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Effects of Exhaust Gas Recirculation on Performance and emission of a CI Engine using Diesel and Biodiesel Blends

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Abstract: -- The aspects of availability and price fluctuations of crude oil have made attractive the use of biodiesel as a viable alternate fuel for CI engine. Many researchers and industries have studied the effects of biofuel- diesel blends on the performance parameters of CI engine. However, many studies have been carried out in advance countries having excellent roads and traffic conditions, where the CI engines usually operate at optimum levels. In the Indian context, the CI engines, especially in the transport sector, have to operate at varying load conditions and therefore it is important to study and analyze the effect of engine load on engine performance parameters.

The present study is an attempt to determine the effects of loading a Kirloskar make 3.6 kW, single-cylinder, four-stroke, CI engine with diesel & biofuel as fuel. In this study, the effect of intake charge dilution with exhaust gases on the power and emission characteristics were investigated. With increase in dilution of fresh air with exhaust gases, CO, HC and NOX considerably decreases. As the percentage of EGR is increased from 0% to 15%, slight decrease in BP and & major decrease in NOX are observed, but HC and CO increases as the percentage of EGR is increased. It appears that the intake air dilution by EGR will cause the reduction in temperature in combustion chamber results in reduction of NOx.

Keywords: CO, HC, NOx, BP, Simarouba, Biodiesel.

I. INTRODUCTION

The world is presently confronted with twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground based carbon resources. The search for an alternative or substitute fuel which promises harmonious correlation with sustainable development, energy conservation, management efficiency and environmental preservation, has become highly important in the present context. For developing countries of the worlds, fuels of bio-origin can provide a feasible partial solution to the crisis. The fuels of the bio-origin may be alcohol, vegetable oils, bio mass and bio gas. The power used in agricultural and transportation sector is essentially based on diesel fuel and it is, therefore, essential that alternatives to diesel fuels need to be developed given the widespread of diesel fuels in various sectors. The study concentrates on assessing the viability of using simarouba oil in the existing diesel engine. Simarouba oil has comparable energy density, cetane number, heat of vaporization and stoichiometric air fuel ratio with mineral diesel fuel.

Literature review

Today, emissions from diesel engines such as carbon monoxide (CO), hydrocarbon (HC) & oxides of nitrogen (NOX) have created serious problems in the major cities. However the emissions act on diesel engines gives rise to develop a technology which minimizes the emissions from a diesel engine. The Exhaust Gas Recirculation (EGR) system is an effective measure to reduce NOX emissions [1-3]. The literature shows that the biodiesel will produce fewer emissions for HC, CO and slight increase in NOX in comparison to diesel [4]. The NOX emission is influenced by combustion temperature. The use of exhaust gas recirculation (EGR) could reduce the combustion temperature due to dilution effects, thermal and chemical effects, resulting in reduced NOX [5]. From emission analysis it is found that water washing system reduces odour and can also reduce CO2, CO, NOX and smoke significantly [6]. It is proved that soot & NOX emissions can reduce by using reduced oxygenated fuels coupled with high EGR ratio [7]. Tsolakis investigated the combustion of rape seed methyl ester with EGR shows higher reduction in NOX [8]. Murayama studied both combustion emission characteristics of a diesel engine fuelled with dimethyl carbonate with EGR system [9]. Wei Zhang et al.Their results show that NOX emissions can be reduced significantly without decrease in thermal efficiency of an engine. Wei Zhang et al. found that the oxygen enriched combustion of diesel engines can reduce smoke emissions and increase in thermal efficiency [10]. Rui Junzhu et al. report that the brake thermal efficiency

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fluctuates at small EGR rate, while decreases with the further increase with EGR ratio. With an increase of EGR ratio, NOX emission is reduced at the cost of increased smoke, HC & CO emissions [11].

Lei Zhu, et al. found that the presence of oxygen in the fuel has the potential to lower the exhaust particle number concentration in diesel engine [12]. Hatim achrafi et al. report that the dilution seemed to increase the emission CO, HC & CO2 [13]. Haifeng Liu et al. study showed that fuel properties and oxygenated structures have little effect on NOX, CO emissions & indicated thermal efficiency [14]. However, the changes in EGR rates have dominant effects on the gaseous emissions and indicated thermal efficiency. Donghui Qi et al. observed that with increasing of EGR rate, the brake specific fuel consumption & soot emission were slightly increased, and NOX emission were evidently decreased. Under higher EGR rate, the peak pressure was slightly lower, and the peak heat release rate kept almost identical at lower engine load, and was higher at higher engine load. With the main injection timing retarded, BSFC slightly increased, NOX emission was evidently decreased, and soot hardly varied [15].

