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Performance and Emission Analysis of Diesel Engine with Exhaust Gas Recirculation: A Review

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Abstract: ***The cost of diesel is lesser than gasoline and also diesel have higher efficiency that's why now-a-days, the use of diesel engines are higher than petrol engines. The performance of diesel engine is mainly depends on compression ratio, air-fuel ratio, speed etc. With increasing compression ratio the efficiency of diesel engines increases. But the exhaust gas from diesel pollutes the environment. There is big problem associated with diesel engine that is NOx formation. NOx contribute to a wide range of environment effects including the formation of acid rain and destroy ozone layer. The main causes for NOx formation are high in-cylinder temperature and high oxygen concentration. So there is a need for a technique which could reduce the emission without affecting the performance of engine. One of such technique is EGR (exhaust gas recirculation). EGR is a common way to control in-cylinder NOx formation. A review have been made to analyze the performance and emissions characteristics of diesel engine with EGR.***

Keywords--- EGR, Engine performance, combustion, Efficiency, Emissions and NOx

I. INTRODUCTION

The vehicle population across the world has grown significantly, from the last decades. The emissions from the vehicle vary with operating condition, engine type and fuel utilized, and all these points need to be addressed simultaneously for their abatement. The emissions from the vehicle severely affect the human health. The emissions from the diesel operated vehicles are NOx and particulate matter that are responsible for deterioration of ambient air quality. Many countries eliminating diesel operated vehicle and enforcing heavy taxes. Indian government also banned the registration of diesel operated private cars with the capacity of 2000 CC [1]. Numerous researches have been done to reduce emissions and low fuel consumptions for diesel engine [2].The main challenge for diesel engine is emission control technology. The NOx/ PM emission could be restricted through in-cylinder control measures well ahead of their formation, or through after treatment control devices which involve the conversion of NOx/ PM emission to relatively benign compounds [3]Achieving lower emission in diesel engines through after treatment technologies is economically unattractive and through in-cylinder technologies present a formidable challenge EGR (exhaust gas recirculation) is an effective technology for NOx emission reduction in diesel engine [4,5] 50% of exhaust gas can be recycled in case of diesel engine, however for petrol maximum EGR limit is 20% without affecting combustion stability [6]..jothithirumal et.al. [7] Presented in their paper the optimum amount of EGR for diesel engine operated with biodiesel blend. Biodiesel is obtained from Neem oil. From the experimental with increasing amount of biodiesel in blend for reducing NOx from biodiesel EGR is used and it is observed that with increasing EGR NOx emission reduces.Experimental studies by Mohebbi et.al. Represent that NOx in fluencies of EGR on diesel engine combustion. The experiments had been done on turbocharged DI diesel engine working under full load condition at two different injection timing to obtain engine parameter with hot and cooled EGR. Using Hot EGR reduces NOx emission whereas PM emissions are increased PM reduction occurs when advance of injection timing but both NOx and fuel consumption increases. From the study it is clear that the use of cooled EGR was more effective than hot EGR [8].studies by Swamy et.al. [9] Shows that the cooling rate of an IC engine stands one of important parameters that govern the performance and emissions. The experiment is done on single cylinder water cooled diesel engine operated at various cooling rate and compared with that operated under EGR.Suresh kumar et.al. [10] have proposed various solutions for reduction in emission , especially for NOx in diesel engine. Diesel engine was operated on Jatropha biodiesel blend with diesel. While the performance and other emission are lesser than diesel EGR is used to reduce NOx engine operated with blend.

Abd-Alla reviewed the NOx reduction potential of EGR in diesel, gasoline and dule fuelled engines. from study it concluded the reduction in NOx is more while using EGR along with the intake air of diesel engine rather than air displacement method [11]. Thus, the future diesel vehicles demand engine modification as well high quality fuels to adhere with stringent emission norms. It is

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inferred that, EGR has become an essential control strategy for both advanced combustion engine [12] and alternate fuelled engine applications [13, 14]Detailed discussions on the influences of advanced combustion on performance characteristics of diesel engine [15-18] and alternate fuels [27-29] are available in the existing literature. Also, there are few review articles discussing the EGR affects on diesel engine combustion and NOx emissions [5,11].

