ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.4

Effect of Varying Compression Ratio on Engine Performance and Emissions in a Twin Spark Ignition Engine Fueled with Blends of Gasoline and Ethanol

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Abstract:
Owing to the fact that Ethanol can be produced from renewable source of energy, Ethanol has become one of the most favorable and possible alternate sources of fuels that can be used in internal combustion engines to extend the availability of fossil fuels. Ethanol can be easily and conveniently mixed with Petrol and Diesel in all proportions, this property enables it to be used as a fuel in Spark Ignition (SI) engines as well as in Compression Ignition (CI) engines without making any changes to the existing engines. In a single spark plug engine, often the charge is not completely burnt and results in engine underperforming and increased emissions of Carbon monoxide (CO) and unburnt hydrocarbons (HC), from the engine exhaust. With the introduction of second spark plug we can expect better engine performance and reduced emissions. This paper brings out the performance characteristics and exhaust emissions of a twin spark ignition engine. The engine was fueled with different blends of petrol and ethanol under different compression ratios. The performance of the engine was studied under different compression ratios at constant speed conditions. From the investigations it is observed that, the blends of petrol and gasoline yielded better results than pure petrol. Increasing the compression ratio of the engine, increases the mechanical efficiency and brake thermal efficiency considerably with lesser percentage of engine emissions like CO CO_2 and HC. It was experimentally observed that with the increase in percentage of ethanol in the gasohol blend CO and UHN emissions were reduced significantly.

Keywords: Compression ratio, ethanol, gasoline, Carbon monoxide-(CO), Carbon-di-oxide -(CO_2), Unburnt hydrocarbon-(HC), twin spark ignition.

I. INTRODUCTION

It has been a century and a half that the various enforcements to protect the earth from harmful pollutants have become very stringent. Ethanol is a biofuel which has the properties very close to that of gasoline and can be mixed blended with gasoline in all proportions. On blending with gasoline the combined properties of the fuel such as the anti-knock characteristics and octane number is improved. Gasoline has a lower value of octane and is thus less knock resistive as compared to ethanol

With increasing content of ethanol in the blend, the octane number and antiknock characteristics of the blend increases. Although ethanol can be used as a fuel in its pure form, due to the competition of "food or fodder" and also due to limited technology ethanol has not been used as a complete fuel.

India is the second largest sugarcane growing country in the world, owing to this blending ethanol with gasoline improves the economic status of the country and protects the environment from harmful radiations. These parameters compelled our investigation to move in that direction and investigate the optimal gasoline ethanol blend that could be safely blended and used in the existing vehicles without making any modifications.

