Effect of various operating parameters on CI engine fuelled by D-DEE-E blend

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Abstract: All over the world air pollution has become a big threat for future of the next generation and as such researchers are working relentlessly to find an alternative clean fuel in other green fuel recourses for running CI engine. Using oxygenated additive with diesel in CI engine is the most promising technology for improving the performance and reducing the emissions. Diethyl ether and ethanol both are type of oxygenated fuel and capable of reducing the exhaust emission and improving the combustion process. In this study, performance and emission analysis has been carried out with the blend of diesel (80%) +diethyl ether (10%) +ethanol (10%) in single cylinder variable compression ratio diesel engine. The main purpose of this study was to understand the effect of compression ratio and injection pressure on the performance and emission of the CI engine. From the result, it was found that engine at 19.5 CR and 210 IP give the best results for BTE, BSFC, NOx and smoke.

Keywords: Diesel engine; Diethyl ether; Ethanol; BTE; NOx.

1. INTRODUCTION

All over the world air pollution has become a big threat for future of the next generation and as such researchers are working relentlessly to find an alternative clean fuel in other green fuel recourses for running CI engine. In 2016 EPI (environmental performance index) gave 141 ranked to India out of 180 countries. In 2018 India got 9th rank on most polluted (included both air and water pollution) countries in the world [1]. In India 70 percent of air pollution comes from the automobile. Vehicles on the city roads have exceeded 210023289 and there has been a consistent increase in the number vehicles at an average of 8% per year [2]. These vehicles emit the poisons gases carbon monoxide (CO), oxides of nitrogen (NOx), hydrocarbon (HC) etc., which create the unhealthy environment. But society very much dependent on these vehicles and cannot eliminate the entire vehicle from the society. To overcome the dirty gases from the vehicle, the government released the vehicle of BS-IV in the country on 1 April 2017. Now Government wants to introduce a BS-VI vehicle by April 1, 2020 [3].

Diesel engines are widely used all over the world. They play very important role in the economy of the Country. According to the CSO's report, India's economic growth in the year 2018-19 was 7.2%, which was more than 0.5% from the year 2017-18 [3]. Economy growth increases fuel and gas energy consumption. Improvement in the performance of the engine can create the good difference in the economy and the health of the human. Diesel engines are very popular for their high efficiency and lower fuel consumption. But they produces high NOx, CO, smoke and Particulate matter (PM) with conventional diesel fuel. Engine performance parameter and emission characteristics can be improved by changing various parameters like compression ratio (CR), Injection timing (IT), and injection pressure (IP) [4, 5]. Changing the engine design is difficult and expensive, so it should be appropriate to change some operating parameters. Diesel engine emits more NOx compared to spark ignition (gasoline engine) [6]. The NOx are responsible for acidic rain and photochemical smog. Higher pressure and temperature in the combustion chamber increases the percentage of NOx in the compression ignition (CI) engine [7].

The simplest way to remove this problem is fuel additives. Fuel additive are the chemical compounds added with major fuel (diesel or petrol) in the engine to improve the quality and performance of the vehicle. Oxygenated additives have the potential to improve the combustion process inside the combustion chamber [2,8] oxygenated fuels are sustainable source of energy and their oxygen atoms improve the combustion process. Alcohol and ether both have high oxygen content, low viscosity and significant density which makes them the appropriate additive for the compression ignition engine [9].

The main purpose of this research work was to understand the performance and emission characteristics of the direct injection on variable compression ratio (VCR) diesel engine at different compression ratio and different injection pressure for the blend of diesel, ethanol and diethyl ether. The work is carried out at 80% diesel 10% ethanol

and 10% diethyl ether blend (As suggested by the literature). For this purpose we did not change the engine design. The research work was also compared the performance parameters of ternary fuel (Diesel-Diethyl Ether-Ethanol) blend with the pure diesel in direct injection variable compression ratio diesel engine.