II. EXHAUST GAS RECIRCULATION

For NOx control EGR method is used. In the IC engine the exhaust gas mainly consist of carbon dioxide, nitrogen, carbon monoxide etc. and mixture has specific heat compared to atmospheric air. Recirculated exhaust gas entering to combustion chamber along with air and exhaust gas also contain carbon dioxide and water vapour. After the displacement of air the less amount of oxygen available in the combustion chamber. Due to less oxygen available in chamber reduction in A/F ratio occur.

This reduction influences the exhaust emission. Hence combination of minor oxygen quantity in the intake air and reduced flame temperature lowers rate of formation of NOx reactions. The EGR (%) is termed as the mass % of EGR (MEGR) in the total intake mixture (Mi)

EGR (%) = (MEGR ÷ Mt) × 100

A pictorial representation of the EGR effect on diesel combustion is provided in fig.1 though EGR results in lower NOx emission and higher soot, CO, HC emission and inferior engine performance [38, 26, 21, 22, 19].

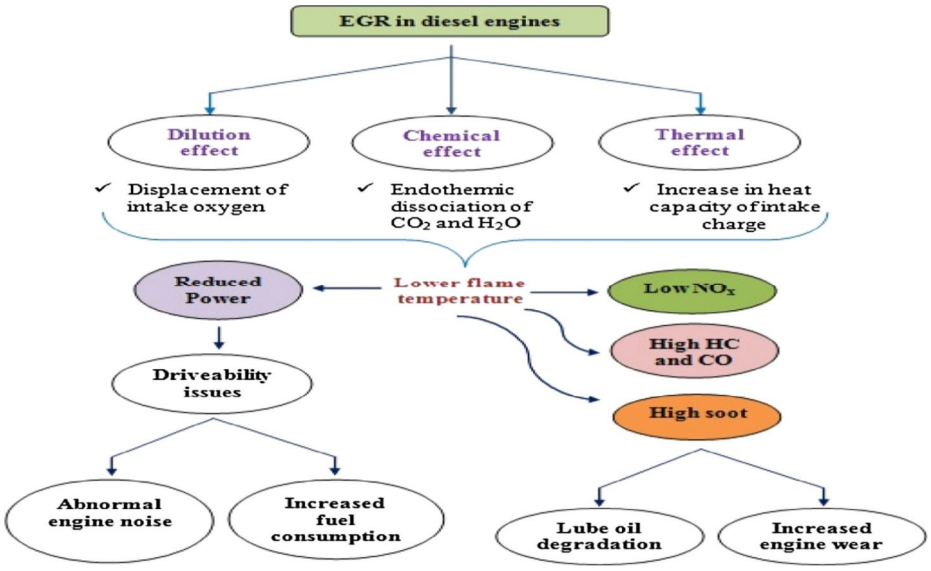

Fig. 1 Effects of EGR on diesel combustion and pollutant formation [38, 26, 21, 22, 19

Landommatos et.al.[20] describes two more effects, viz. increase in inlet charge temperature and thermal throttling hot EGR. According to his study he illustrates various diluents such as CO2 [21, 22] water vapour and their combinations [24, 25] were inducted along with the intake air to simulate EGR.

For the diesel engine influence of dilution effect in the major factor responsible for reduction in NOx and soot emission. Using EGR excess air ratio reduces which in turn increases the ignition delay. That's why cylinder temperature reduced and soot formation [26]. Further no formation kinetic is affected by dilution effect through the reduction in the partial pressure of oxygen concentration.

III. ADVANTAGE WITH EGR

A. High power obtain
B. Less NOx emission due to reduced cylinder temperature
C. Control air pollution
D. No formation of toxic gases
E. Increase efficiency of engine
F. Complete combustion of fuel
G. Fuel consumption improves

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IV. DISADVANTAGE WITH EGR

A. 15-20% bigger radiator size required
B. High cost of engine
C. Complicated design
D. More space required
E. More cooling required

V. PERFORMANCE ANALYSIS

A. Brake thermal efficiency

From the experimental studies it is clear that with increasing load brake thermal efficiency also increases. Maximum efficiency obtained at maximum load. Along with EGR there is a slight increment in brake thermal efficiency. 10% cold EGR shows higher efficiency when the engine running at partial loads [30]. At higher loads hot EGR has higher efficiencies due to the fact that engine has high efficiency when the inlet temperature are higher [33]. Due to high intake temperature the combustion velocity increases which decrease the lead time thereby increasing brake thermal efficiency.