II. LITERATURE SURVEY

Ethanol is a pure substance and has a chemical formula as C_2H_5OH. The presence of hydroxyl group makes it a partially oxidized hydrocarbon. With different ethanol-gasoline blends, the improved efficiency and reduced emission of the engine is observed. This hydroxyl group is responsible for complete combustion of the fuel [1]. Ethanol mixes with water in all proportions whereas ethanol and water forms an immiscible mixture. This immiscible nature of gasoline causes the blended fuel to contain traces of water which corrodes the engine components when they come in contact with water. To bring down the ill effects of ethanol-gasoline blend, materials which gets corroded easily with water should not be used [2]. Ethanol has a greater affinity towards rubber, thus all the rubber products react easily with ethanol at higher concentration of ethanol in the blend and creates a blockage to the fuel flow [3]. Ethanol has a higher auto ignition temperature of about 365°C and a higher flash point of 16.6 °C as compared to auto ignition temperature of 280^0 C and Flash point −43 °C for gasoline thus it can be easily transported and stored. Ethanol has a latent heat of evaporation 5 times greater than that of gasoline; this lowers the intake manifold temperature and thus there is an increase in volumetric efficiency with increase in the ethanol content in the blend. With increasing ethanol content, the heating value of the blend also decreases, as ethanol has a lower calorific value of 29.7 MJ/kg as compared to that of gasoline's 45.5 MJ/kg thus to produce the same amount of output energy we require 1.5 times more alcohol than that of gasoline. Due to the presence of hydroxyl group the stoichiometric air fuel ratio of ethanol gets reduced to 2/3rd that of gasoline, thus complete combustion occurs at a relatively lesser air fuel ratio as compared with that of gasoline. The most important contributors for the air pollution are the industries and the automobiles. Pollution caused by the emissions of automobile became prominent in the year 1940 and it was proved in 1952 by Prof. Haagen Smit that automobiles were the major contributors for the increasing levels of carbon monoxide and nitrogen oxide derivatives. As a result of this, the emissions norms were first introduced in the California and in turn this was followed by the rest of the world. Using suitable proportions of Ethanol and gasoline blends in Internal Combustion Engines (IC) would result in reducing the emissions, extend the availability of gasoline and improve the efficiency of the IC engine [4,5,6,7]. Various researchers in their investigation have found that ethanol is the best alternate for gasoline. In his investigations on different blends of ethanol and gasoline Palmer [8] has found an increase in power output by 5% with 10 % ethanol addition and also octane number increased by 5% with every 10% ethanol addition. Bata et al [9]. studied the effect of ethanol and gasoline blend in their experimentation and arrived at the conclusion that addition of ethanol to gasoline would increase availability of oxygen required for complete combustion and thus reduces the exhaust emissions like CO and unburnt HC. Also Palmer [7] has suggested that by adding 10% of ethanol to gasoline resulted in the CO reduction to about 30%. Abdel Rahman et.al [10] in his experiments with Ethanol-gasoline blends has investigated that, addition of ethanol would increase the octane number but will reduce the heating value of the fuel with the increasing ethanol percentage the blend attains higher antiknock properties and thus can be operated at higher compression ratios. Alexandrian and Schwalm [11] in their experimental investigation have shown that using ethanol with gasoline reduces the CO and NOx at fuel rich conditions but the use of ethanol gasoline blend results in the emission of formaldehyde, acetaldehyde and acetone 5.12–13.8. The harmful effects of aldehydes and acetone to the atmosphere as compared with that of the poly nuclear emissions of petrol is far lesser thus, higher quantity of ethanol can be blended with gasoline [12].

III. EXPERIMENTAL SETUP AND PROCEDURE

Test rig used in the experimentation comprises of a Single cylinder, four stroke, twin spark ignition, Pulsar 220 CC Bajaj make engine. The specifications of the engine are as shown in Table 1.

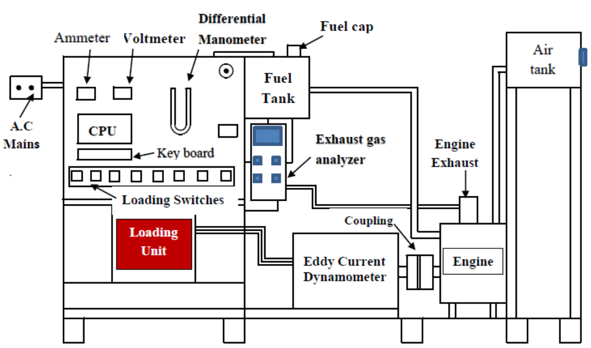


Figure .1. Experimental Setup

Fuel flow Measurement is recorded by noting down the time taken for 10 cc of fuel flow through a burette mounted on the panel board of the test rig. Air flow measurement is made with an orifice meter mounted on one side of a cubical box. Head on the engine is noted by a U-tube differential manometer. Speed of the engine is measured by a proximity sensor connected to a digital clock. The engine is loaded electrically by a heat bank and time taken for five blinks of energy meter is noted using a stop watch. The engine is mounted with an encoder and a piezoelectric transducer to measure pressure developed inside the cylinder at different crank angles. Piezoelectric transducer and the encoder readings are obtained on the screen of a computer. The signal from the pressure transducer is conditioned by means of a charge amplifier and is sent to the acquisition equipment.