Simarouba oil in its raw form cannot be used in IC engines because of the presence of triglycerides. It has to be converted a more engine friendly fuel called biodiesel. Biodiesel is a chemically modified alternative fuel for diesel engines, derived from vegetable oils. It is been reported that it emits far less regulated pollutants than petroleum diesel fuels. Also this paper aims to study the influence of EGR on performance and emission characteristics of the diesel engine using a biodiesel blend as a fuel.

II. MATERIALS AND METHODS

Simarouba Glauca L. is a new crop having multi utilities that can be tapped for production of biofuel in India and Central America. As the kernel has high non-edible oil content, this oil can be an appropriate candidate for production of biodiesel (Simarouba oil methyl ester). Simarouba fruit was procured for the study from Gandhi Krishi vidya Kendra, Agriculture Science College. [GKVK], Bengaluru. The sample was cleaned manually to remove all foreign materials such as dust, dirt, immature fruits etc., and pooled together to obtain approximately 100kg of fruit materials. The fruits were sun-dried and kept in jute bags and allowed to dry under ambient room conditions (27-32oC) to the equilibrium moisture. The simarouba fruits were fed to a decorticated equipment to remove the kernels. The shells and kernels were separated manually. Once the seeds are separated from the kernels, the seeds are passed into the mechanical crusher to extract the crude oil. Then this Simarouba crude oil is converted to biodiesel by transesterification process. Now the biodiesel is ready to use on any diesel engine.

Table-1 shows the comparison between the properties of diesel and Simarouba biofuel.

TABLE-1: PROPERTIES OF DIESEL & SIMAROUBA BIOFUEL

Properties	Diesel	Simarouba biofuel
Specific gravity	0.84	0.87
Kinematic viscosity @40^{0}c in CST	4.59	5.4
Flash point	45^{0}C	160^{0}C
Fire point	56^{0}C	172^{0}C
Pour point	-23^{0}c	2^{0}C
Calorific value KJ/kg	45,000	38,480
Cetane no	47	64

EXPERIMENTAL SET UP & PROCEDURE FOR EXPERIMENTATION

The tests were conducted on four stroke single cylinder, direct injection, water cooled, and naturally aspirated engine. The engine was operated at its rated speed. The specification of the engine is given in Table-2.

TABLE-2: SPECIFICATIONS OF THE ENGINE USED

Sl. No.	parameter	Specifications
1.	Number of cylinders	1
2.	Bore	80 mm
3.	Stroke	110 mm
4.	Volume	553 cc
5.	Compression ratio	16.5 :1
6.	power	3.6 kW(5 HP)
7.	speed	1500 rpm
8.	load	Electrical loading

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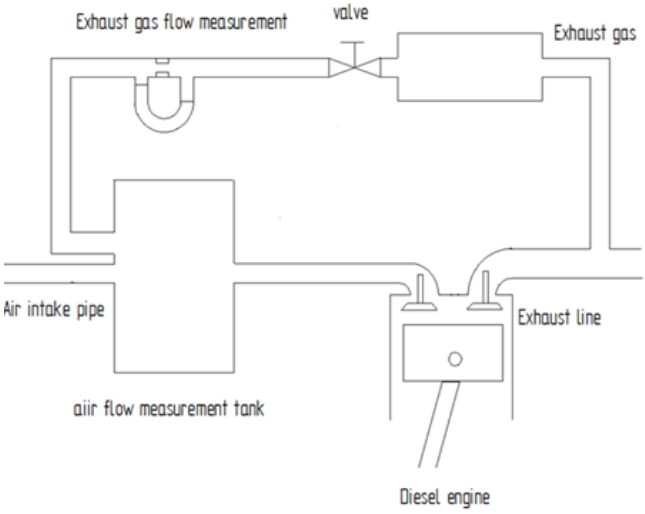

