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Evaluation of C.I Engine Performance and Emission Characteristics Fueled with Cng and Ethanol Blends as Alternative Fuel

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Abstract: Environmental air pollution and global warming are alarming concern world wide. Increasing air pollution, rapid growth of industrialisation and the global trend of urbanisation have totally disturbed the eco balance of resources on earth. These present study was done to visualize the potential of ethanol blends and CNG as an alternative fuel in C.I engine. The effect of ethanol on brake thermal efficiency, brake specific fuel consumption, characteristics for single-fuel and dual-fuel (CNG- diesel blends with ethanol) was investigated. The experimental setup consist of single cylinder four stroke engine using 3Kw diesel engine generator, with compression ratio of 16.5:1 and injection pressure of 240bar. The tests were performed at engine speed ranges from 1500 rpm at different loads with 10% CNG and 90% air and with mixtures of E10%, E15%, E20%, E25%, E27%, E30 and E50% in diesel fuel blends. The overall engine performance parameters include brake power, specific fuel consumption and brake thermal efficiency are calculated and compared with conventional diesel engine performance by plotting graphs.

Keywords: Diesel engine, ethanol blends, Calorific value, brake specific fuel consumption,

1. INTRODUCTION

In the face of escalating oil prices and depleting oil reserves, the search for alternative sources of fuels has been intensified more than ever before in the history of mankind. Aside energy security concerns, issues of climate change as a result of the emission of carbon dioxide (CO2) and carbon monoxide (CO) and other harmful compounds associated with the use of fossil fuel have also been one of the driving forces in the search for alternative sources which are environmentally friendly and sustainable.

Dr. Saif Ul Barietal in his research of "Effect Of Carbon Dioxide On Performance Of Diesel/Biogas Engine" concluded that the presence of 40% carbon dioxide did not deteriorate the performance of engine compared to that of natural gas (96% methane), in duel fuel mode. Presence of 30% of carbon dioxide had improved the performance of engine as compared to same as running with natural gas. Provision should be made for adequate flow of CNG and Diesel Ethanol blends (dual fuel mode) for high carbon dioxide content.

Semin, Rosli Abu Bakar, his project on" A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines" their discussion is Natural gas is promising alternative fuel to meet strict engine emission regulations in many countries. Compressed natural gas (CNG) has long been used in stationary engines, but the application of CNG as a transport engines fuel has been considerably advanced over the last decade by the development of lightweight high-pressure storage cylinders. For spark ignition engines they are discussed on two options, a bi-fuel conversion and use a dedicated to CNG engine. For compression ignition engines converted to run on natural gas, there are two main options discussed, there are dual-fuel engines and normal ignition can be initiated. Natural gas engines can operate at lean burn and stoichiometric conditions

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with different combustion and emission characteristics. In his paper, the CNG engines research and development fueled using CNG are highlighted to keep the output power, torque and emissions of natural gas engines comparable to their gasoline or diesel counterparts. The high activities for future CNG engines research and development to meet future CNG engines is recorded in the paper. [8]

The initial investigations into the use of ethanol in diesel engines were carried out in South Africa in the 1970s [9] and continued in Germany and the United States during the 1980s [10, 11]. Most of these works relate a reduction in the smoke and particle levels emitted in the exhaust [12]. This point, of increasing importance today, alone justifies the incorporation of ethanol into fuels.

E. Ramjee, K. Vijay Kumar Reddy, and J. Suresh kumar their project title is " Performance and emission characteristics of compression ignition (C.I) engine with dual fuel operation (diesel + CNG) " the main objective of this work is to study the Performance and emission characteristics of compression ignition (C.I) engine using CNG for following conditions . i) At constant speed by varying injection pressure and load ii) Dual fuel combustion phenomenon. Some of the pollutants released by the engine are un-burnt hydro carbons (UBHC), CO, NOx, smoke and particulate matter. His conclusion is the engine performance is better on CNG compared to pure diesel up to engine loads of about 75.67% . [13]