Table.1.Test engine specifications

Engine Type	4-Stroke, DTS-I, Single Cylinder
Engine Displacement(CC)	220 cc
Power (PS @ rpm)	20.76 bhp @ 8500 rpm
Torque (Nm @ rpm)	19.12 Nm @ 7000 rpm
Bore	67 mm
Stroke	62.4 mm
Rated Compression Ratio	9.5:1
No Of Cylinders	1
Valves (per cylinder)	2
Fuel supply System	Carburetor
Engine Cooling System	Oil and air cooled
Fuel Type	Petrol
Ignition	Digital Twin Spark

The signal provided by the encoder with a resolution of 0.1 grades (3600 pulses per revolution) is fed to the same instrument. A sampling frequency of 120 kHz is used for cylinder pressure monitoring. Thus the engine's thermodynamic cycle is reconstructed from the chamber pressure data and crankshaft position with respect to the top dead center. An emission analysis system is also equipped to measure the exhaust emissions of the engine.

IV. TEST FUELS

The engine was fuelled with blends of ethyl alcohol and gasoline. For the experimentation anhydrous ethanol of 99.9 % purity is used. The percentage of ethanol in the blends is increased by 5% starting from E0 and the blends are designated as E0, E5, E10, E15, E20, E25, E30 and E35. In the designation 'E' represents 'Ethanol' and the number following 'E' indicates the volumetric percentage of ethanol contained in the blend. Properties of Ethanol and gasoline are tabulated in table 2.

Blends containing 5%, 10%, 15%, 20%, 25%, 30% and 35% ethanol are prepared by "splash blending"

Table.2.Properties of Gasoline and ethanol

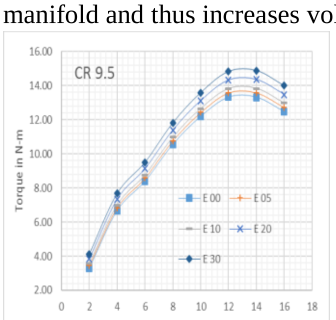
Fuel property	Gasoline	Ethanol
Formula	C_8H_{18}	C_2H_5OH
Molar C/H ratio	0.445	0.333
Molecular weight (kg/kmol)	114.18	46.07
Latent heating value (MJ/kg)	44	26.9
Stoichiometric air/fuel ratio	14.6	9
Auto-ignition temperature (°C)	257	425
Heat of vaporization (kJ/kg)	305	840
Research octane number	88–100	108.6
Motor octane number	80–90	89.7
Freezing point (°C)	40	114
Boiling point (°C)	27–225	78
Density (kg/m3)	765	785

Experiments were first conducted using pure gasoline and the corresponding readings at the rated compression ratio are tabulated. Further the experimentation is carried out by changing the compression ratio from 9.5:1, to 10:1 and then to 10.5:1, corresponding readings are recorded. The same experimentation is conducted using different gasohol blends at the rated compression ratio and varying the compression ratios from 9.5:1, to 10:1 and to 10.5:1 the corresponding readings are recorded.

V. RESULTS AND DISCUSSIONS

Brake torque, Brake power and volumetric efficiency at constant load

The effects of ethanol gasoline blends on engine torque, brake power and volumetric efficiency at constant speed of 6000 rpm and compression ratios of 9.5:1, 10:1 and 10.5:1 are shown in Figures 2, 3 and Figure 4 respectively. from the graphs it is evident that in comparison with E0, the ethanol gasoline blends showed a significant increase in brake torque, brake power and volumetric efficiency under constant speed of 6000 rpm. As the ethanol percentage is increased, the heating value of the blend decreases but, torque and power increases significantly. As ethanol is an oxygenated fuel, it aids in complete combustion of the fuel by readily contributing the oxygen required for complete combustion. The second spark plug in the combustion chamber reduces the flame front propagation time. Ethanol has a higher density, due to this fact a larger quantity of fuel will be admitted into the combustion chamber. Also with the increasing proportions of ethanol in gasohol blend, the latent heat of evaporation of the corresponding blend increases. This increase in latent heat of evaporation lowers the temperature at intake manifold and thus increases volumetric efficiency.