Brake therma efficiency: $\eta(bth) = [b.p./(m*Cv)]$

Where,
η (bth)= brake thermal efficiency,
b.p. = brake power in Watt,
m = mass flow rate of fuel in Kg/hr and
Cv = calorific value of fuel in KJ/KgK.

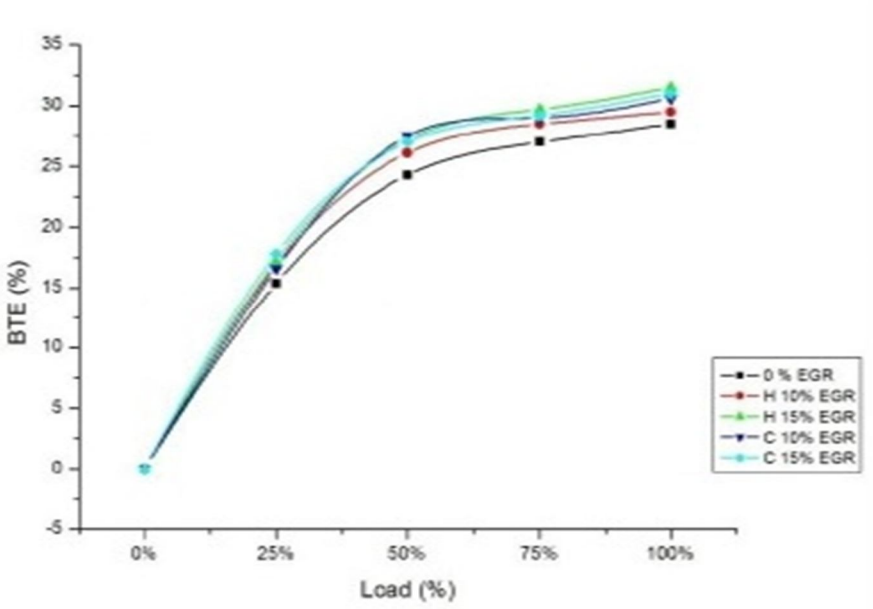

Fig**. 2** Variations of brake thermal efficiency with load for different % of cold and hot EGR [31]

B. Brake specific fuel consumption

The changes of the brake specific fuel consumption (BSFC) along the different loads is shown in graph by taking load on X axis and BSFC on Y axis as shown in figure . It can be observed from experimental studies that brake specific fuel consumption decreases as the load increases. As the EGR % is increased the brake specific fuel consumption is also increases and we can say that diesel without EGR has the lower specific fuel consumption [35,36]. The following equation is used for the calculation of BSFC.

BSFC = (m/ b.p.)

Where,
BSFC = brake specific fuel consumption in Kg/hr,
ṁ = mass flow rate of fuel in Kg/hr and
b.p. = brake power in Watt.

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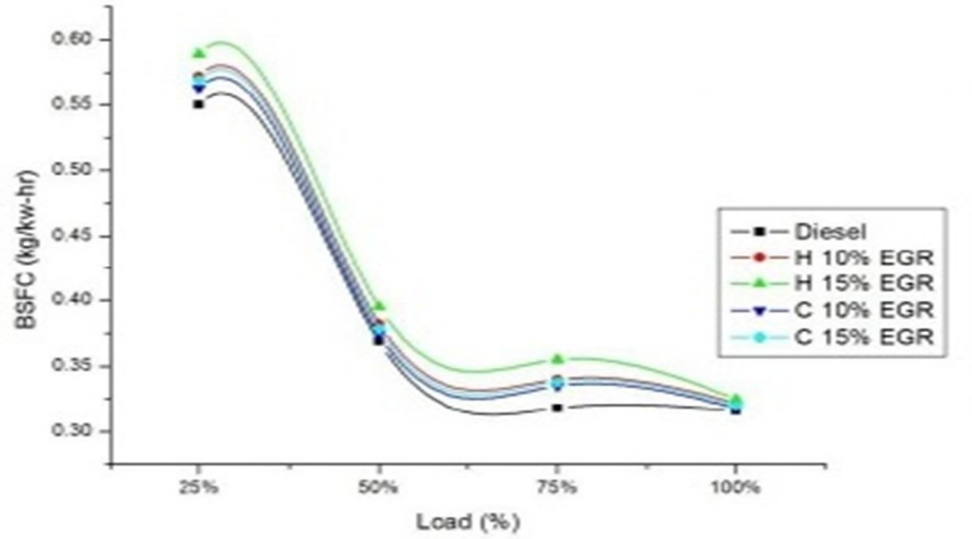