Prof.H.B.Parikh, Prof.V.M.Prajapati, Prof.K.H. Thakkar, their project title on "Performance evaluation and emission analysis of 4-s, I.C engine using ethanol bio-diesel blends with diesel fuel " their Experiment set up was developed to carryout engine performance and emission characteristic studies on selected fuel blends at different load conditions. The present work has resulted in giving a good insight into the performance and emission characteristics of the C.I. engine using ethanol, biodiesel, diesel fuel blends. As fuel property point of view density and pour point of all the fuel blends are under the standard limits for diesel fuel. Heat of combustion of all blends is found to be lower than that of diesel fuel alone. Their conclusion is D70B20E10 gives lower CO and HC emission and slightly higher thermal efficiency than other blends. [14]

Abhishek Paul, Probir Kumar Bose, Raj Sekhar Panua, Rahul Banerjee their title on "An experimental investigation of performance-emission trade off of a CI engine fueled by diesel–compressed natural gas (CNG) combination and diesel–ethanol blends with CNG enrichment" Their study deals with one such approach in which the potential of diesel ethanol blending and subsequent CNG (compressed natural gas) enrichment have been investigated. Their study starts with a miscibility test of ethanol in diesel, which paves the way for an experimental comparison between performance and emission characteristics of Diesel Ethanol blends, Diesel CNG combinations and Diesel Ethanol blends with CNG enrichment. Their results indicates that diesel ethanol blend D95E5 (95% diesel 5% ethanol) with low CNG enrichment produces a better performance-emission characteristics as compared to base diesel operation as well as diesel ethanol blend operation. Results also portrayed ethanol's potential in reducing NOx emission, BSEC and smoke opacity [19].

2. FUEL PROPERTIES

2.1 Ethanol Properties: Ethanol is a volatile, colorless liquid that has a slight odor. It burns with a smokeless blue flame that is not always visible in normal light.The physical properties of ethanol stem primarily from the presence of its hydroxyl group and the shortness of its carbon chain. Ethanol's hydroxyl group is able to participate in hydrogen bonding, rendering it more viscous and less volatile than less polar organic compounds of similar molecular weight, such as propane.

Ethanol is slightly more refractive than water, having a refractive index of 1.36242 (at λ=589.3 nm and 18.35 °C or 65.03 °F)[1]. The triple point for ethanol is 150 K at a pressure of 4.3×10^{-4} Pa[2]. Ethanol is a versatile solvent, miscible with water and with many organic solvents, including acetic acid, acetone, benzene, carbon tetrachloride, chloroform, diethyl ether, ethylene glycol, glycerol, nitromethane, pyridine, and toluene.[1][3] It is also miscible with light aliphatic hydrocarbons, such as pentane and hexane, and with aliphatic chlorides such as trichloroethane and tetrachloroethylene.[3]

An ethanol-water solution that contains 40% ABV (alcohol by volume) will catch fire if heated to about 26 °C (79 °F) and if an ignition source is applied to it. This is called its flash point.[4] The flash point of pure ethanol is 16.60 °C (61.88 °F), less than average room temperature.[5]. Alcoholic beverages that have a low concentration of ethanol will burn if sufficiently heated and an ignition source (such as an electric spark or a match) is applied to them. For example, the flash point of ordinary wine containing 12.5% ethanol is about 52 °C (126 °F).[6].

2.2 CNG as a fuel Characteristics

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The octane rating of natural gas is about 130, meaning that engines could operate at compression ration of up to 16:1 without "knock" or detonation. Many of the automotive makers already built transportation with a natural gas fuelling system and consumer does not have to pay for the cost of conversion kits and required accessories. Most importantly, natural gas significantly reduces CO_2 emissions by 20-25% compare to gasoline because simple chemical structures of natural gas (primarily methane – CH_4) contain one Carbon compare to diesel ($C_{15}H_{32}$) and gasoline (C_8H_{18})[15, 18]. Like methane and hydrogen is a lighter than air type of gas and can be blended to reduce vehicle emission by an extra 50%. Natural gas composition varies considerably over time and from location to location[15]. Methane content is typically 70-90% with the reminder primarily ethane, propane and carbon dioxide[16, 17]. At atmospheric pressure and temperature, natural gas exists as a gas and has low density. Since the volumetric energy density (joules/m3) is so low, natural gas is often stored in a compressed state (CNG) at high pressure stored in pressure vessels.

