International Journal of Engineering & Technology, 7 (1.9) (2018) 1-5

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Experimental investigation on characteristics of algae biodiesel in a diesel engine

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Abstract

The study titled "Performance and Emission Studies on a 4 stroke Diesel Engine Using Methyl Ester of ALGAE Oil with EGR" involves detail investigation of characteristics (performance and emission] of Blends of Methyl Esters of ALGAE oil by varying the EGR control value (5 to 20%] using direct injection diesel engine. From the preceding studies on similar title it's established that the release of NO_X is higher in ALGAE based biodiesel. The focus of this study is about the NO_X emission and how it can be reduced by using the cooled EGR.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

With increasing population on this earth there is an unprecedented demand for energy especially petroleum based energy. The energy consumption forecast by international energy outlook is estimated to significantly rise from 83 million barrels/ day in 2004 to 97 million barrels/ day in 2015 and just over 118 million barrels/day in 2025. Almost half of the total resources across the globe would be depleted by 2025 if this forecast comes true.

Yet another serious global issue is climate change due to global warming. Kyoto protocol effective since February, 2005 is to curb the greenhouse gases. Presently more than 160 countries have signed aiming to reduce the greenhouse gas emission by a collective average of 5% below 1990 level of respective countries. As per Intergovernmental Panel on Climate Change (IPCC] global warming would cause the global surface temperatures to rise 1.1^0 C to 6.4^0 C between 1990 and 2100 Thet et al[1].

So, renewable energy is the best solution to address both energy and environmental problems. An alternative for diesel fuel is biodiesel produced through the process of transesterification with least impact on the environment. Catalyst is part of this process wherein vegetable oils and animal fats react with alcohol. The fatty acid alkyl esters produced through the reaction is called as biodiesel.

In contrast to the diesel, biodiesel possess higher viscosity, density, pour point, flash point, cetane number and on a mass basis its energy content is about 12% less.

Another positive point of biodiesel is it significantly reduces exhaust emissions. Reports reveal that biodiesel of hundred percent purity releases lower tail pipe exhaust emissions compared to the diesel fuel. And biodiesel is considered to be sulfur - free fuel with 99% less SO_x release as compared to diesel. Though higher oxides of nitrogen (NO_x] are released with biodiesel which is of hundred percent purity.

2. Transesterification process

This process is generally used in the production of biodiesel. With catalyst present, the fatty acid alkyl ester is formed as fatty acid in vegetable oil reacts with an alcohol such as methanol.

3. Pollution control techniques

Air injection, exhaust gas being circulated again and catalytic converters are few important techniques used for pollution control. Senthil et al [3].

Exhaust gas recirculation techniques

The cooled EGR is used in this project since it can curb the NO_x emission. In this technique, the levels of recirculation vary from 5 to 20% EGR check value. EGR limit is controlled with check value having gradient scale around the tuning of value. The varied levels facilitates in finding the corresponding emission level. Then optimized values are considered for use as finer ALGAE based biodiesel.

In the traditional practice the EGR used are of hotter type which makes NO_x emission higher. In order to overcome this problem cooled EGR is used. EGR is cooled by using water. The combustion temperature is lowered by reducing the concentration of oxygen.

External and internal are the two types of EGR system.

External EGR:

In external EGR system, external piping is used for the circulation of gases from the exhaust manifold to the intake port which enables recirculation.

In order to match operating conditions the EGR value can be turned off. $NO_{x\ emission}$ can be significantly reduced through this technology. External piping, by pass lines and related cooling mechanisms are some of the additional parts necessary for efficiently operating many external EGR systems. The corrosion of system components can also be exacerbated through the combustion of exhaust gas and moisture in the external piping causing problems of reliability.

4. Experimental apparatus and procedures

In the experiment the test engine consists of a single cylinder direct injection Kirloskar diesel engine. It is naturally aspirated water – cooled four stroke diesel engine as shown in figure.

Kirloskar engine is one of the most commonly used engines for many purposes. The construction of the engine is so rugged that it can endure higher pressures during tests. Further, it is very feasible for modifications on the cylinder head and piston crown. This study used a single cylinder, water cooled, four stroke direct injection compression ignition engine with a displacement volume of 661 cc, compression ratio of 17.5:1, developing 5.9 kW at 1800 rpm. And at 1800 rpm the variable load tests were conducted for no load, 1.5, 3.01, 4.52 and 5.9 kW power output. The fuel injection pressure was 200 bars and at 60^0C cooling water exit temperature. Murugesan et al [2].

