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PERFORMANCE STUDY OF A DIESEL ENGINE WITH EXHAUST GAS RECIRCULATION (EGR) SYSTEM FUELLED WITH CASTOR BIODIESEL

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ABSTRACT:

The enormous rise in automobiles will lead to requirement of more alternative energy sources. The alternative energy may obtain from natural resources like bio-fuels. When energy is generated, oxides and nitrogen are released which are dangerous to the greenhouse emission. Biodiesel is an alternative to the conventional fuels. But it will create additional NOx in emissions. But when we make use of Exhaust Gas Recirculation (EGR), there will be lessening in NOx emissions. This paper concentrates on influence of the EGR, Exhaust gas temperature (EGT) and emissions, NOx, CO, CO_2, HC, and unburned hydrocarbons (UBHC). Single cylinder diesel engine equipped with EGR is examined for finding out the performance at part load condition and fuel is tested by maintaining engine at 1500rpm. The experiment shows considerable increase of fuel consumption using castor biodiesel, and decrease in exhaust gas temperature and emissions.

Key words: Emissions, EGR, EGT, Castor biodiesel, UBHC.

1. INTRODUCTION

The cautionary to the whole existence of the world is because of atmospheric pollution and global warming. As there are many types of reasons for the pollution, the main reasons are the pollutants from the automobiles and power generation units, which use petroleum fuels, mainly for all energy sources. The economic growth of our country mainly depends on the automobiles and power production, so their usage is uncontrollable. Despite of environmental imbalance the two-by-third economy of India depends on the petroleum products. So, there will be deficiency of fossil fuels in the future.Hence it is mandatory for the environmentalists, researchers and scientists, socialists, policy makers. India has wide range of biological area and abundant in plants and animal varieties.By the end of the year 2017, world countries have planned to reduce the consumption of fossil fuels by mixing the biodiesel (20%) in diesel. In the year of 2016 diesel fuel utilized is 93.52 billion liters and this consumption stipulate increased to 97.7 billion liters in the year 2017.The biodiesel produced in the year 2016 was 140 million liters and that was demanded to 150 billion liters in 2017.By measuring the era evaluation of the biodiesel, by mixing 20% with diesel the need for the biodiesel in the entire year 2017 is 20 billion liters. By visualizing the requirement and capacity, there are 150 times blemished biodiesel generation in India. Besides, there is a high explosiveness of fossil fuel cost in the world’s market. All these cause a huge requirement for biodiesel. Biodiesel can be generated from all the classification of the plant oil and dependability should be taken that not production of fuel by sacrificing food. Hence biodiesel is the major alternating source of energy which can solve all the above problems. Traditional oil feed stocks for biodiesel production mainly includes soybean, rapeseed, canola, cotton seed, palm, corn, sun flower, peanut, castor oil (Ricinus oil) and coconut oil. Even though these have long chain hydrocarbon structure, good ignition characteristicsbut they cause some serious difficulties such as high viscosity, high density, low heating value, more molecular weight and deprived combustion. Transesterification process is used to modify the above mentioned problems of the fuel. The chemically transesterified fuel ought to be used for getting better performance. Therefore, many reports on bio-fuels including biodiesel have already been conducted on efficiency and emission features of diesel engine with partial or complete replacement with petroleum fuels.

In general combustion of diesel fuel emits less carbon monoxide (CO) and higher oxides of nitrogen (NOx). Diverse experiments have already been conducted to research the result of EGR on numerous biodiesel blends predicated on the engine performance, emission and combustion characteristics.Previous experiment outcomes considerably disclosed that EGR in contemporary engines is the way for reducing NOx emissions.The experiment desires a require cost, time, and labor power, there are some anticipated approaches including numerical simulation, and modeling methods. To improve performance, reduce NOX emissions and to decrease Exhaust Gas Temperature (EGT) some of the authors investigated on various fuels with diesel. The present experimental work is to study the performance of diesel engine with castor biodiesel, emission characteristics, Exhaust Gas Recirculation and Exhaust Gas Temperature. The test fuels of 5%, 10%, 15%, 20% blends with diesel fuel is prepared based on the volume basis. The load applied during the experimental investigation is 44.44 % of the maximum engine load, combination of blend and load are used based on the literature survey and no one has done my combination.