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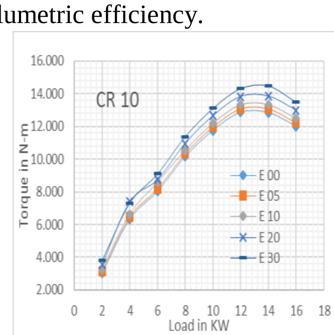

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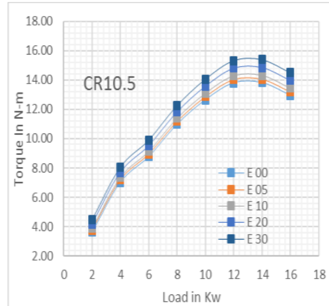

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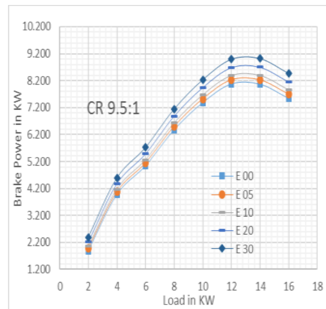
Figure.1. Effect of ethanol gasoline blends on engine torque under varying load for (a) CR 9.5:1 (b) 10:1(c) 10.5:1



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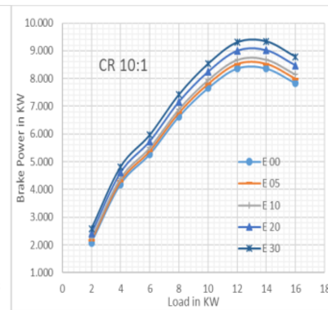

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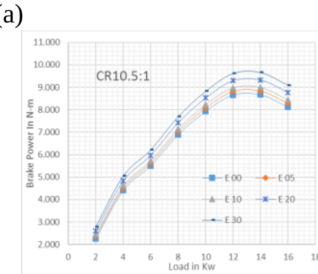

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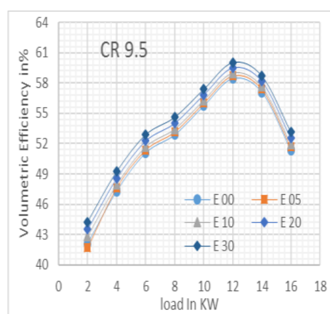
Figure .3. Effect of ethanol gasoline blend on brake power under varying load for (a)CR 9.5:1, (b)10:1(c)10.5:1



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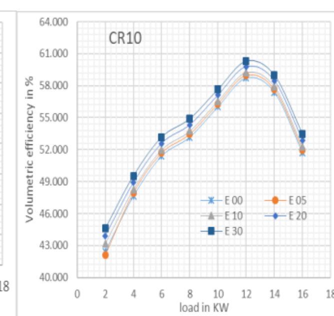

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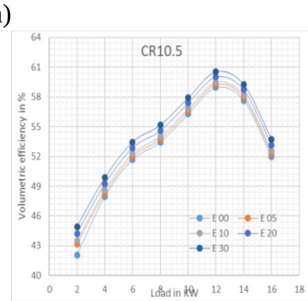


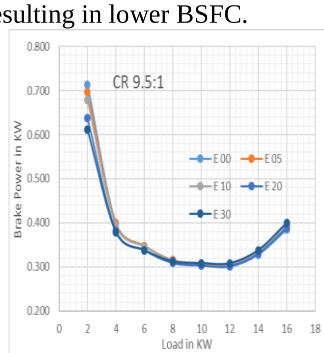
(c)

Figure.4. Effect of ethanol gasoline blends on Volumetric Efficieency under varying load for (a) CR 9.5:1 (b) 10:1(c) 10.5:1

The power and torque developed by an engine, is a dependant factor on the charge that is being admitted into the engine's combustion chamber. By increasing the compression ratio, providing second spark plug and increasing the ethanol percentage in the gasohol blend, it is observed that the brake power and brake torque increases significantly.