The manufacturer recommended injection timing at 27^0 BTDC (spill]. The push rods help in operating overhead valves of the open combustion chamber. Cylinder pressure was measured with piezoelectric pressure transducer mounted on the cylinder head surface.

Fig 1: is a representation of the set–up

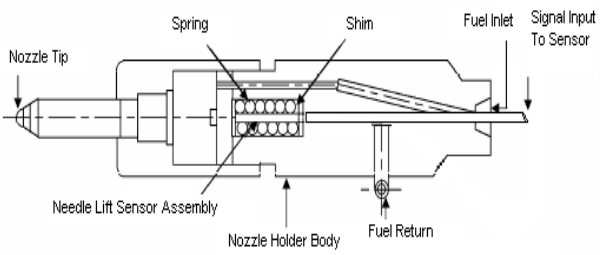

Fig. 2: Needle Lifter Sensor.

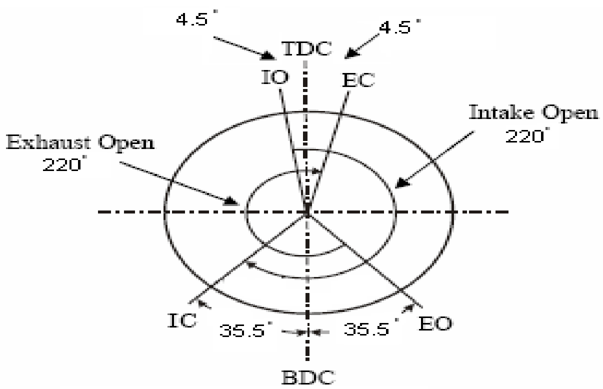

Fig. 3: Valve Installation Position Timing of Test Engine.

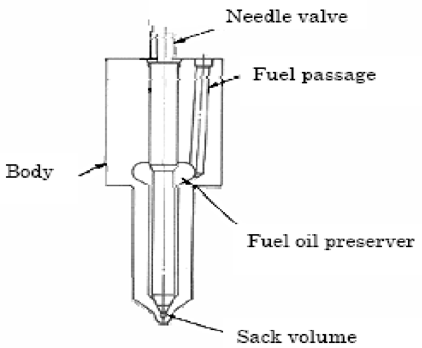

Fig. 4: Injection Nozzle of Test Engine.

Fig. 5: Pressure transducer.

The evaluation of the performance features is with regards to brake thermal efficiency, features of emission with regards to smoke, HC, CO, CO_2,NO_X and features of combustion with regards to pressure traces, maximum pressure, heat release, cumulative heat release, combustion duration and delay period. Results of baseline diesel engine and evaluation all these above three are compared.

Electric Dynamometer

A high speed type electric dynamometer with eddy-current electro brake is used in this study.

Load and Speed Measurements

At a persistent speed of 1800 rpm the engine was run. Load cell reading provided the load of the engine and its speed was checked by utilizing sensor together with digital speed indicator.

Measurement Devices for consumption of fuel

Diesel tank placed in the panel board supplied the fuel for the engine. The panel board had the burette so that the fuel to the engine will flow from the burette whenever the fuel cock was closed. Time taken for 10cc of fuel consumption was noted for the fuel flow rates.

Temperature Measurement

Using the chrome alumel (K – Type) thermocouples the temperature of the cooling water inlet, outlet and exhaust gas was calculated.

Combustion Characteristics Measurement Devices

Detecting the crank angle, measurement of the fuel injection and combustion pressure helps in examination of combustion characteristics. Detection of the lift amount of a needle valve of the fuel injection nozzle gave the Fuel injection timings. A needle lift sensor was placed in the fuel injector nozzle in order to detect the lift amount of needle valve. A digital scope recorder recorded the output signal of the needle lift sensor. The fuel ignition timing was estimated based on the wave determined by the crank angle or driving condition of the engine. The position of needle lift sensor used is shown in fig 2.

