fuel. Gaseous fuel can be easily used as alternative fuel in IC engine in dual fuel mode. The previous studies in this field ware aimed to reduce pollution from exhaust gas. However, work in the field of acetylene gas effect on the vibration, noise and running cost of the diesel engine is still limited.**

In Present experimental work a setup is prepared to run an internal combustion engine in dual fuel mode using acetylene gas as an alternative fuel and to find out the effect of acetylene gas on performance and operating cost of diesel engine. The experiment is performed with different acetylene flow rate and on different loading condition on engine. This experimental work shows that use of small quantity of acetylene with intake air is can improve the performance and reduce the operating cost of engine. Based on the performance and cost analysis the acetylene flow rate is optimized to 0.068 kg/h.

***Keywords*: Acetylene, Dual fuel mode, CI engine, optimization and cost analysis.**

I. INTRODUCTION

Due to increasing population and changing lifestyle energy demand is continuously increasing. Most of the energy resource used today is oil, coal, and natural gas, to fulfil the world energy demand. These energy source are non-renewable. The petroleum based oils are commonly used in internal combustion engine. To reduce the consumption of petroleum based fuel in internal combustion engine many alternative fuels ware invented like biodiesel [1], methanol [2], hydrogen [3], liquid petroleum gas, compressed natural gas [4] etc.

A good alternative fuel should be environment friendly, cheap and easily available. Acetylene can be obtained by the reaction of calcium carbide and water, the residue in this process is calcium hydroxide slurry which doesn't harm environment. It has higher calorific value per kg compared to diesel and gives good combustion efficiency. Acetylene shows many such qualities that make it good alternative fuel.

Gaseous fuel can be easily used in dual fuel mode [5]. In dual fuel mode the gaseous fuel called as primary fuel is either aspirated with inlet air or directly injected inside the combustion chamber. The ignition is achieved by timed injection of liquid fuel called pilot fuel near the end of combustion chamber. The pilot fuel auto -ignite first and release heat inside the combustion chamber. This heat ignite the primary fuel (gaseous fuel) and air mixture. Hence the combustion of gaseous fuel occur by flame initiation due to auto ignition of pilot fuel. In this operation amount of pilot fuel required is very small, Most of the energy released by gaseous fuel. The disadvantage of dual fuel mode is the reduced volumetric efficiency due to replacement of fresh air by gaseous fuel [6].

II. ACETYLENE GAS

Acetylene is combustible hydrocarbon gas discovered in 1836 by Edmund Davy. In 1862, Friedrich Wohler discovered a reaction to generate acetylene by hydrolysis of calcium carbide [7]. According to the reaction -

$CaC_2 + H_2O_2$ --------------- $Ca(OH)_2 + C_2H_2$

Acetylene is also manufactured by heating the hydrocarbon and rebounding their atoms. At atmospheric pressure acetylene cannot exist in liquid state. Acetylene is unstable in pure form.

Due to danger of explosion pure acetylene cannot be compressed to a pressure more than 0.1Pa above atmospheric pressure. So acetylene is supplied in steel cylinder in which it is dissolved with acetone under pressure of from 16 to 22 atm gauge pressure. Acetylene cylinder is filled with porous filler material like charcoal [8].

TABLE 1: COMBUSTION PROPERTY OF ACETYLENE GAS

S. no.	Properties	Acetylene	Diesel
1	Formula	C_2H_2	C_8 –C_{29}
2	Molecular weight	26.04	200
3	Density, kg/m^3, at 20 ^{0}C and 1 atm,	1.092	840
6	Stoichiometric air fuel ratio, kg/kg	13.2	14.5
7	Flammability limit, volume %	2.5-81	0.6-5.5
9	Auto ignition temperature, ^{0}C	305	257
10	Lower calorific value, kj/kg	48,225	42,630
13	Ignition delay period, sec	--	0.002
17	Flash point, ^{0}C	32	74

III. LITERATURE REVIEW

T. Lakshman et al. [9] performed the experiment on diesel engine using acetylene on dual fuel mode. They used fixed acetylene flow rate of 3 lpm. They concluded that at this acetylene flow rate due to higher combustion rate of gaseous fuel mixture brake thermal efficiency in dual fuel mode was reduced. They also observed decrease in emission of carbon monoxide, unburnt hydrocarbon on dual fuel mode and increase in peak pressure, ignition delay due to acetylene supply.