Compressed natural gas (CNG) has long been used in stationary engines, but the application of CNG as a transport engines fuel has been considerably advanced over the last decade by the development of lightweight high-pressure storage cylinders.

CNG Properties	Value
Density (kg/m3)	0.72
Flammability limits (volume % in air)	4.3-15
Flammability limits (Ø)	0.4-1.6
Autoignition temperature in air (0C)	723
Minimum ignition energy (mJ)b	0.28
Flame velocity (ms-1)b	0.38
Adiabatic flame temperature (K)b	2214
Quenching distance (mm)b	2.1
Stoichiometric fuel/air mass ratio	0.069
Stoichiometric volume fraction %	9.48
Lower heating value (MJ/kg)	45.8
Heat of combustion (MJ/kgair)b	2.9

3. EXPERIMENTAL SETUP

In the present work an experimental investigation was carried out on a single cylinder compression ignition engine to optimize the performance and emission characteristics and to find out the best composition of ethanol and CNG along with diesel under dual fuel mode. Engine used in the present study is a Kirloskar, single cylinder, water cooled diesel engine with the required specification. 10lpm CNG was sent through induction method under 0.5kw, 1.0kw, 1.5kw, 2.0kw, 2.5kw and 3kw loads with 10%, 15% , 20%, 25% and 30% of ethanol in diesel.

3.1. Experimentation: The experimental setup consist of single cylinder four stroke engine using 3kw diesel engine generator, with compression ratio of 16.5:1 and injection pressure of 240bar. The tests were performed at engine speed ranges from 1500 rpm. In this type of engine, both diesel and natural gas were introduced into the engine cylinders during compression. As natural gas will not ignite under compression alone, the diesel is required to act ignite gas/air mixture. When natural gas refuelling points are not available, the engine can revert to conventional operation.

3.2 Engine Specifications:

Manufacturer	Kirloskar Engine
Type	Single cylinder, 4 stroke, vertical compression air cooled, fixed throttle
Make:	Kirloskar AV-1
Rated power :	3.7 KW, 1500 RPM
Bore and stroke:	80mm×110mm
Compression ratio:	16.09:1, variable from 13.51 to 19.69
Cylinder capacity:	553cc
Dynamometer :	Electrical-AC Alternator
Fuel :	Diesel and Biogas
Calorimeter:	Exhaust gar calorimeter
Starting : Hand cranking and auto start so provided.	

Table 3.2.1. Engine Specifications

3.3 . Experimental Procedure

The engine was started with neat diesel as fuel at no load by pressing the inlet with decompression lever and it was released suddenly when the engine was hand cranked at sufficient speed and it was allowed to run about half an hour till the steady state conditions reached. The engine was then loaded gradually from no load to full load (i.e. 0% to 100%) in the step of 20% keeping the speed within the permissible range and the observations of different parameters were recorded. With the fuel measuring apparatus and stop watch the time elapsed for the fuel consumption for 20 ml of fuel

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was measured. The other observations recorded were brake load reading, engine speed, exhaust gas temperature, cooling water inlet & outlet temperatures etc. Besides these parameters, CO (carbon monoxide), HC (hydro carbon) emissions were also measured or recorded by "Gas Analyzer" for various blends of diesel and ethanol with CNG 10Lpm. This experiment was taken into account to prepare base line data for neat diesel. The various blends of ethanol with diesel and constant flow of CNG 10 lpm with 90% of air that was tested on same engine in the same manner as described above are as follows:

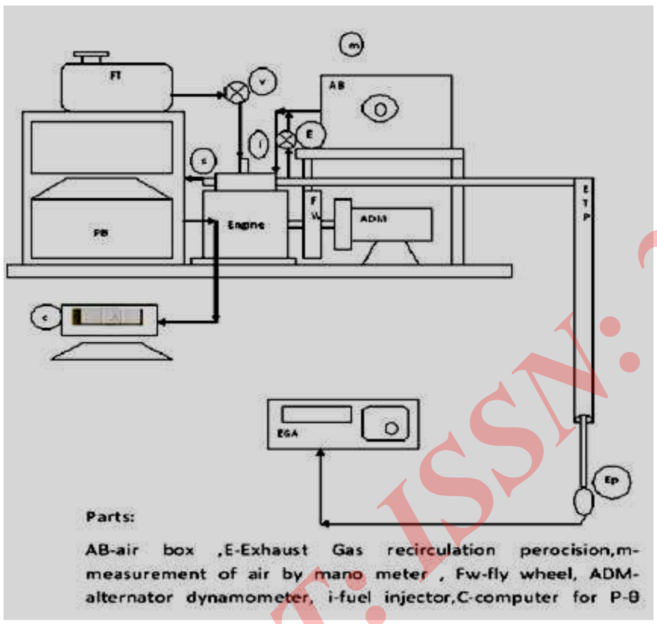

Fig. 3.2.1 Engine Setup

4. RESULTS AND DISCUSIONS

4.1. Brake Thermal Efficiency Vs Brake Power

The brake thermal efficiency is a measure of the engine's ability to make efficient use of fuel For the fuel tested, increase in Brake Thermal Efficiency was found with increase in brake power. It can be seen from this below figure 4.1 graph that at different loads, the Brake Thermal Efficiency of D80E20 is slightly higher than D100, D90E10, D85E15, D75E25, D73E27, D70E30, D50E50, blends.

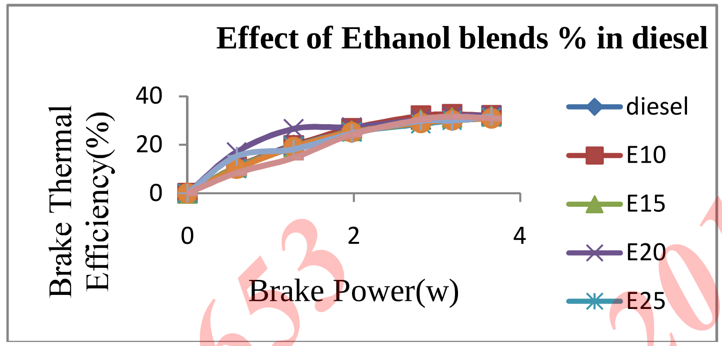

Figure 4.1: Brake power versus brake thermal efficiency of Ethanol blends with diesel

4.2 Brake Specific fuel Consumption at Different Loads

Brake Specific Fuel Consumption (B.S.F.C.) is the fuel consumed by the engine per unit of power output or produced. For fuel tested, decrease in B.S.F.C. was found with increase in brake power. It can be seen from below figure 4.21 graph that as Brake Power increases, B.S.F.C. decreases to minimum different load condition. By observing related results at different loads engine condition, the value of B.S.F.C. for D50E50 blend is minimum. As compared to diesel, calorific value of ethanol is less, so slight rise in Brake Specific Fuel Consumption was found in the blends D90E10, D85E15, D80E20, D75E25, D73E27, D70E30 than Diesel fuel

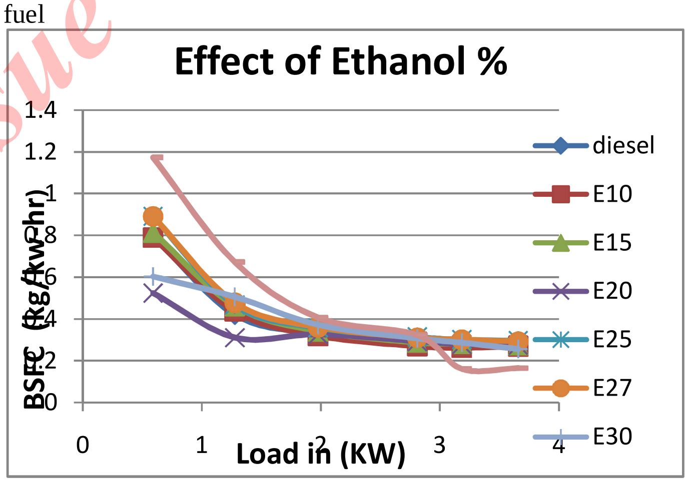

Fig: 4.21 Brake Power versus BSFC in ethanol blends with diesel at various loads

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Brake Specific Fuel Consumption (B.S.F.C.) is the fuel consumed by the engine per unit of power output or produced. For fuel tested, decrease in B.S.F.C. was found with increase in brake power. It can be seen from below figure (6), graph that as Brake Power increases, B.S.F.C. decreases to minimum different load condition. By observing related results at different loads engine condition, the value of B.S.F.C. for D70E30 blend is minimum. As compared to diesel, calorific value of ethanol is less, so slight rise in Brake Specific Fuel Consumption was found in the blends D90E10, D85E15, D80E20, D75E25, than Diesel+ethanol blends with 10lpm CNG.