2. LITERATURE SURVEY

M. Arunkumar, M. Kannan, G. Murali [1] The author had done investigation on the Castor biodiesel to find out the performance of the CI engine when it is fuled with Castor biodiesel and it is used as another fuel for the diesel; the usage of castor biodiesel reduces the CO emissions, HC emissions andreduces the NO_x in considerable percentages. The experimental outcome of the author explains that the usage of castor biodiesel reduced the CO by 9%, HC by 8.8% and NO_x. But the problem is the mixing of Castor biodiesel in diesel increased the Specific fuel consumption by 4% and decreased the break thermal efficiency 2.2.

M. Arunkumar, G. Murali [2]

The internal combustion engines equipped with EGR can reduces the emissions by transferring the exhaust heat to the intake of the cylinder. So, the exhaust temperature is reduced by the EGR. The reduction in temperature of the exhaust causes the decrease in emissions particularly NO_X. The author used the EGR equipped test setup to test palm biodiesel for determining the emissions. The results of his experiment revealed that the usage of EGR reduced the emissions.

3. MATERIALS USED

The alternative fuel considered for the in the present work is castor biodiesel, which is in light yellow color. The following figures show castor oil and biodiesel which are used in this experimental work. The following table shows the chemical and physical properties of the castor biodiesel which are calibrated with the help of the relevant instruments.

Fig. 1.a. Castor oil

Fig. 1.b. Castor biodiesel

Characteristics	D100	C5-D95	C10-D90	C15-D85	C20-D80
Kinematic viscosity @40^{o}C	2.25	2.2	2.49	2.89	3.678
Density @ atmp Temp	790	883.4	771.2	821	861.7
Calorific Value	44,250	44,157	43,785	43,466	42,471
Specific gravity	0.79	0.883	0.771	0.821	0.861
Flash point	56	56	54	52	53
Fire point	58	58	57	59	60

Table.1. Properties of the castor biodiesel.

2. OBJECTIVES

The main objective of present assessment is to effectively employ castor oil as an alternative fuel in a diesel engine and thus minimizing the environmental tribulations caused by exhaust emissions.

1. To study the performance of an engine fuelled with castor biodiesel.
2. To lessen the consequence of NOx emissions by utilizing EGR method.
3. To reduce emissions by using biodiesel which is a rich content of oxygen compare to diesel fuel.
4. To improve mass flow rate of an air by 20% using EGR valve and to reduce Exhaust Gas Temperature by using calorimeter.

4. EXPERIMENTAL SETUP

KIRLOSKAR single cylinder water cooled variable compression diesel engine equipped with EGR is used for the experimental tests. Eddy current dynamometer is used to apply loads on the engine. Eddy current dynamometer is attached to the flywheel to apply loads on the engine. An injection pressure of 200bar is maintained to inject the fuel. The cylinder pressure is measured by the piezo-sensor fitted on the engine cylinder head and crank angle encoded fitted on the fly wheel. The standard engine has a provision of injection point variation 0 to25^{o}BTDC. The emissions HC, CO, CO_2, UBHC and NOX are measured by using AVL-DIGAS 444 fire gas analyzer. The opacity of the smoke is measured by AVL smoke meter.

Engine make	**Kirloskar,Model**
Type	1 Cylinder,4-Stroke,Water cooled, VCR Multi Fuel with open ECU for petrol Mode and EGR (HOT)
Displacement	661 cc
Bore & Stroke	875 mm & 110 mm
Compression ratio	12.1-18 .1
Fuel	Diesel &Petrol
Rated brake Power	3.5 KW
Rated Speed	1500rpm
Ignition system	Compression Ignition
Injection point variation	0-25 deg BTDC
Connecting rod length	234mm

Table.2. Engine specifications.

Fig.2. Experimental setup

5. TEST METHOD

Experiment has been conducted with diesel and castor biodiesel. The tests are carried out with two stages. In first stage the experimental investigation is done to get base line parameters by using standard diesel. In second stage of investigation the castor biodiesel blends are used i.e. C5-D95, C10-D90, C15-D85, and C20-D80 as a fuel in the engine. In above two stages of investigation, two types of instruments are used, one is the fire gas analyzer to measure emissions (CO, HC, NOX, and UBHC) and another one is smoke meter to measure smoke opacity.

6. RESULTS AND DISCUSSION

6.1. Performance Analysis

The KIRLOSKAR single cylinder water cooled variable compression diesel engine equipped with EGR standard engine is used for the testing. Though the engine has maximum load capacity of 18 kg butduring the experimental investigations, 44.44% of load (i.e. 8kg) is only used. The performance of the engine with different blends and diesel is described below.