Malaha et al. [10] investigated the effect of addition of diethyl ether with diesel when engine is running on dual fuel mode with acetylene. They concluded that by adding diethyl ether on dual fuel mode engine operation, the brake thermal efficiency become similar to the engine operation on pure diesel condition. Reduction in NOx emission, exhaust gas temperature and brake specific energy consumption is obtained by adding diethyl ether on dual fuel mode with acetylene.

D kumaran et al. [11] used the diesel containing turpentine in engine running on dual fuel mode with acetylene as gaseous fuel. The experiment shows that turpentine addition in dual fuel mode provide wide range of flammability and increased brake thermal efficiency due to quick combustion. They concluded that the tri fuel mode operation reduce the emission of harmful gases.

IV. EXPERIMENTAL SETUP

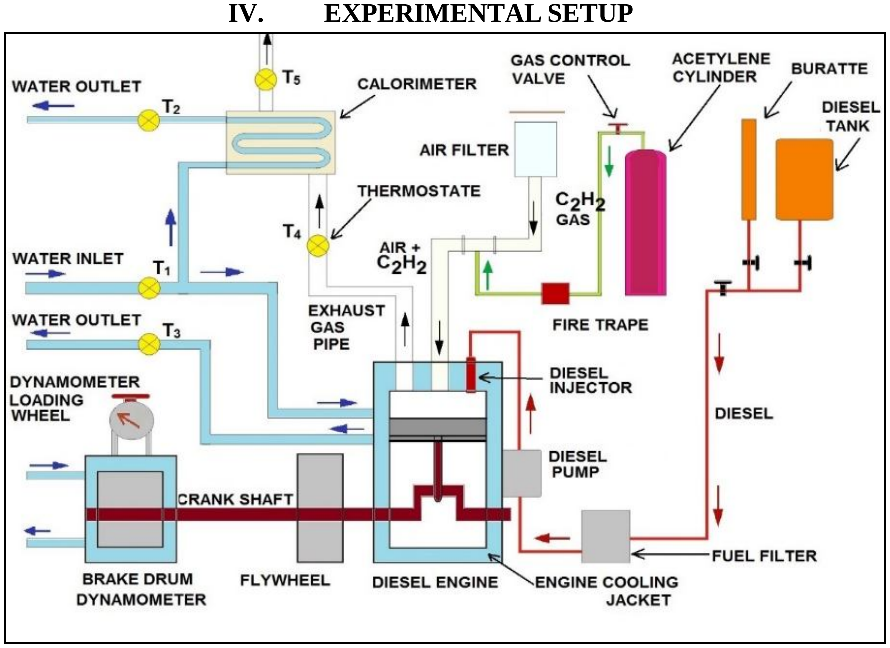

Fig.1 Schematic diagram of experimental setup

The experiments are carried out in a diesel engine test rig. The diesel engine used for experiment is single cylinder, four stroke, water cooled, vertical headed engine is having rated power of 5 HP at speed of 1500 rpm. The engine is having bore diameter of 85 mm and stroke length of 110 mm. A conventional acetylene gas cylinder is used for gaseous fuel. For supplying the acetylene with inlet air the acetylene gas pipe is connected to inlet air pipe of engine. Flow of acetylene is controlled by the control valve. Regulator contain a two pressure gauges, one pressure gauge shows the cylinder pressure and another gauge shows the line pressure. For loading the engine, a water-cooled hydraulic dynamometer is used. The diesel engine test rig contain calorimeter and thermocouples. Burette is used to measure the flow rate of diesel in ml. The diesel is directly poured into the burette.