Fig. 3 Variations of brake specific fuel consumption with load for different % of cold and hot EGR [31]

C. Exhaust gas temperature

The changes in the Exhaust gas temperature (EGT) along with the different loads is shown in graph by taking load on X axis and EGT on Y axis as shown in figure. Extremely high temperature is the basic reason for NOx formation in the combustion chamber. The below graph shows that as we increase the EGR rate the exhaust gas temperature decreases. So it can be concluded that the combustion chamber temperature also reduces and thus the formation of Nox also reduces [37]. The cold EGR has a significant effect on the exhaust gas temperature.

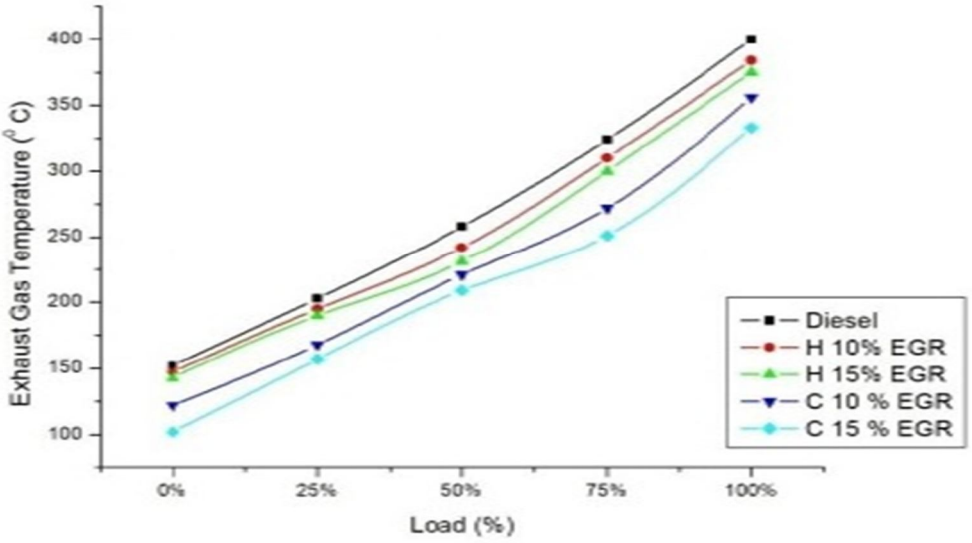

Fig.4 Variations of exhaust gas temperature with load for different % of cold and hot EGR [31]

VI. EMISSIONS ANALYSIS

A. CO emission

The changes in the CO emissions along the different loads are presented in graph by taking load on X axis and CO on Y axis as shown in figure. The figure indicates that the CO emissions increase as the load increases. As the EGR rate is increased CO emissions also gets reduced [30-33]. This can be attributed to the reduction of available oxygen to combine with carbon.

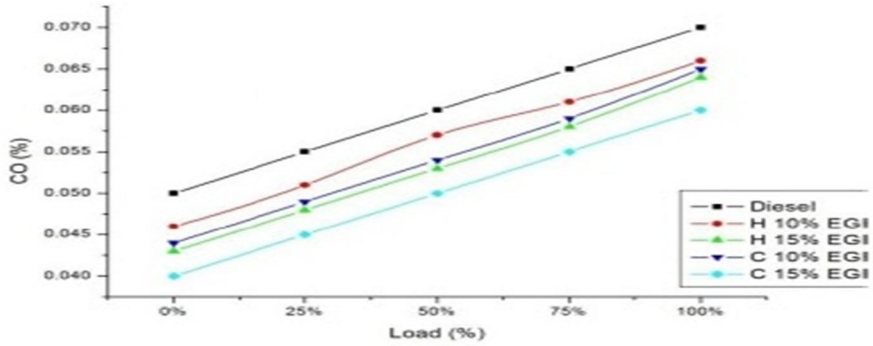

Fig. 5 Variations of CO emission with load for different % of cold and hot EGR [31]