6.2. Brake thermal efficiency (BTE):

Brake thermal efficiency is the ratio of brake power to the product of fuel consumption and calorific value. As the load increase, brake thermal efficiency is also increased. In the following figure the graph is drawn between load and brake thermal efficiency for the engine fuelled with various blends (i.e. D100, C5-D95, C10-D90, C15-D85, and C20-D80). The brake thermal efficiency of all blends and diesel at 8kg load is varied from 19.98% to 26.12% is observed. As the castor oil concentration increased in diesel the brake thermal efficiency decreases due to increase in viscosity of the fuel. In the graph, the maximum brake thermal efficiency is 26.12 % of diesel and 24.6% of blend C5-D95 is observed. After C5-D95 the maximum BTE is obtained with blend C10-D90 of 20.7%. The minimum BTE is obtained at blend C20-D80 is 19.98%.

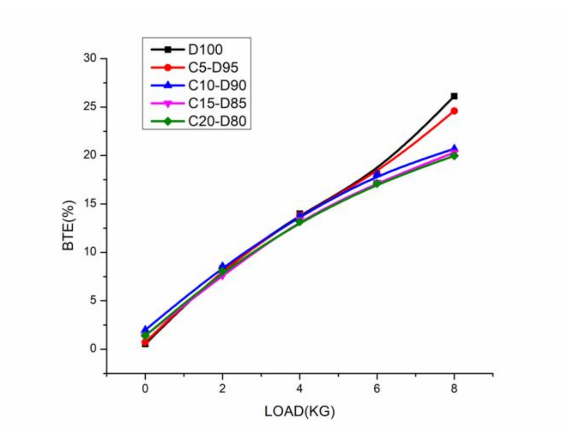


Fig. 3. Graph between the load and brake thermal efficiency.

6.3. Specific Fuel Consumption (SFC)

The quantity of fuel need to generate one KW of power is known as specific fuel consumption. The variation of SFC with load for standard engine with various blend proportion (i.e. D100, C5-D95, C10-D90, C15-D85 and C20-D80) is shown in fig4.1. To develop unit power the SFC does not depends on fuel and energy input. SFC increases with castor biodiesel concentration due to increase in viscosity & decrease in calorific value of the fuel. The minimum SFC is 0.35 kg/kWh of diesel fuel is obtained. The minimum SFC of the blends concentration is 0.41 kg/kWh at the blend C5-D95 & C10-D90.The maximum SFC is 0.43 kg/kWh is at the blend C20-D80.

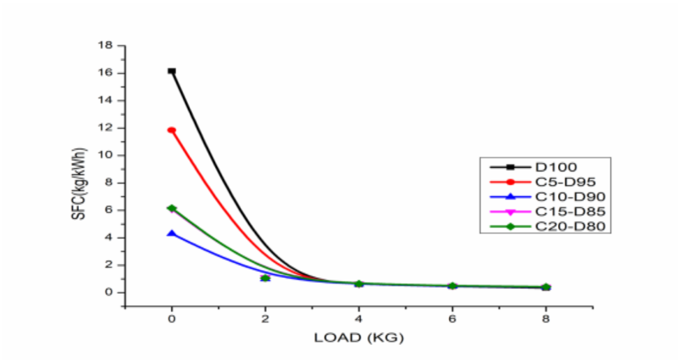
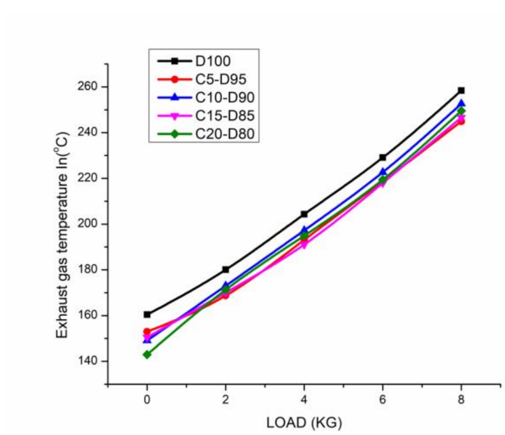


Fig. 4. Graph between the load and brake thermal efficiency.