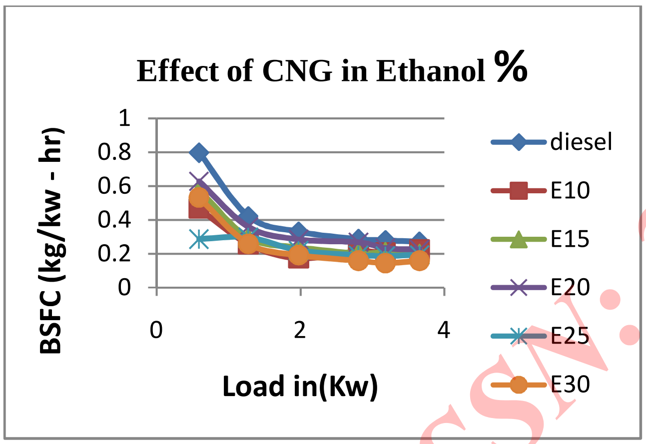

Fig: 4.2.2 Brake Power versus BSFC at ethanol blends in diesel with CNG 10lpm at various loads

4.3. Hydro Carbons (HC) in Diesel-Ethanol

Fig. 4.3 HC (ppm) Vs B.P. (W)At different load conditions, Hydrocarbons (HC) were recorded by "Gas Analyzer" for various blends of diesel and ethanol i.e. D90E10, D85E15, D80E20, D75E25, D73E27, D70E30 and D50E50. The partially decomposed and oxidized fuels in exhaust, which are un-burnt species, are collectively known as unburnt hydrocarbon emissions.Fig:7.shows graph for variation of HC emission with respect to brake power for various blends of diesel, and ethanol. HC emission for diesel fuel is slightly higher at different loads than other all blends

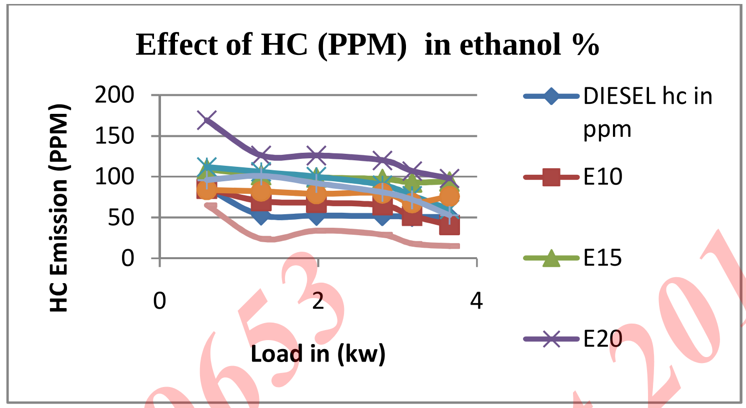

Fig: 4.3 Brake Power versus HC emission with diesel - ethanol blends at various loads

4.4. Carbons Dioxide (CO2) in Diesel-Ethanol

From the fig 4.4 CO2 (%) Vs B.P. (W) At different load conditions, Hydrocarbons (CO2) were recorded by "Gas Analyzer" for various blends of diesel and ethanol i.e. D90E10, D85E15, D80E20, D75E25, D73E27, D70E30 and D50E50. The partially decomposed and oxidized fuels in exhaust, which are un-burnt species, are collectively known as un-burnt hydrocarbon emissions.Fig:9.shows graph for variation of CO2 emission with respect to brake power for various blends of diesel, and ethanol. CO2 emission for D85E15 is slightly higher than diesel fuel at different loads than other all blends.