By reviewing the various research papers it was found that there is a scope for study on diesel, diethyl ether and ethanol blend (D80DEE10E10) at different compression ratio and injection pressure [10].

Diethyl ether

DEE is having the high cetane number, low auto ignition temperature, high volatility and high oxygen content. One of the exceptional properties of the DEE is that it burns smoothly in the rich fuel region inside the combustion chamber.

- High volume of diethyl ether with diesel promotes knocking in the engine [11]
- Smoke, NOx and PM can reduce by adding DEE with diesel in CI engine [12]
- Brake thermal efficiency (BTE) 7.2% increased and brake specific fuel consumption (BSFC) 6.7% decreased, when diesel engines were given to diethyl ether with diesel [13]

Ethanol

Ethanol is a good fuel additive among the all alcohols for CI engine. It can be obtain from various sources, like sugarcane, sugar beets, corn and waste biomass materials. Ethanol is a favorable alternative fuel for CI Engine due to its properties like low flash point, low boiling point and high oxygen content. It is also safe additive because of its low flash point. Ethanol gives us the better and complete combustion compare to the diesel.

- Ethanol has a capability to reduce the PM and NOx of the exhaust emission [14]
- Dissolving in diesel ethanol can reduce the emissions of the vehicle
- The amount of ethanol increased the HC and CO from the engine's emission [15]
- Brake Thermal Efficiency and Break Specific Fuel Consumption Both increases with the amount of ethanol [16]
- 10% vol. ethanol addition with diesel did not require any modification and stabilizer in the engine [17]

Many studies have been carried out on direct injection diesel engine with diethyl ether and ethanol. Iranmanesh et al. [18] had evaluated the potential of DEE as supplementary fuel to improve combustion and emission of CI Engine. The experiments showed that there is a small increase in brake specific fuel consumption and brake thermal efficiency. Mohanan et al. [19] studied the effect of diethyl ether on the performance and emission of a four stroke direct injection diesel engine. The blend of 5% DEE with diesel was found to be most effective on emission and performance parameter. Patil et al. [20] conducted the experiments on single cylinder four stroke water cooled direct injection engine. The result showed that the low efficiency, high BSFC and high at full load condition. Huang et al. [21] investigated the potential of ethanol in diesel engine. The fuel consumption increased by 5 to 31% at different blending ratio of the ethanol. The CO and HC decrease at high load condition whereas NOx decreases at low load condition. Li et al. [22] explored the performance and emission of single cylinder direct injection water cooled diesel engine with the ethanol blending with diesel. Their results showed that the BSFC and BTE increase with the ethanol in blending. The smoke reduced at 10 and 15% of the ethanol in diesel. The NOx and CO also deceased at 10 and 15% of ethanol in diesel engine. Paul et al. [23] concluded that ethanol is not miscible beyond the 10% in diesel, but up to 10% there is no problem of miscibility with ethanol in diesel. Rakopoulos et al. [24] had investigated the performance of diesel engine with blending of diesel and DEE. The smoke and NOx were reducing significantly with the higher concentration of the DEE in the blending. The HC unburned particles were increased with higher concentration of the DEE in the blend. Paul et al. [10] had evaluated the performance and emission characteristics of a CI engine with blending of DEE and ethanol.

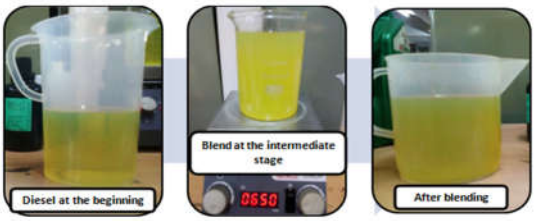


Figure: 1 Different stage of blend preparations

Among all the blends the 10% ethanol, 10% DEE and 80% diesel was found to be best. It gives the high performance and low emissions.