6.4. Exhaust Gas Temperature (EGT)

EGT is the quantity of exhaust gases at exhaust manifold. As air fuel ratio is the increases the temperature of the gases also increases. So, it can be used as a basis for regulating air fuel mixture. One of the objectives of this investigation is to reduce EGT before entering in to the atmosphere. The standard engine has the provision of calorimeter of type pipe in pipe to reduce the EGT. The variation in temperature In and Out of the calorimeter is discussed below.



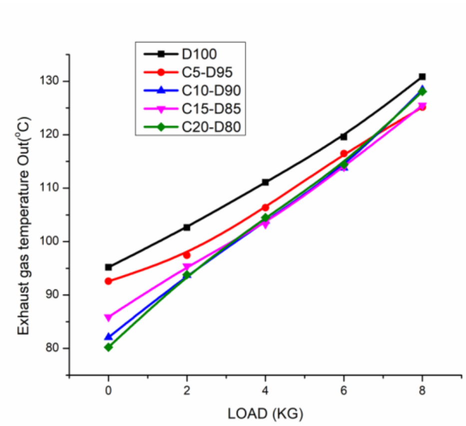


Fig. 5.EGT with load for the diesel fuel.

Fig. 6.EGT with load for the diesel fuel.

6.5. Emission Analysis

In general diesel engine emits more NOx emissions then CO&HC emissions. The NOx emissions are harmful to the environment as well as human health. The present investigation is deliberated to reduce the NOx emissions. The diverse varieties of emissions are discussed below.

6.5.1. Carbon monoxide (CO)

Co emissions increases with increase in load, the fig 7 shows a graph plotted between load and CO of engine fuelled with (i.e. D100, C5-D95, C10-D90, C15-D85 and C20-D80). In, general CO emissions are less in blends compared to diesel fuel, due to more oxygen content in the blends. Due to EGR presentation in experimental investigation a slight increase in CO emissions, compared with Engine without EGR. By considering the fuel CO emissions are less in the blend C20-D80 (i.e.0.11%) and maximum in the blend C5-D95 (0.16%). CO emission in the diesel fuel of 0.17 % is observed.

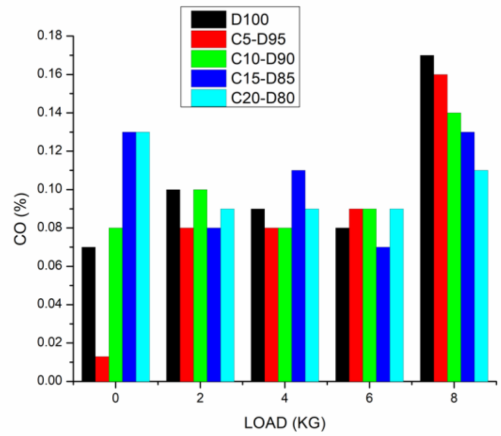


Fig. 7. The graph between load and CO emissions.

6.5.2. Carbon monoxide (CO)

Due to partial combustion and fuel evaporation the HC emissions are exists. The HC emission increases with increase in the load. The fig.8 shows a graph plotted between load and HC of the engine fuelled with (i.e. D100, C5-D95, C10-D90, C15-D85 and C20-D80). Due to EGR presentation in experimental investigation a slight increase in HC emissions .HC emissions will decrease with increase of blend proportion due to additional oxygen content. By considering the fuel the minimum HC emissions are in the C10-D90 (38ppm) and maximum in the blend C5-D95 (47ppm). HC emissions in the diesel fuel of 48ppm are found.

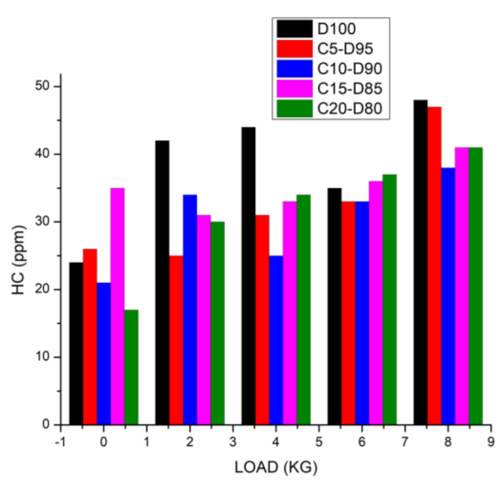


Fig. 8. The graph between load and HC emissions.