Brake specific fuel consumption-

Brake Specific fuel consumption (BSFC) was determined under constant speed condition, by measuring the fuel admitted into the combustion chamber of the engine. The fuel consumed for a particular period of time was measured. The variations in the brake specific fuel consumption using different blends with respect to engine speed of 6000 rpm at compression ratios of 9.5:1, 10:1 and 11:1 respectively are shown in Figure 5. In comparison with neat petrol, E5, E10, E20 and E30 showed a considerable change in BSFC With increasing load at constant speed, the brake specific fuel consumption decreases form a higher initial value to a lower mid value and again increases to a higher end values at higher loads. In the current experimental investigation BSFC decreased by 2% for maximum torque at a Compression ratio of 10.5:1 and E30 blend, When the engine is cranked from rest, a greater amount of energy is required to overcome the effect of load on engine and internal frictional losses. As the engine warms up and gains momentum, quantity of fuel required to overcome these losses will be reduced resulting in lower BSFC.



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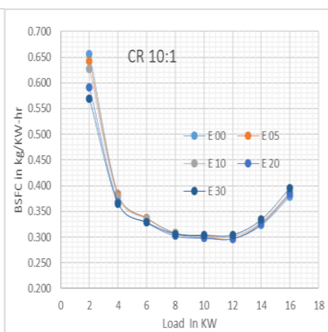

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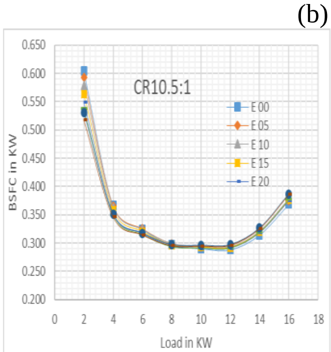

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Figure .5. Effect of Ethanol gasoline blend on BSFC under varying load for (a) CR 9.5:1, (b)10:1, (c) 10.5:1

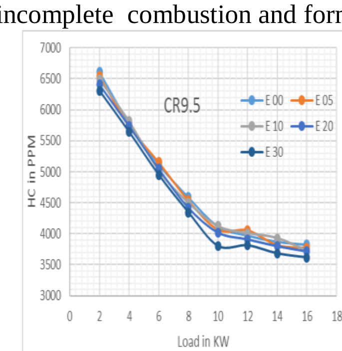
Eventually when load on the engine is increased, energy required to overcome frictional losses at same speed increases thus BSFC again starts increasing.

Brake thermal Efficiency

Brake thermal efficiency of a twin spark ignition engine is found to increase at higher compression ratios and with the higher ethanol content in the blend. Higher loads reduce the friction to brake power ratio thus combustion temperature increases with increase in load, additional spark plug in the combustion chamber minimizes the flame propagation time and oxygen in ethanol will readily support the combustion process resulting in complete combustion. It is observed in the current experimentation that the maximum brake thermal efficiency increases by 23.5% for E 30 at a compression ratio of 10.5:1. Brake thermal efficiency increases with the load to a maximum and then starts to decrease the effect of ethanol and gasoline blends are shown in figure 6.

Un burnt Hydrocarbon and Carbon monoxide CO

At higher engine speeds, time available for flame propagation is too less, oxygen required in the charge for complete combustion of fuel is also very less. These two parameters result in incomplete combustion and formation of CO.



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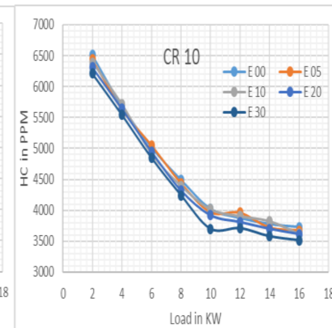

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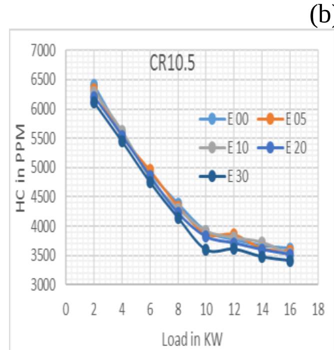