To get in each instance the existing information in the combustion chamber of the engine it is essential to measure the pressure and find the combustion chamber pressure. To monitor the combustion, information concerning the existing pressure in the combustion chamber in each instance is essential. This information will help in detecting the timing (initial & final] of the combustion and ignition timing. So a piezo electric pressure transducer was placed in the upper side to ascertain the combustion chamber pressure of the test engine. The pressure detection component called the piezo-electric crystal consists of self-temperature – compensating gage developed by superior micro technology. During temperature changes and zero-point variations, there are least fluctuations in sensitivity facilitating its use over a broad temperature range. The tracing of the smallest mechanical variations occurred response to combustion pressure helps in accomplishing actual combustion pressure. And using an amplifier the signals identified through the pressure transducer were sent to digital scope recorder. Fig 5 describes the engine pressure transducer.

As discussed earlier, detection of the crank angle is key in finding the engine's combustion characteristics. The crankshaft rotational direction is the key to accurately establish the fuel injection and ignition timing. In this study, crank angle detector assembly fitted on the crank shaft was utilized to identify the crank angle of the test engine. The output signal from crank angle detector assembly was sent to digital scope recorder.

A digital scope recorder was used in this study for recording and saving the data of two types namely HDR and WVF. At every crank angles, the data of injector needle lift, compression pressure and crank angle were sampled and average on 50 cycles were recorded.

Exhaust Gas Emission Measurements Devices

In this study, measurement of nitrogen oxides (NO_X) , hydrocarbon (HC], carbon monoxide (CO) and smoke emissions from the exhaust gas were done.

5. Crypton 290 series emission analyser

Was used to measure the emissions from the test engine. To measure NOX, a chemical sensor which is a catalyst fitted next to the oxygen sensor is used. Sample exhaust gases taken from exhaust pipe were passed through a filter and then entered to the NO_X analyzer. The smoke emission from the test engine was measured by using an opacity (AVL make) type smoke meter.

Experimental Procedures

All the conditions such as fuel tank, oil level and coolant of the test engine were checked before commencing the experiments. And until stability was accomplished the test engine was started and allowed to run. Gradually the engine load was increased to maximum recommended load ad simultaneously by following the makers' instruction manuals the dynamometer, all analyzers and meters for measurements were switched on and required planning and settings for measurements were executed. The steady state engine test experiment commenced only after the test engine reached its stability and all the process for measurements were completed. 0%, 25%, 50%, 75% and 100% were the five different levels of application of loads with engine speeds fixed at 1800 rpm. At each load level data was recorded for the measurements of consumption of fuel, intake air and its temperature, exhaust gas and engine coolant temperature, crank angle and all emissions. Experiments for both fuels the conditions, methods used and procedures applied were similar. Experimental data estimation and the examination were conducted after the engine experiments for all kinds of fuels were completed. The methods are explained in detail.

6. Results and discussion

Brake Thermal Efficiency:

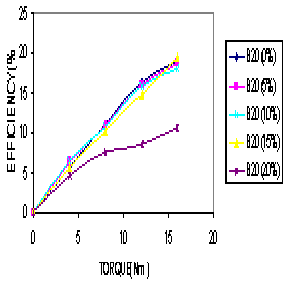

Fig.6 Torque vs efficiency B20

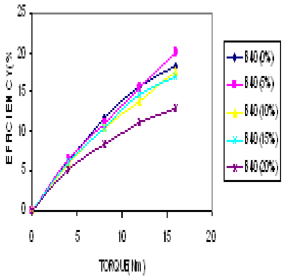

Fig.7 Torque vs efficiency B40

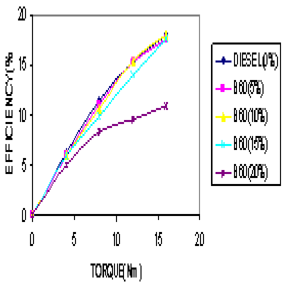

Fig.8 Torque vs efficiency B60

As shown in Fig 6 to 8 the Brake Thermal Efficiency of engine decreased as biodiesel blends increased. And rate of efficiency increases as EGR rate is increased and further than 15% EGR level there is drastic reduction in the BTE.

7. Specific energy consumption

SEC is used for performance comparison of such engines.