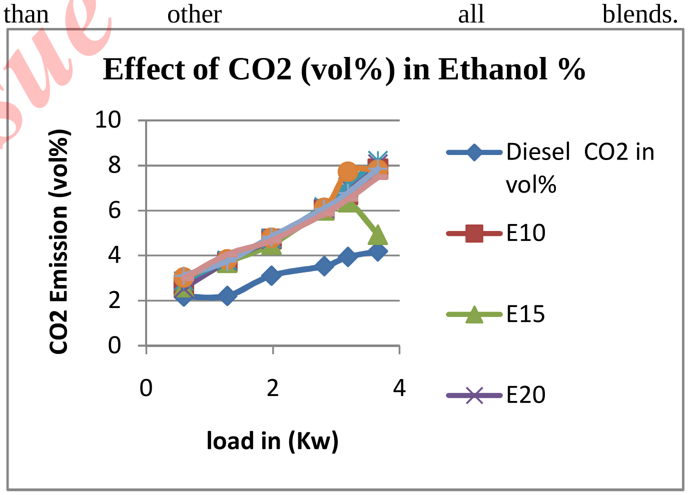

Fig: 4.4 Brake Power versus CO_2 with diesel - ethanol blends at various loads

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4.5 Carbon Monoxide (CO) in Diesel-Ethanol Blends

At different load conditions, Carbon Monoxide (CO) was recorded by Gas-Analyzer for various blends of diesel & ethanol i.e. D90E10, D85E15, D80E20, D75E25, D73E27, D70E30 and D50E50. Fig: 4.5 shows graph for variation of CO emission with respect to brake power for various blends of diesel, biodiesel and ethanol. It can be seen from graph that the CO emissions are low at D85E15 and D50E50 is slightly decresing to comparing for various blends

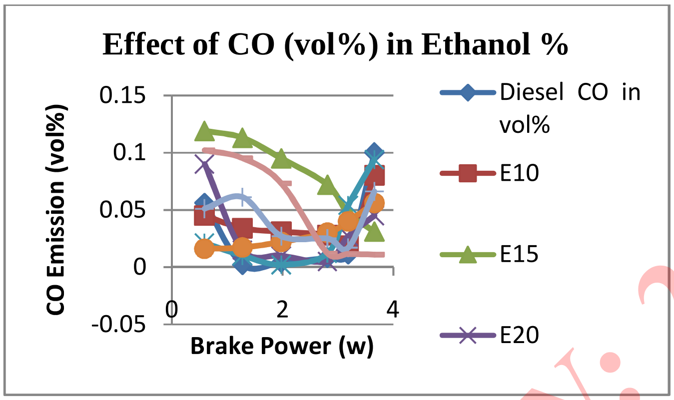

Fig: 4.5 Brake Power versus CO with diesel - ethanol blends at various load

4.6. Hydro Carbons (HC) in Diesel-Ethanol Blends With CNG 10lpm

Fig:4.6 HC (ppm) Vs B.P. (W) At different load conditions, Hydrocarbons (HC) were recorded by "Gas Analyzer" for various blends of diesel and ethanol with 10lpm CNG i.e. D90E10, D85E15, D80E20, D75E25,and D70E30 for dual fuel operation. The partially decomposed and oxidized fuels in exhaust, which are unburnt species, are collectively known as un-burnt hydrocarbon emissions.Fig:12.shows graph for variation of HC emission with respect to brake power for various blends of diesel-ethanol with 10lpm CNG. HC emission for D80E20 with 10lpm cng is slightly lower at different loads than other all blends.

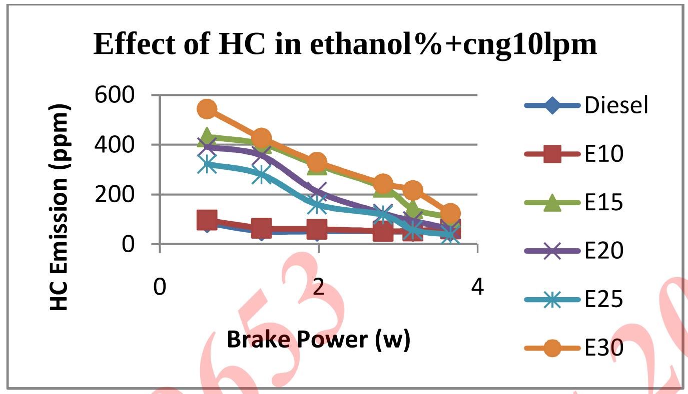

Fig: 4.6 Brake Power versus HC (ppm) in ehanol blends and (CNG 10lpm) with dual fuel operation