V. METHODOLOGY

First, the engine is started using desired amount of diesel and run for half an hour with pure diesel. Various observation are noted in this condition. Then acetylene valve is slowly opened which initiates acetylene flow and then acetylene is mixed with inlet air. The air gas mixture is then sucked into combustion chamber and take part in combustion process.

Diesel flow rate is measured in each load by measuring change in diesel level in burette and acetylene flow rate is measured by change in the weight of acetylene cylinder. The temperature at various location are shown on the digital temperature indicator.

VI. RESULT AND DISCUSSION

TABLE 2 - fuel designation

Designation	Fuel
A 0	Diesel + Acetylene 0 kg /h.
A 0.059	Diesel + Acetylene 0.059 kg /h.
A 0.116	Diesel + Acetylene 0.116 kg /h.
A 0.203	Diesel + Acetylene 0.203 kg /h.
A 0.282	Diesel + Acetylene 0.282 kg /h.
A 0.379	Diesel + Acetylene 0.379 kg /h.
A 0.456	Diesel + Acetylene 0.456 kg /h.
N 0.25	Diesel + Al_2O_3 nanoparticle 0.25 gm/h
N 0.50	Diesel + Al_2O_3 nanoparticle 0.50 gm/h
N 0.75	Diesel + Al_2O_3 nanoparticle 0.75 gm/h
N 0.25 + A 0.082	Diesel + Al_2O_3 nanoparticle 0.25 gm/h + Acetylene 0.082 kg /h.
A 0.068	Diesel + Acetylene 0.068 kg /h.
A 0.409	Diesel + Acetylene 0.409 kg /h.

A. Variation in diesel fuel consumption with increasing load on engine

From the graph on fig. 2 and 7. It is clear that when acetylene is aspirated with intake air diesel consumption rate start to decrease due to combustion of gaseous fuel. It has been observed that for very small acetylene flow rate on region OA, the fuel consumption is decreased due to high calorific value of the acetylene gas per unit weight. Further increase in acetylene flow rate in region AB, causes increase in the diesel consumption rate. This may be due to decrease in air flow rate. Further increment of acetylene flow rate from point B decreases the diesel consumption rate up to the point C which is due to uniform mixing of gaseous fuel i.e. acetylene with air and proper combustion of fuel inside the engine. After point C for acetylene flow rate more than 0.379 kg/hr the volume of diesel that auto ignite first become very small, which results in improper combustion of gaseous fuel in engine. This require more diesel injection which is indicated in region CD on fig. 7.

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B. Variation in brake thermal efficiency with acetylene flow rate

Variation in brake thermal efficiency with acetylene is shown in graph on fig. 3. It is clear from the graph that brake thermal efficiency is maximum at small acetylene flow rate of 0.059 kg/hr and minimum at higher acetylene flow rate. The brake thermal efficiency is more in dual fuel mode compare to efficiency of the engine in pure diesel condition for acetylene flow rate is 0.059 kg/hr and 0.116 kg/ hr. On increasing acetylene flow rate from 0.116 kg/hr, the brake thermal efficiency become lower than the pure diesel condition. The reason may be that acetylene has higher calorific value per kg as compare to the diesel and because of sufficient availability of the fresh air. On increasing acetylene flow rate more fresh air is replaced by the gaseous fuel which causes reduction in volumetric efficiency and brake thermal efficiency. On acetylene flow rate of 0.456 kg/hr the brake thermal efficiency is significantly reduced because of increase in the diesel consumption rate and improper combustion of gaseous fuel.