B. NOx emission

The changes in the NOx emissions along the different loads are presented in graph by taking load on X axis and NOx on Y axis as shown in figure. The significant effect of EGR can be found in NOx emissions. The reason for reduction in NOx with EGR is the reduction of cylinder temperature as a result of the addition of exhaust gases to the intake air which reduces the combustion temperature. Still higher EGR % is able to reduce NOx emissions by a large amount, which however is accompanied by a reduction in BTE. There NOx reduces about 28% when engine run at full load [31, 32].

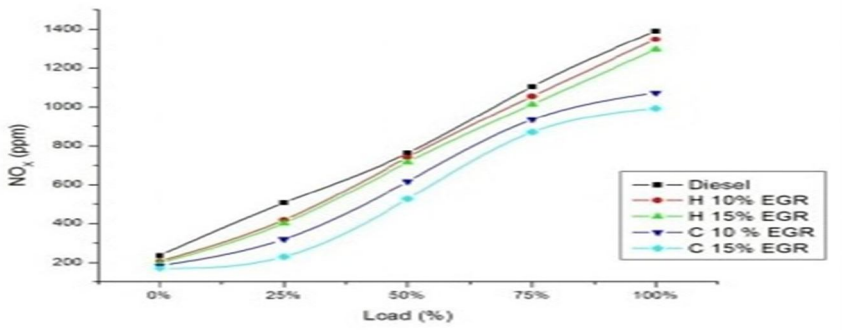

Fig. 6 Variations of NOx emission with load for different % of cold and hot EGR [31]

C. Smoke emission

The changes in the smoke along the different loads are presented in graph by taking load on X axis and smoke on Y axis as shown in figure. The smoke increases slightly as the EGR % increases [34]. This is because of the recirculation of exhaust gases into the cylinder. The effect of cold and hot EGR is insignificant in case of smoke opacity.

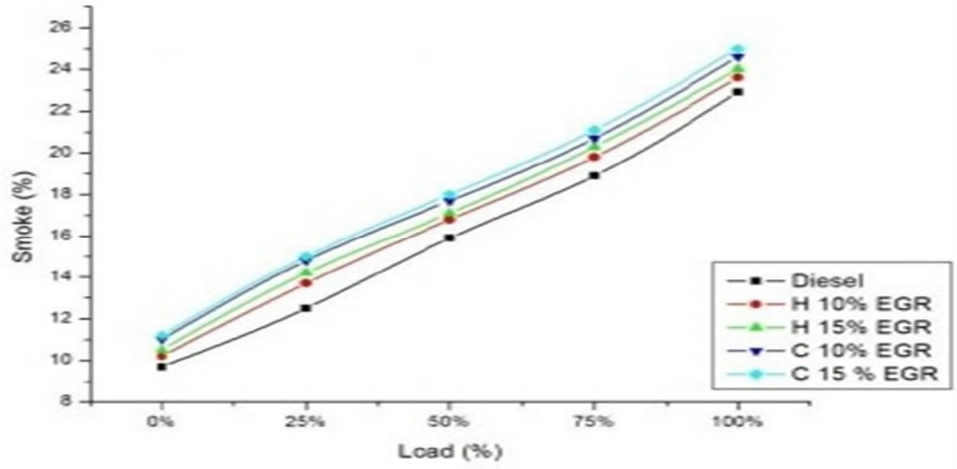

Fig.7 Variation of smoke emission with load for different % of cold and hot EGR [31]

VII. CONCLUSION

The following conclusions can be derived from the studies

A. The effect of EGR significantly found on emission of NOx.
B. With increasing amount of EGR for diesel engine efficiency increases but brake specific fuel consumption decreases at lower load.
C. Smoke increases slightly with EGR.
D. There are slight increments in the emission of CO and HC because of EGR.
E. When we compare the hot EGR and cold EGR, Cold EGR has the greater advantage if it is well designed.
F. When we use biodiesel as fuel, there is a problem with increase in NOx emissions as well as there will be reduction in performance of the engine. But if EGR technique is incorporated with the biodiesel, then there will be greater advantage of increasing the performance of engine as well as reduction in all the emissions.