Fig.1: Sketch of Exhaust Gas Recirculation System

The study investigates the impact of exhaust gas on performance and emission of a diesel engine. A series of experiments were conducted using diesel and Simarouba biodiesel blended with diesel as B10, B20, and B30 as fuel under full load. The exhaust gas analyzer was used to record the emission levels. The model which was used for experimentation was INDUS 5 GAS analyzer model PEA 205. The tests were conducted for diesel by varying the EGR [0, 5, 10 & 15%] at full load condition for each test note down voltmeter, & ammeter reading and also the values of emissions such as HC, CO, & NOX were also recorded during each trial. The experiments were repeated for other fuels [B10, B20 &B30]. Fig.1 shows the schematic of EGR used.

In this study, the performance and exhaust emissions of a single cylinder direct injection diesel engine were measured for diesel & biodiesel at different EGR rates. To determine the emission characteristics of the engine, tests were conducted at full load. The results of the engine emissions like, carbon monoxide (CO), hydro carbon (HC), & oxides of nitrogen (NOX) for various percentages of EGR (0%, 5%, 10% ,15%) were noted down for diesel & various blends like (B10,B20,B30). The graphs are plotted for BP, CO, HC and NOx respectively versus percentage of EGR.

III. RESULTS & DISCUSSIONS

1) Nitric oxide (NOx) Emissions

The formation of the nitric oxide in the combustion zone is due to high-temperature combustion, when the combustion temperature goes higher than 1400 K [16]. In this mechanism, the formation rate of NO increases exponentially with the increase in the combustion temperature, and vice versa. Fig. 2 is a plot of NOx emission as a function of EGR for diesel and different biodiesel blends.

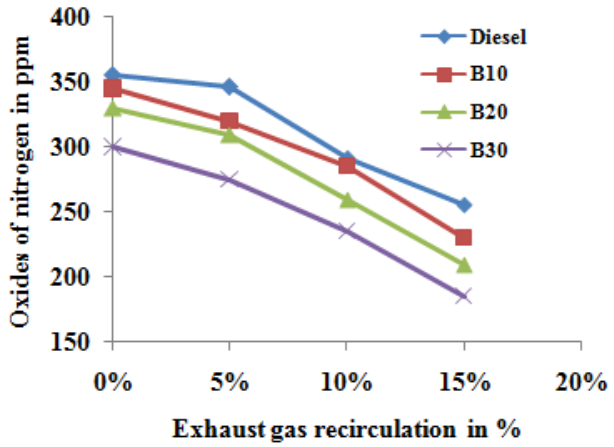

Fig.2: Effect of EGR on NOx Emission

Two inferences can be drawn from the Fig.2:

i) With increase in EGR, the NOx in emission decreases, because EGR reduces the combustion temperature.

ii) As the blending percentage increases, NOx emission decreases because of the lower calorific value of biodiesel.

It can be clearly noted that conventional diesel emits the maximum amount of nitric oxide.

2) HC emissions

Fig. 3 is a plot of HC in PPM as a function of EGR for diesel and different biodiesel blends. Again, two inferences can be drawn from Fig.2:

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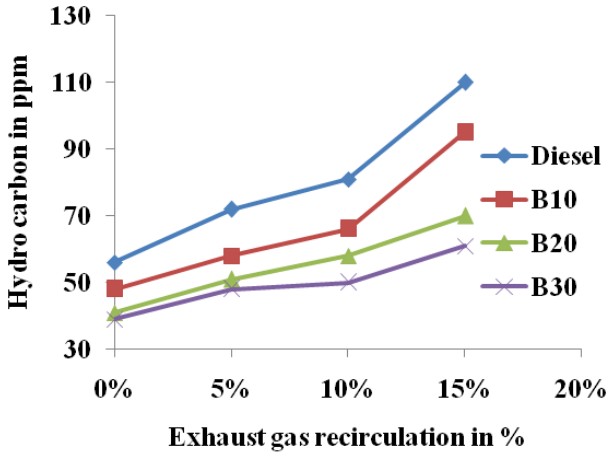

Fig.3: Effect of EGR on HC variation

Two inferences can be drawn from the Fig.3:

i) With increase in EGR, the HC in emission increases, because the higher percentage of EGR results in less oxygen to support for the combustion of fuel and hence at higher loads HC increases.

ii) As the blending percentage increases, HC emission decreases because Simarouba biofuel consists of high oxygen content (9%) [16] which supports for combustion of fuel, lowering the HC emission.