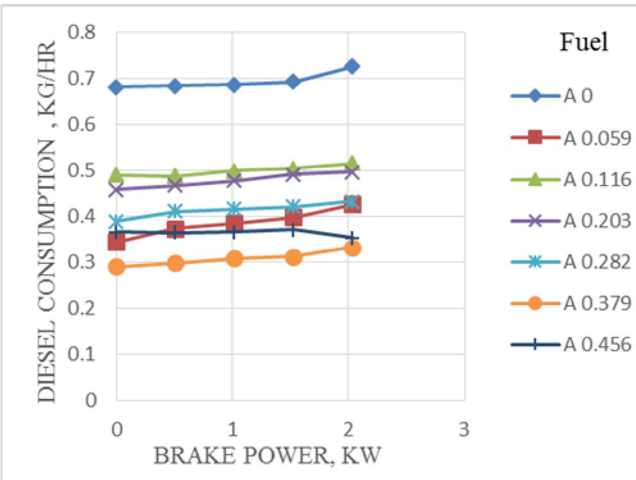

Fig. 2 Variation in mass flow rate of diesel on different engine load

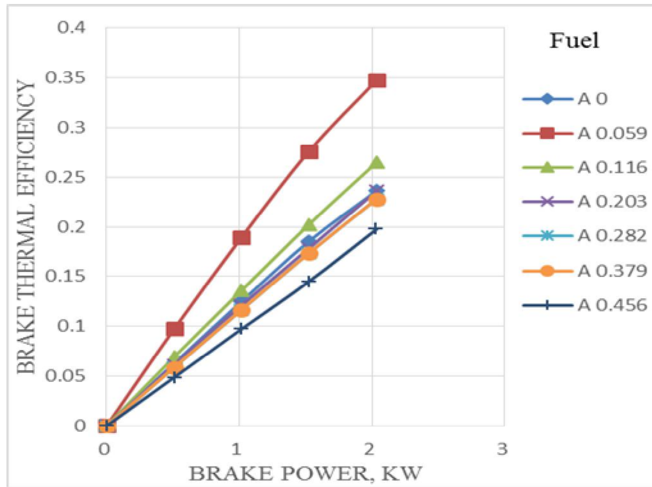

Fig. 3 Variation in efficiency with brake power

C. Variation in brake specific fuel consumption

Variation in brake specific fuel consumption with acetylene flow rate is shown in fig. 4. It is clear from the graph that on duel fuel mode when acetylene flow rate varies between 0.059kg/ hr and 0.379 kg/ hr the brake specific fuel consumption continuously reduced. Further in dual fuel mode brake specific fuel consumption is always less than pure diesel mode. When acetylene flow rate is 0.059 kg/hr the reduction in brake specific fuel consumption is more compared to acetylene flow rate of 0.116 kg/ hr. This may be due to negligible reduction in incoming fresh air, high calorific value of incoming gaseous fuel, complete and more uniform combustion of fuel mixture in the engine. On increasing acetylene flow rate from 0.059 kg/hr to 0.116 kg/ hr, part of the fresh air is replaced by the gaseous fuel and brake specific fuel consumption is slightly increased.