2. EXPERIMENTAL SETUP

Blend preparation

Blend production was the first task of the experiments. One single blend of diesel, diethyl ether and ethanol was prepared on volume basis (D80, DEE10 and D10). Magnetic stirrer with heating plate was used to preparation of the blend. This blend has been compared with the pure diesel. Various properties of the diesel, diethyl ether and ethanol have shown in the table 1.

Table 1 : Comparison of Properties of diesel, diethyl ether and ethanol [2,5,9]

Properties	Diesel	DEE	Ethanol
Chemical formula	$C_{12}H_{23}$	$C_4H_{10}O$	C_2H_5OH
Calorific value (KJ/kg)	44000	33900	26950
Density (kg/m^3)	829	713	792
Viscosity (cSt)	2.45	1.20	1.04
Cetane number	52	125	07
Latent heat of evaporation (KJ/kg)	250	350	840
Oxygen content (%)	0	22	34
Self ignition temperature (^{o}C)	250	380	420
Flash point (^{o}C)	78	-45	16.60

Engine set up

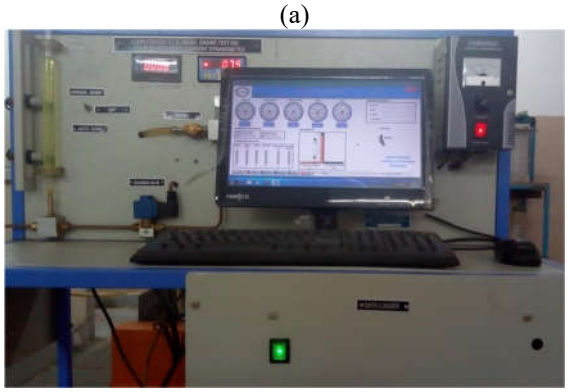
4 stroke single cylinder water cooled variable compression ratio direct injection compression ignition engine was used in this testing. Compression ratio of the engine can be change by changing the position of cylinder head with the help of handle mounted on the top of the engine head. A calibrated protector is placed on the injection nozzle, so that nozzle pressure can be change with that protector. Figure 2 shows the pictorial view of engine setup.

There were various sensors attached with engine to measure the temperature of various positions in the engine. The engine is also attached with eddy current dynamometer, computer, smoke analyzer, gas analyzer and control panel. The specifications of all equipments are given in the table 2.

Test procedure and condition

The experiments were carried out at the constant speed of 1500 rpm. The load had been varied like 0%, 25%, 50%, 75% and 100%. The load calculation had done by the eddy current dynamometer. The experiment was started by ignition switches for this battery was connected with their terminals. All the water connections should be open for cooling of the engine. Check the leak in the gas analyzer also. Now moderately varies the load on the engine by adjusting dimmer state on the control panel. The applied load on the engine is measure by strain gauge load cell. After 20-25minutes performance and emission data had been observed and recorded for different load condition on the engine.

(a)



(b)

Figure: 2 (a) Pictorial view of engine and **(b)** Pictorial view of control panel

Table 2 Equipment specifications and set up

Equipment	Specification
Engine	TVI Kriloskar, Constant rpm (1500), single cylinder, four stroke, 3750W, 0.556 litre, 8cm bore, 10.1cm stroke length, 14-21 CR, self/crank start
Dynamometer	Power mug, eddy current type, power rating 3750W, constant rpm (1500), air cooled, load sensor S type.
Exhaust Gas analyzer	AVL-DIGAS Modal- 444N NOx gas- Electrochemical, Range 0-5000 PPM , Resolution 1PPM
Fuel rate measurement	Range of fuel rate- 0-10kg/hr, resolution-0.06kg/hr The fuel rate is measured by two capacitive sensors with a glass burred and solenoid valve.
Air intake measurement	An orifice and differential pressure transmitter used for the measurement of air flow (m^3/s). range of air rate – 50m^3/hr, resolution – 0.1m^3/hr
Temperature measurement	K Type thermocouple , range 0-700^{0}C, Resolution -1^{0}C
Water flow measurement	Transducer- turbine flow type, range- 0- 99.9cc/s, resolution-0.1 cc/s