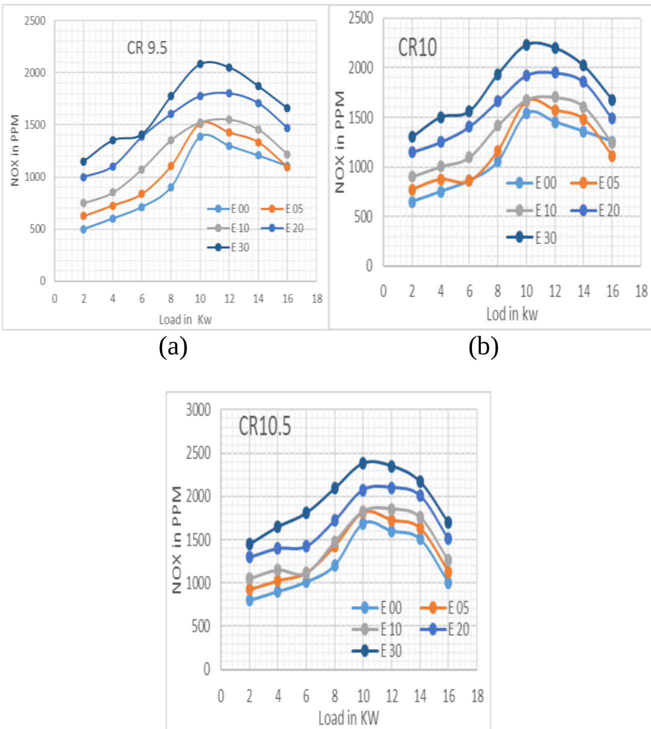
(c)

Figure.6. Effect of ethanol and gasoline blends on Unburnt hydrocarbons at varying load for (a) CR 9.5:1, (b) 10:1, (c)10.5:1

Providing an additional spark plug, increasing the compression ratios and blending the fuel with an oxygenated fuel would result in stable combustion processes and increased flame front propagation speed leading towards lesser CO emission. The charge temperature, at the end of compression stroke under higher compression ratios would be sufficiently high to burn maximum hydrocarbons. Increased Ethanol content in the blend readily suffices the extra oxygen required resulting in complete combustion Figure 5 shows the effect of ethanol gasoline blends on a twin spark ignition engine at constant speed and varying loads under different compression ratios.

NO_X derivatives

When the engine is operated under higher loads and higher compression ratios, stable combustion processes and faster flame propagation speed is achieved resulting in increased combustion chamber temperature. This increased temperature aids in the formation of a series of nitrogen oxide derivatives. Thus formation of NO_x derivatives at higher temperatures can be coined as a necessary evil. though complete combustion of the admitted charge is necessary to minimize exhaust emissions the resulting increased in-cylinder temperature leads to the formation of NO_x. Due to this, the engine when operated at higher compression ratios and higher speeds, NO_x emissions increases and can be seen in the Figure 7.



(a) (b)

(c)

Figure.7. Effect of ethanol and gasoline blends on Nitrogen oxides at varying load for (a) CR 9.5:1, (b) 10:1, (c)10.5:1

Various methods like Exhaust Gas Recirculation (EGR), Water injection and water emulsion, and Selective Catalytic Reduction (SCR) techniques may be implemented to bring down the NO_x content in the exhaust emissions.

VI. CONCLUSION

In the present experimental work, it is observed that using higher blends of ethanol with gasoline in a Twin Spark ignition engine minimizes the exhaust emission like CO and unburnt HC at higher loads and compression ratios. Ethanol has a higher octane rating of about 120 of 90 as compared with that of petrol. Addition of ethanol to petrol increases the octane rating of the petrol, with this increased octane number, the blend develops better knock resistance as compared to gasoline alone.

- Higher percentage of ethanol in the blend assures combustion of the blend without knocking even at higher compression ratios.
- The higher latent heat of evaporation of ethanol produces better brake torque for all loading conditions in comparison with pure gasoline.
- Blending ethanol with gasoline up to 30 % showed an increase in brake power by 20%.
- At compression ratio of 10.5:1, E30 showed 8% reduction in CO and an increase of 12% in Carbon di Oxide and Unburnt hydrocarbon content reduced by 10% in the exhaust gases.

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VIII. ACKNOWLEDGEMENTS

I thank the management, Principal, HOD, my colleagues, non-teaching fraternity and supporting staff of KSSEM, for providing me the facilities and helping me with all the valuable support and inputs in bringing out my work much more efficiently and successfully