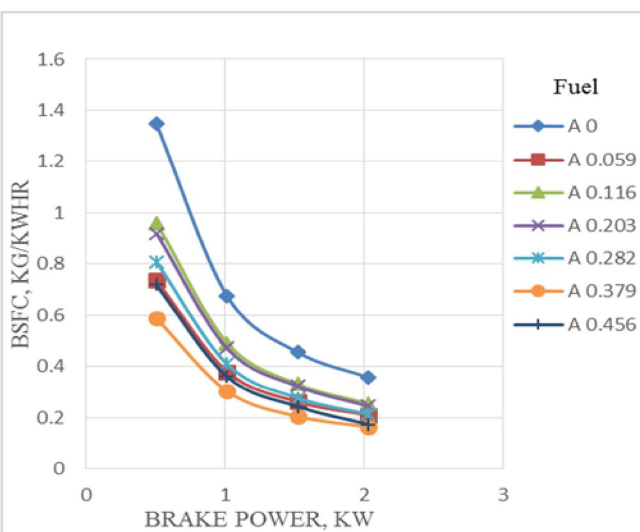

Fig.4 Graph between brake power and Brake specific fuel consumption

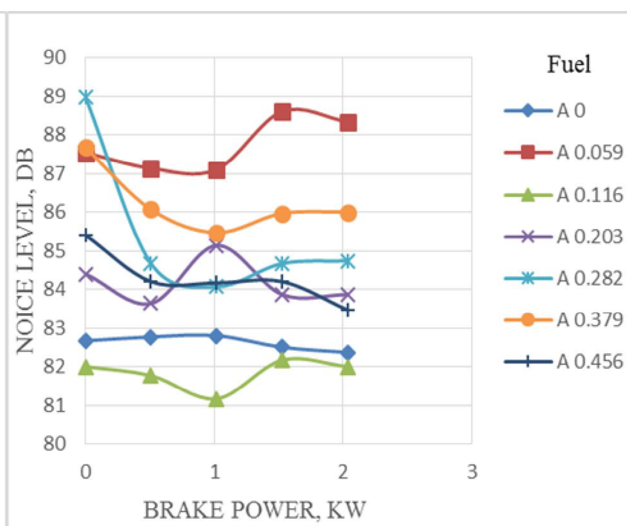

Fig. 5 Graph between brake power and noise level

D. Variation in noise level with different acetylene flow rate

The variation in noise level is shown in graph in fig. 5. It is clear that noise level is gradually increases with increasing acetylene flow rate. The reason behind this may be high combustion rate of gaseous fuel mixture and high heat release rate. For acetylene flow rate of above 0.116 kg/hr the noise level is high as compare to baseline diesel operation. Noise level is comparatively low for acetylene flow rate of 0.116 kg/hr and higher for acetylene flow rate of 0.059 kg/hr.

E. Variation in exhaust gas temperature

Variation in exhaust gas temperature at different acetylene flow rate and load is shown in graph on fig. 6. It is clear from the graph that exhaust gas temperature gradually decreases with increasing acetylene flow rate with inlet air. The reason behind this may be more uniform combustion of gaseous fuel and decrease in fresh air supply. The exhaust gas temperature was higher as compare to baseline diesel operation at acetylene flow rate of 0.059 kg/hr and 0.116 kg/hr. This may be due to high calorific value of gaseous fuel and availability of sufficient amount of fresh air. At very high acetylene flow rate of 0.456 kg/hr the exhaust gas temperature fluctuates above and below baseline diesel operation.

F. Optimization of acetylene flow rate for minimum diesel consumption

To optimize the acetylene flow rate at which diesel consumption rate is minimum a graph has been plotted between acetylene flow rate and diesel consumption rate for different loads on the engine as shown on fig. 7. It is clear from the graph that when very small acetylene flow rate of 0.059 kg/hr has been used the diesel consumption rate has also been reduced compare to the pure diesel operation. Diesel consumption rate is slightly increased for acetylene flow rate of 0.116 kg/hr as compare to 0.059 kg/hr and after this point continuously decrease up to acetylene flow rate of 0.379 kg/hr. After increasing acetylene flow rate from this value the diesel consumption rate again starts to increase. To determine acetylene flow rate the trend line is drawn on the graph for maximum load on engine. By solving the equation of the trend line the acetylene flow rate for minimum diesel consumption rate obtained is 0.409 kg/hr.