6.5.3. Oxides of Nitrogen (NOx)

NOx emissions are increased with increase in load. Fig 9 shows a graph plotted between load and NOx emissions of an engine fuelled with (i.e. D100, C5-D95, C10-D90, C15-D85 and C20-D80). Due to the arrangement of EGR in the experimental setup, the NOx emissions are decreased when compared to the engine without EGR. NOx emissions increase with blend proportion due to increase oxygen content. By considering fuel the minimum NOx emissions are in the blend C10-D90 (85ppm) and maximum in the blend C5-D95 (140ppm). NOx emissions in the diesel fuel of 139ppm are found.

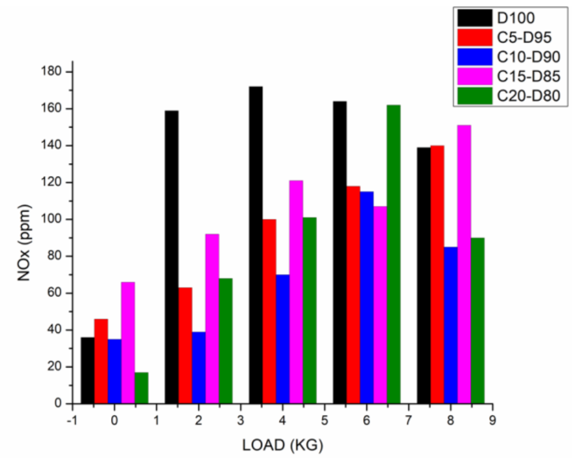


Fig. 9. The graph between load and NO_Xemissions.

6.5.4.Smoke Capacity

Smoke opacity increases with increase in load. Fig 10 shows a graph plotted between load and smoke opacity of the engine fuelled with i.e. (D100, C5-D95, C10-D90, C15-D85 and C20-D80). In, general diesel fuel has more smoke opacity than other fuels. Smoke opacity decreases with increase in blend proportion due to more oxygen content. By considering the fuel the minimum smoke opacity is in the blend C15-D85 (48.6ppm) and maximum in the blend C5-D95 (73.1ppm). The smoke opacity in the diesel fuel is 73.1ppm is observed.

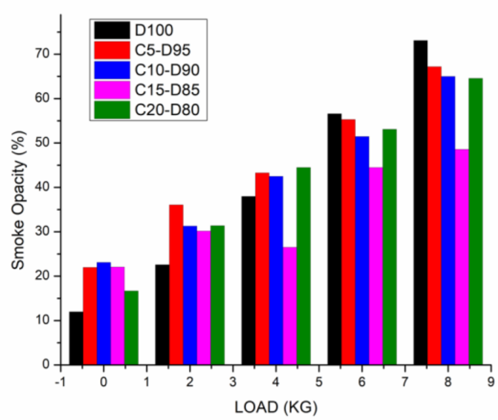


Fig. 10. The graph between load and NO_Xemissions.

7. CONCLUSIONS

In this paper, the experimental investigation is carried out on the performance, emission characteristics and the comparison is done between the castor biodiesel and diesel fuel for EGR and EGT tests. The subsequent conclusions are given based on the experimental outcomes and calculations Based on the experiment, on 4stroke, single cylinder VCR diesel engine with EGR is powered successfully by various fuel blends in diesel such as D100, C5-D95, C10-D90, C15-D85 and C20-D80. The results of castor biodiesel are presented here. By considering fuel blends the optimum BTE & SFC is obtained with the blend C10-D90.The EGT of the blend C10-D90 is preferable due to its better temperature values.The emission characteristics for the blend C10-D90 are most favorable due to less values compare with an engine without EGR. This blend gave low emissions (i.e. CO, HC, NOx and smoke opacity) and is better when compared to the other blendsin the perspective of emissions. Among all test fuels the blend C10-D90 can be chosen, this blend is preferable from current study due to report of finer engine characteristics.

NOMENCLATURE	
Symbol	Abbreviation
D100	Diesel 100%
C5-D95	Fuel blend of castor biodiesel 5% + diesel 95%
C10-D90	Fuel blend of castor biodiesel 10% + diesel 90%
C15-D85	Fuel blend of castor biodiesel 15% + diesel 85%
C20-D80	Fuel blend of castor biodiesel 20% + diesel 80%
BTE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
CO	Carbon Monoxide
HC	Hydrocarbons
NOx	Oxides Of Nitrogen
EGR	Exhaust Gas Recirculation
EGT	Exhaust Gas Temperature
UBHC	Un Burnt Hydrocarbons

Table.3. Nomenclature of the abbreviations.

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