3) CO emissions

Fig. 4 is a plot showing the effects of EGR% on CO emissions.

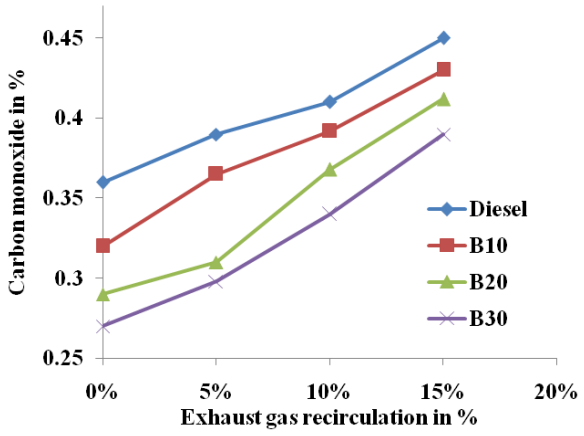

Fig.4. Effect of EGR on CO Emissions

Two inferences can be drawn from the Fig.4:

iii) With increase in EGR, the CO in emission increases, because the higher percentage of EGR results in less oxygen to support for the combustion of fuel and hence at higher loads HC increases.

iv) As the blending percentage increases, CO emission decreases because Simarouba biofuel consists of high oxygen content (9%) [16] which supports for combustion of fuel, lowering the CO emission.

4) Brake Power

Fig. 5 sows the effects of increasing EGR% on the brake power for diesel and different biodiesel blends.

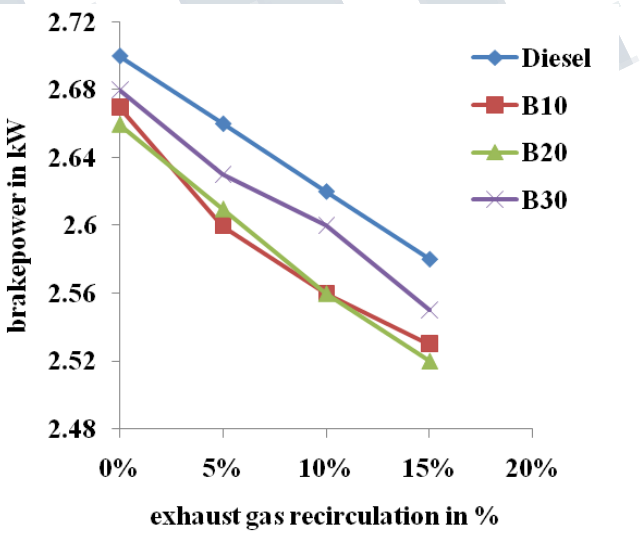

Fig.4. Effect of EGR on Brake Power

Two inferences can be drawn from the Fig.4:

v) With increase in EGR, the brake power decreases, because of dilution of charge in the combustion chamber and lesser availability of oxygen to support combustion of fuel.

vi) As the blending percentage increases, brake power decreases because Simarouba biofuel has lesser calorific value than diesel.

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IV. CONCLUSIONS

The present work aims at investigating the effect of EGR on the combustion and exhaust emission characteristics of a diesel engine.

1) As the percentage of EGR is increased, both diesel and biofuel show decrease in NOx emissions. Fuel B30 produces 27% less NOx emission compared to Diesel fuel.
2) As the percentage of EGR is increased, both diesel and biofuel show increase in CO emissions. Fuel B30 produces 39% less CO emission compared to Diesel fuel.
3) As the percentage of EGR is increased, both diesel and biofuel show increase in HC emissions. Fuel B30 produces 44% less HC emission compared to Diesel fuel.
4) As the percentage of EGR is increased, both diesel and biofuel show decrease in BP. Fuel B20 produces 2.3% less BP compared to Diesel fuel.
5) while biodiesel results in significant decreases in NOx, CO and HC emissions (27%, 39% and 44%), the reduction in brake power is only marginal (2.3%), thus making use of Simarouba biodiesel blends attractive for CI engines.

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