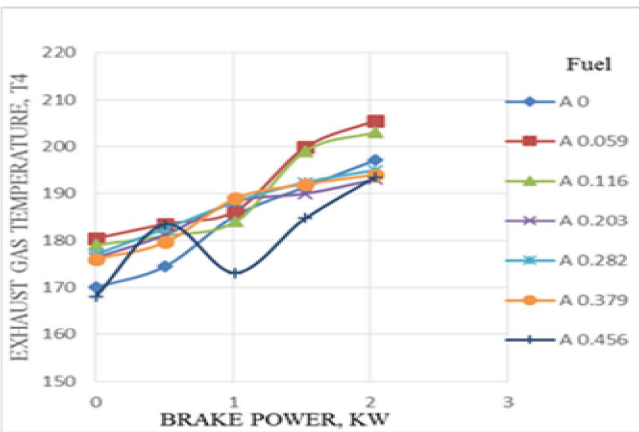

Fig. 6 Graph between brake power and exhaust gas temperature

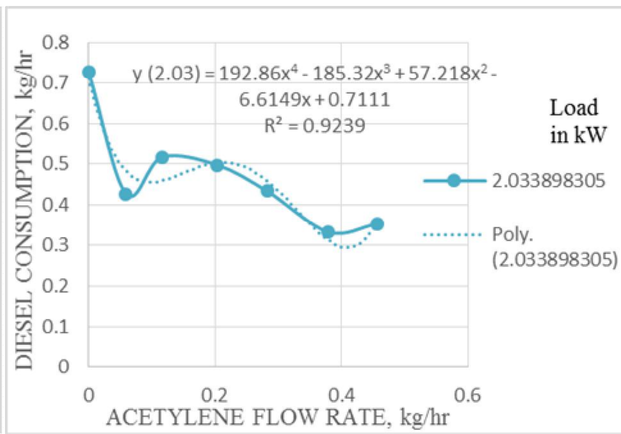

Fig. 7 Graph between acetylene flow rate and diesel consumption

G. Optimization of acetylene flow rate for maximum brake thermal efficiency

For this graph is plotted between acetylene flow rate and brake thermal efficiency of engine and a trend line is drawn as shown in fig. 8.

It is observed that brake thermal efficiency is initially increased and then after it is decreased on further increasing acetylene flow rate. To determine the acetylene flow rate for maximum brake thermal efficiency a trend line has been drawn on the curve for maximum load applied on the engine. After optimization it has been found that for acetylene flow rate of 0.068 kg/hr, the brake thermal efficiency is maximum.

H. Cost analysis

On dual fuel mode the operating cost of engine depends on diesel consumption rate and acetylene flow rate and there per unit coat. In India presently the cost of diesel is around rs. 65 per litter and cost of acetylene cylinder is around rs. 1800. The graph for variation in operating cost at different acetylene flow rate and load is shown on fig. no. 9. It is clear from the graph that at condition of maximum efficiency the operating cost on dual fuel mode is reduced by 4.61% than pure diesel condition.

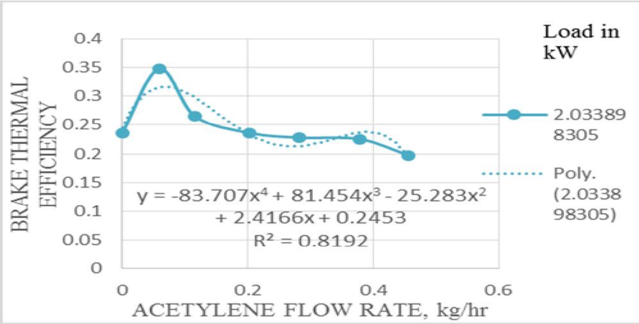

Fig. 8 Graph between acetylene flow rate and efficiency

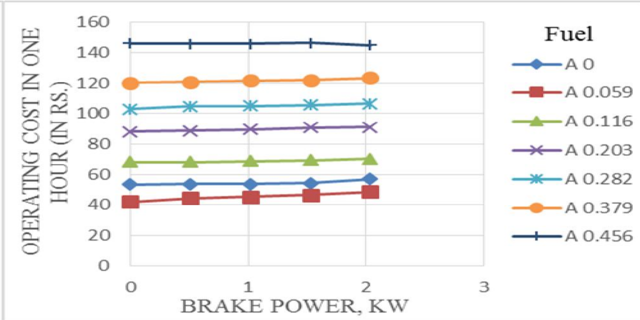

Fig. 9 Variation in operating cost in Rs. of engine with load

VII. CONCLUSION

Diesel engine can easily run using acetylene as gaseous fuel on dual fuel mode with minimum engine modification.

On dual fuel mode operation of diesel engine with acetylene the brake thermal efficiency can be improved by 11.14% in addition with 41.2% reduction in diesel consumption.

On dual fuel mode operation by increasing gas flow rate the diesel consumption can be reduced to certain value and after this further increase in gas flow rate causes increase in diesel consumption rate because of reduction in area of auto ignition by diesel. On dual fuel mode the exhaust gas temperature increases in small acetylene flow rate. In higher acetylene flow rate the exhaust gas temperature reduces. Due to higher heat release rate noise level increases in dual fuel mode.