SEC (in kJ/ kWh) = Calorific value of the fuel * Specific fuel consumption

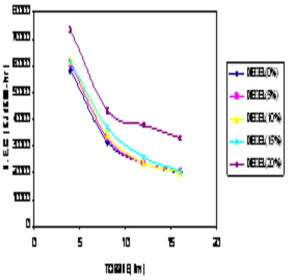

Fig.9 Torque vs S.E.C Diesel

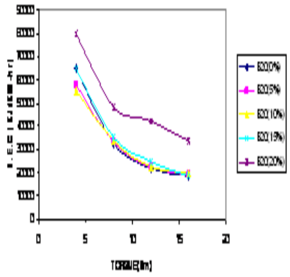

Fig.10 Torque vs S.E.C B20

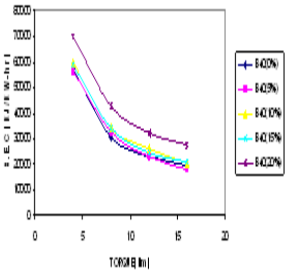

Fig.11 Torque vs S.E.C B40

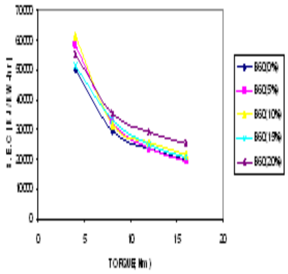

Fig.12 Torque vs S.E.C B60

The disparity of specific energy consumption with varied EGR rate along with different fuels that are blended is depicted in graph (Fig 9 to Fig12). We see that based on the calorific value the specific energy consumption of fuels increased as blended fuels increased.

8. Emission characteristics of the engine

Carbon monoxide (CO)

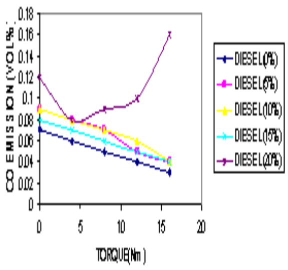

Fig.13 Torque vs CO Diesel

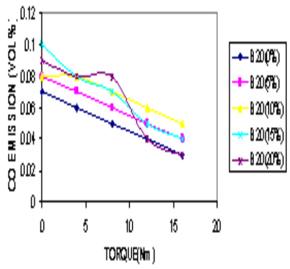

Fig.14 Torque vs CO B20

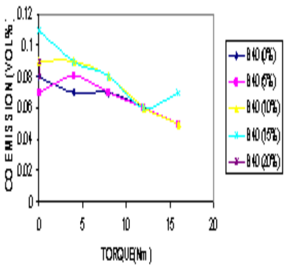

Fig.15 Torque vs CO B40

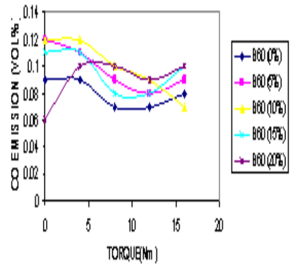

Fig.16 Torque vs CO B60

Variation in CO with various EGR levels is shown in the graph (Fig 13 to Fig16). When compared to diesel emission, the release of CO from bio-diesel was lower. The CO levels increased with EGR. When operating under oxygen scarce condition there is higher CO values for diesel under higher EGR. Whereas deficiency of oxygen is partly compensated with the surplus oxygen for bio-diesel under EGR. The reason for higher CO emissions can be on account of disintegration of CO_2 to CO when loads reach its climax. During this time the combustion temperatures becomes high and comparatively fuel rich operation exists.