3. RESULT AND DISCUSSION

The brake thermal efficiency of engine of ternary fuel with respect to load is shown in figure. When we increase the compression ratio of the engine thermal efficiency was also increases [25]. The maximum efficiency of 45% was obtained at full load with 19.5 CR. But when we change the IP of the engine maximum efficiency of 43.4 % was obtained at the 210 bar which was the highest IP of the engine [25]. BTE increases with increase in injection pressure and load. If the efficiency of ternary fuel blend is compared with the pure diesel then, the blending fuels have higher efficiencies at all higher compressor ratio.

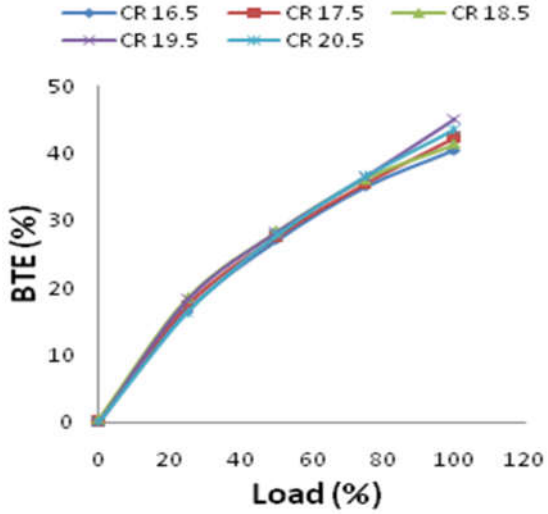


Figure: 3 BTE V/S Load at different CR

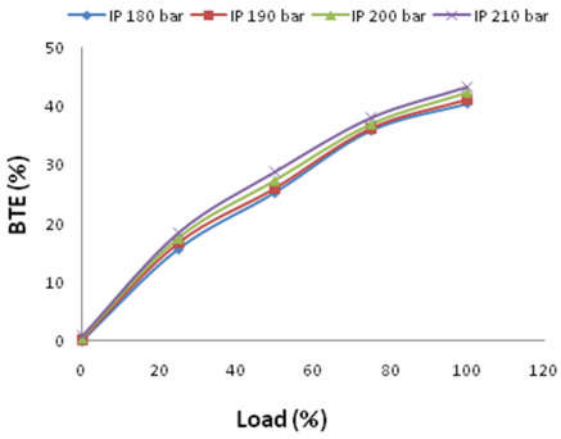


Figure: 4 BTE V/S Load at different IP

Break specific fuel consumption has been shown in the figure 5 that as we increase the load and compression ratio on the engine, BSFC decreases in almost all cases. The lowest BSFC 0.18 kg/kw-hr was obtained at full load condition at 19.5 CR. Generally BSFC decrease with the increase in compression ratio [26].