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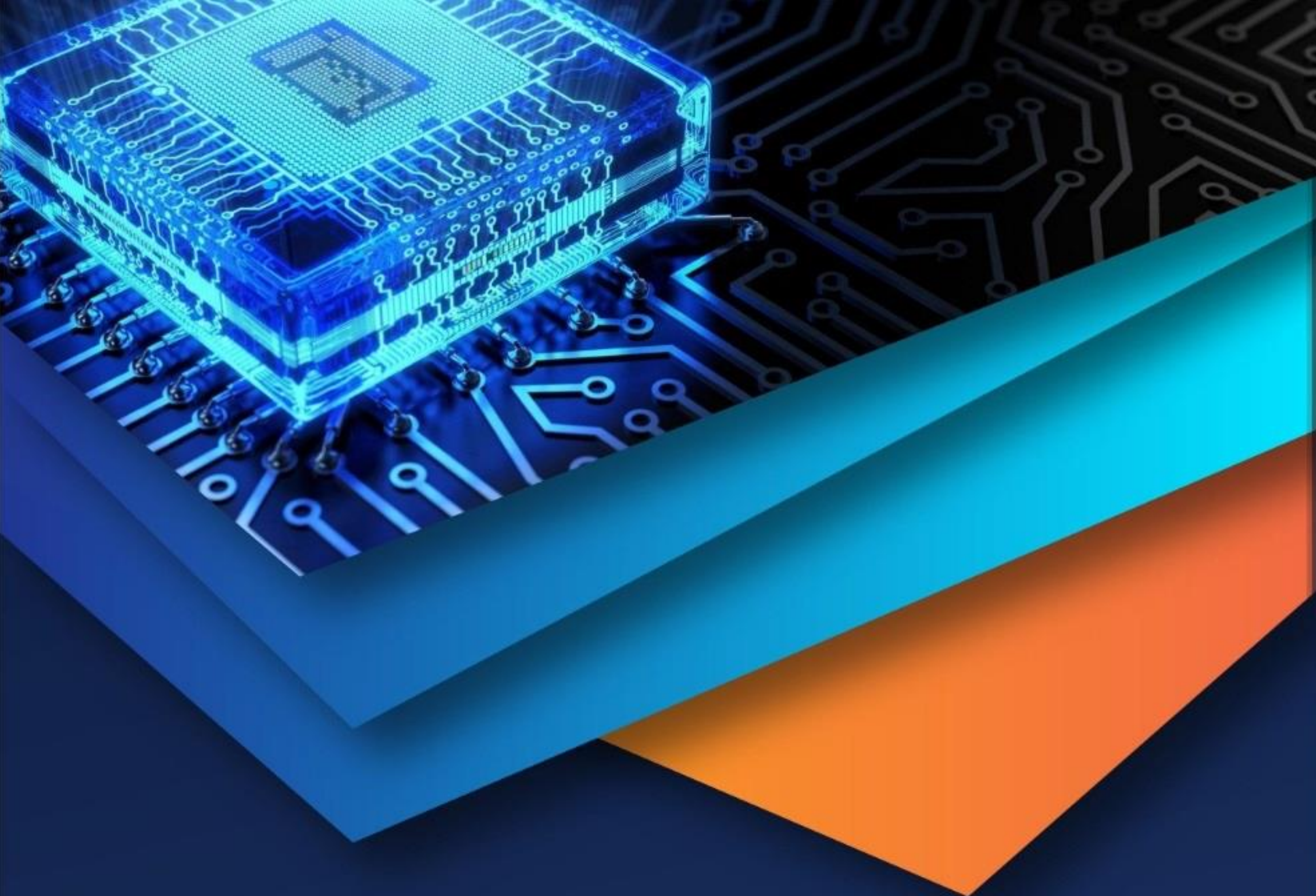

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