9. Unburned hydrocarbons (HC]

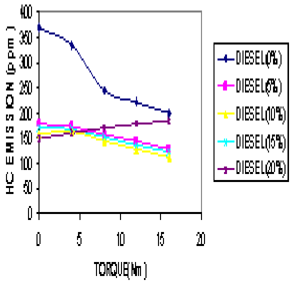

Fig.17 Torque vs HC Diesel

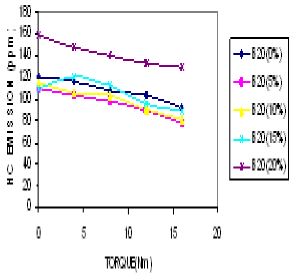

Fig.18 Torque vs HC B20

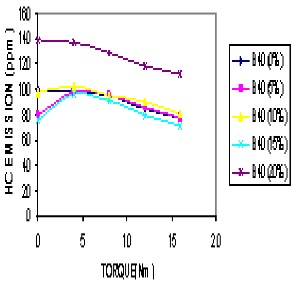

Fig.19 Torque vs HC B40

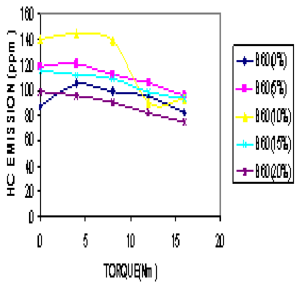

Fig.20 Torque vs HC B60

The graph (Fig 17 to Fig20] shows variation of HC emission with EGR rate. Even as EGR level was increased for bio-diesel there was no drastic increase in HC. It could be because of the surplus oxygen in bio-diesel making it up for the shortage of oxygen which further facilitates the process of complete combustion. The variation over this range was only 10–40 ppm for bio-diesel. As the EGR rate was increased the bio-diesel blends emission reduced. For B40 (15% EGR] is the least value of the HC emission.

10. Oxides of nitrogen (NOX]

The variation of NOx emissions with various EGR rate for the whole load range is shown in The graph (Fig 21 to Fig24]. Emission of NOx increased with increase in the content of biodiesel in the blended fuels. Moreover NOx emission from the biodiesel was higher than diesel. The higher oxygen level could be the possible reason for increase in NOx concentration by about 2 to 10 per cent from biodiesel fuelled engine. As shown in the figure the NOx level decreases with the increase in EGR rate. Despite 20 % EGR reducing NOx significantly, the reduction in BTE, CO increase and HC emissions were observed.

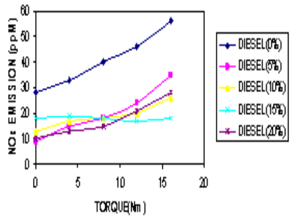

Fig.21 Torque vs NO_X Diesel

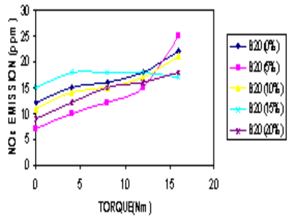

Fig.22 Torque vs NO_X B20

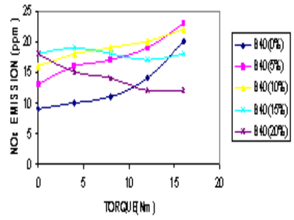

Fig.23 Torque vs NO_X B40

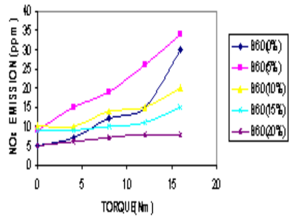

Fig.24 Torque vs NO_X B60

11. Cylinder pressure:

There was no EGR condition comparable for both fuels obtained at 3/4 load. Under these conditions 62 bars (for diesel] and 60 bars (for bio-diesel] was the peak pressure. So at higher loads with high temperatures diesel shows a fair blend formation.

12. Pressure vs. crank angle

The percentage of heat input is taken for diesel and various blends with 15% and without EGR. The fig 24 shows the comparison of the crank angle (deg) with Pressure for all fuels blends with 15% and without EGR. The figure shows that the amount of energy supplied increases with pressure. Without EGR there is minimum values for the engine is and with 15% EGR there is maximum values.

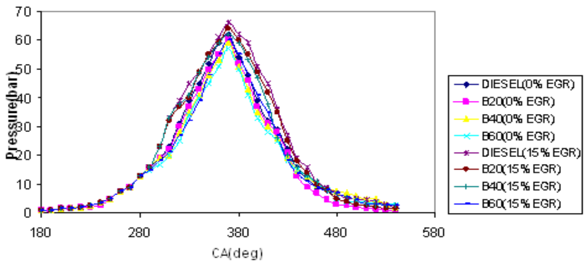

Fig. 25: Pressure vs Crank Angle.

13. Heat release rate

Rate of heat release (HRR) are shown in Figure. For diesel under 3/4 load and 15% EGR there is faintly higher peak HRR of 79.64 J/deg and 76.34 J/deg for bio diesel. Better premixed combustion can increase heat release rate which also facilitates increased NO emission. Higher HRR for bio-diesel devoid of EGR is possibly because of the surplus oxygen content in its structure and a dynamic injection advance apart from static injection advance. With optimized EGR of 15% and without for both fuels is shown.