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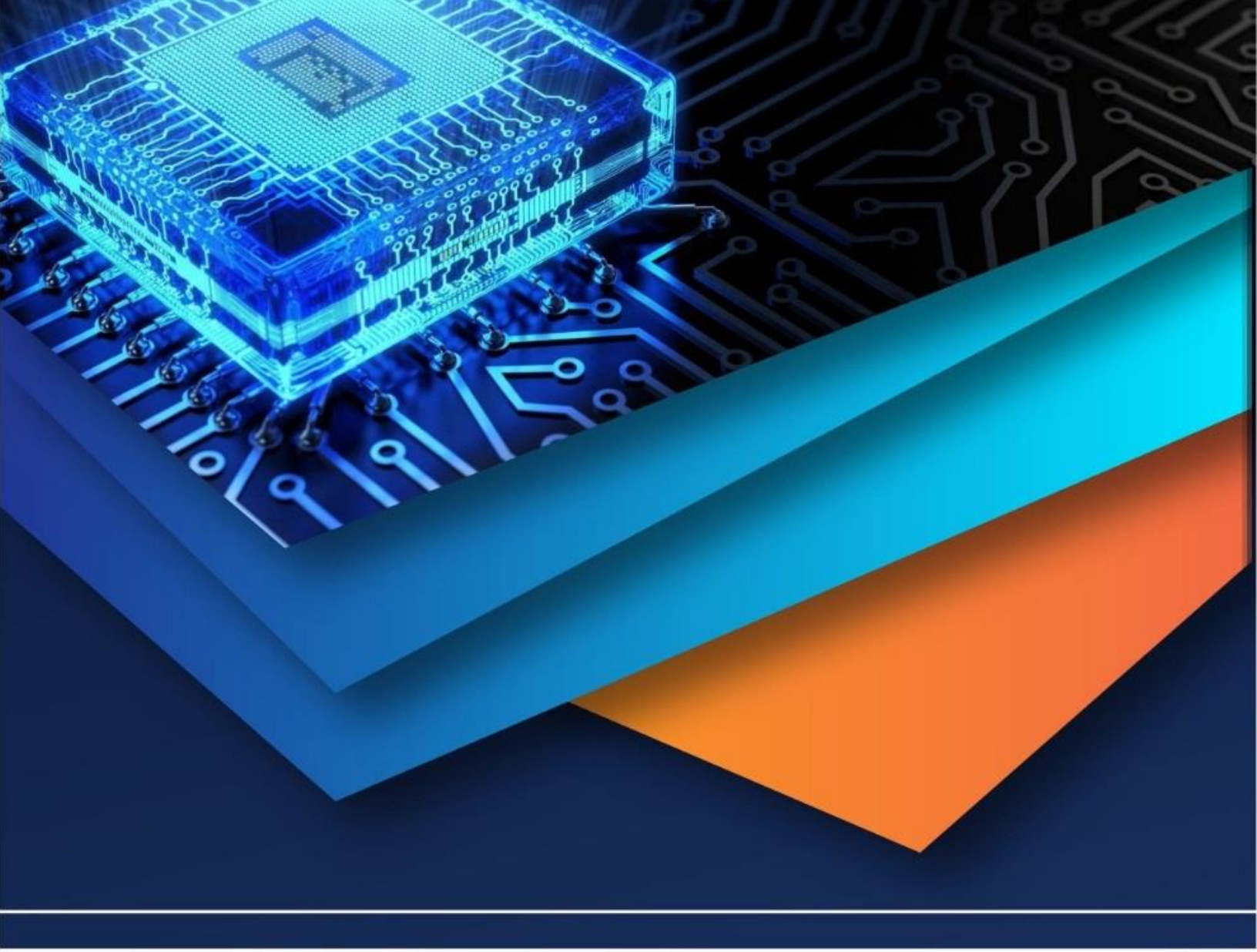

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