4.7 Nitrogen Oxide (NOx) in Diesel-Ethanol Blends With CNG 10lpm

Fig: 4.7 NOx (ppm) Vs B.P. (W) At different load conditions, Nitrogen Oxide (NOx) were recorded by "Gas Analyzer" for various blends of diesel and ethanol with 10lpm CNG i.e. D90E10, D85E15, D80E20, D75E25,and D70E30 for dual fuel operation. The partially decomposed and oxidized fuels in exhaust, which are un-burnt species, are collectively known as un-burnt hydrocarbon emissions.Fig:13.shows graph for variation of NOx emission with respect to brake power for various blends of diesel-ethanol with 10lpm CNG. NOx emission for D80E20 with 10lpm cng is slightly lower at different loads than other all blends

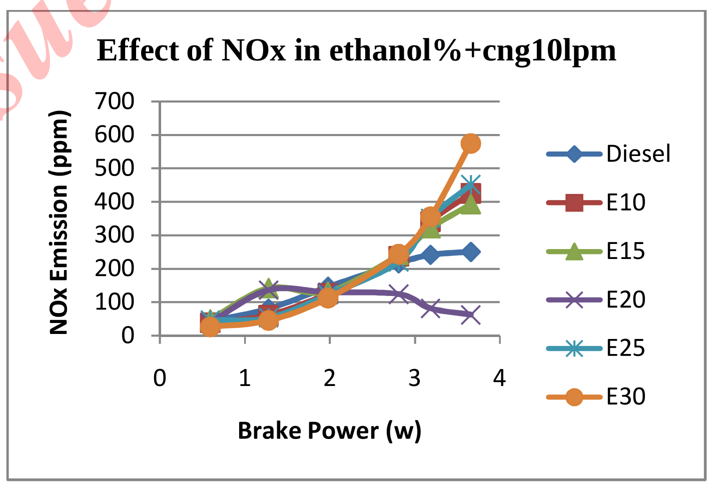

Fig:4.7 Brake Power versus NOx (ppm) in ehanol blends and (CNG 10lpm) with dual fuel operation

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4.8 Carbon Monoxide (CO) in Diesel-Ethanol Blends with CNG 10lpm

At different load conditions, Carbon Monoxide (CO) was recorded by Gas-Analyzer for various blends of diesel-ethanol with CNG 10lpm i.e. D90E10, D85E15, D80E20, D75E25, D73E27, D70E30 and D50E50 for dual fuel operation. Fig.4.8 shows graph for variation of CO emission with respect to brake power for various blends of diesel-ethanol. It can be seen from graph that the CO emissions are low at D85E15 is slightly decresing to comparing for various blends .

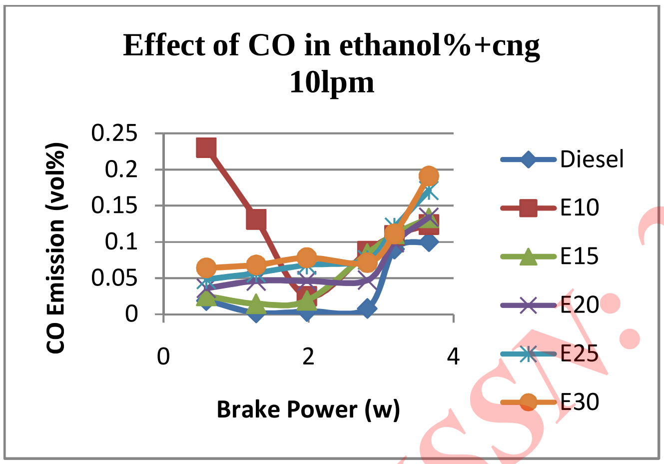

Fig:4.8 Brake Power versus CO (VOL %) in ehanol blends and (CNG 10lpm) with dual fuel operation

5. CONCLUSIONS

- Dual fuel operation is more convenient and economical for conserving the precious conventional liquid fuels
- Using ethanol blends in diesel engine to reducing the emission characteristics
- Improving the engine performance at D80E20 blend with comparing to pure diesel basis
- Improving the engine performance at D70E30 blend with CNG 10lpm for dual fuel operation comparing to pure diesel basis
- Emissions of NOx , HC are decreased at D80E20 blend with CNG for dual operation
- Emissions of CO2, CO are decreased at D85E15 blend with CNG for dual operation