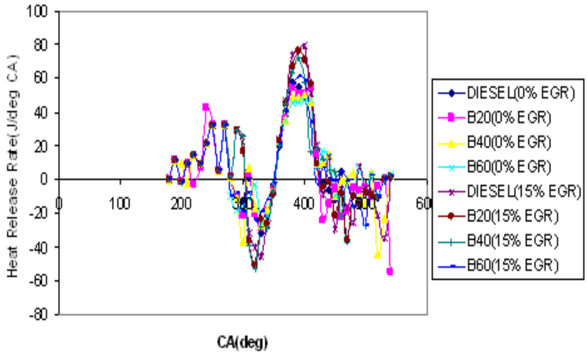

Fig. 26: Heat Release Rate vs. Crank Angle.

14. Rate of pressure rise

The figure shows that the variation of rate of pressure rises with crank angle which is indicative of noisy operation of the engine. With optimized EGR of 15% and without for both fuels, the Rate of pressure rise was found to be comparable. Peak values at ¾ loads were found to be 1. 2 bar/deg. The comparable state is indicative of stable and noise free operation of compression ignition engines with JBD.

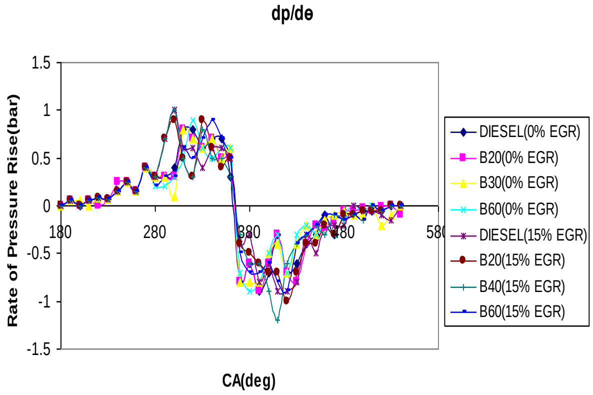

Fig. 27: Rate of Pressure Rise (bar) vs Crank Angle.

15. Cumulative heat release

Without and with optimized EGR of 15% the cumulative heat release were found to be comparable for both fuels as shown in figure. The maximum cumulative heat release rate for diesel with EGR of 15% is 415.29 j/deg.

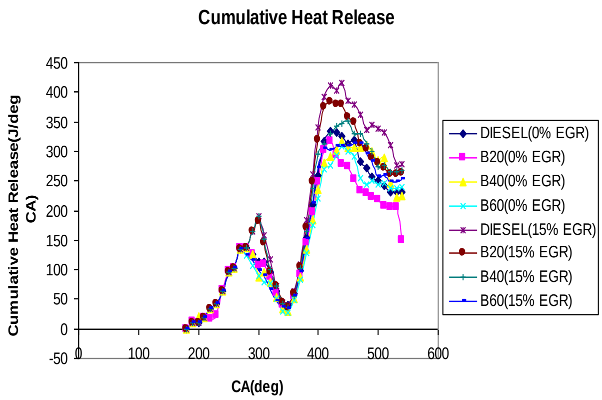

Fig. 28: Cumulative Heat Release vs Crank Angle.

16. Conclusion

In this study, Methyl Esters of ALGAE oil (MEJ] and its mixture were tested with Kirloskar Engine. It was then compared with traditional commercial diesel fuel. Biodiesel and its blends showed a faintly less brake thermal efficiency as compared to diesel fuel at tested load conditions. Specific Energy Consumption of fuels increases with increase in the amounts of blended fuels owing to lower calorific values. It was also found that the release of carbon monoxide (CO) increased as biodiesel blends increased. And as EGR rate increased there was a slight decrease in the efficiency of the engine because of higher EGR and CO. In biodiesel the increase in EGR rate decreased the release of NO_X and HC. It was also found that the release of NO_X and HC from the biodiesel fuel was higher than that of diesel.

For Higher EGR rate, emission is reduced with simultaneous decrease in performance. Therefore 15% EGR for fuels is favorable to enhance its performance and emission characteristics with various EGR rate.

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