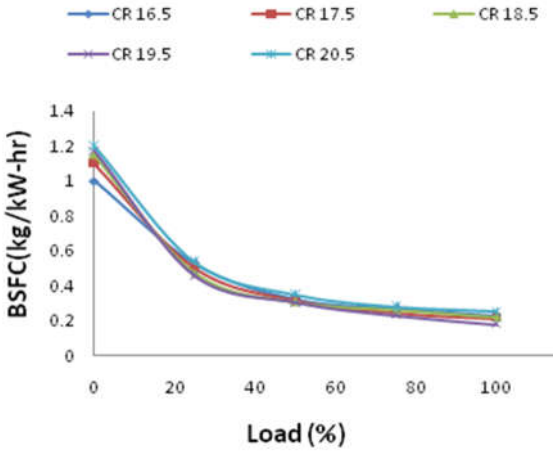


Figure: 5 BSFC V/S Load at different CR

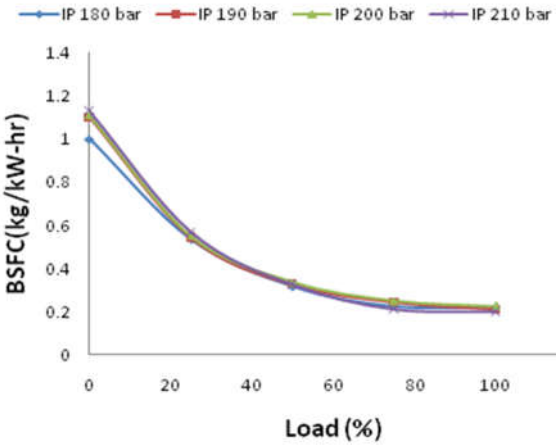


Figure: 6 BSFC V/S Load at different IP

Nitrogen oxides (PPM) have shown in figure with respect to the applied load. The Quantity of NOx increased when applied load and CR were higher on the engine. The value of NOx decreased when the injection pressure of the fuel is lower. From the above we can conclude that by reducing the compression ratio and increasing injection pressure in the engine the quantities of NOx reduce significantly at low load conditions [27].

4. CONCLUSION

In this paper observations have been done on the performance and emission characteristics of the variable compression ratio diesel engine with the blend of ternary fuel (D80DEE10E10). And also investigated on different CR with different IP and have concluded the following:

- Brake thermal efficiency of the engine increases with increase in CR and at the same time with increase in IP. Maximum efficiency of 45% was obtained at 19.5 CR.
- Brake specific fuel consumption of the engine decreases with the blend at almost all CR.

There is no specific improvement in BSFC with respect to change in IP of the engine. Lowest BSFC was obtained at IP of 210 bar of engine with the blend diesel.

Nitrogen oxides were lowest with low load and low CR. High IP has given low NOx. Lowest NOx was obtaining at the 16.5 CR and 210 bar IP.

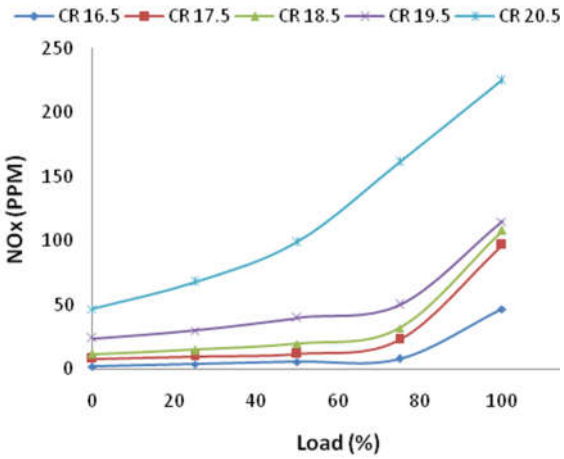


Figure: 7 NOx V/S Load at different CR

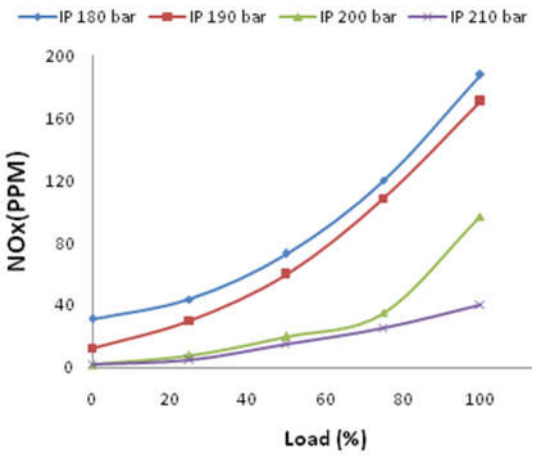


Figure: 8 NOx V/S Load at different IP

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