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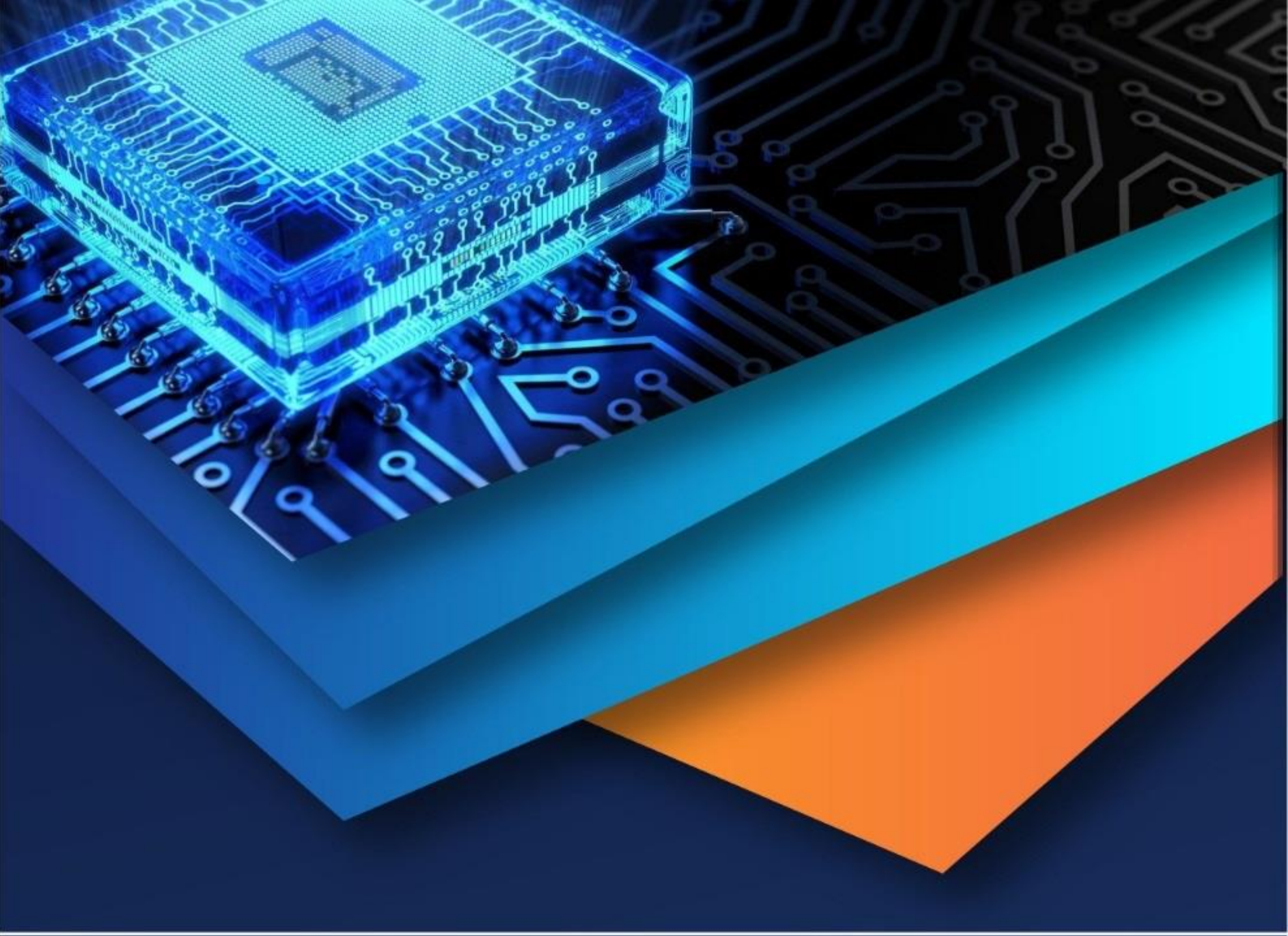

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