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Effect of EGR flow rate in biodiesel (papaya fruit seed oil) powered engine

R. Nesalingam, P. Karthi, P. Saranya
Professor &Assistant Professor, Department of Aeronautical Engineering
Nehru Institute of Technology, Coimbatore.
nitsujithkumar@nehrucolleges.com[1]

ABSTRACT: Automobile Emission is one of the major problems in environment. Engine emits the carbon monoxide (CO), hydrocarbon (HC), Nitrogen oxides (NOx) and smoke density etc. NOx emission leads to dangerous effect in the environment. NOx can travel long distances, causing a variety of health and environmental problems in locations far from their emissions source. These problems include ground level ozone and smog, which are created in the atmosphere by the reaction of nitrogen oxides and hydrocarbons in the presence of sunlight. Various methods are used to reduce the Nox emission. In the present work Exhaust gas recirculation (EGR) technique is used the diesel engine with biodiesel as fuel. Papaya fruit seed oil is used to prepare the biodiesel in this present work. Experiments are conducted in a singlecylinder, four-stroke, water-cooled, directinjection diesel engine coupled to an Eddy current Dynamometer with EGR. The result shows that NOx emission is reduced using EGR for diesel and bio diesel.

Keywords: Biodiesel, combustion, EGR, Emission.

Introduction

The diesel engines dominate the field of commercial transportation and agricultural machinery due to its ease of operation and higher fuel efficiency. The consumption of diesel is 4-5 times higher than petrol in India. Due to the shortage of petroleum products and its increasing cost, efforts are on to develop alternative fuels especially, to the diesel oil for fully or partial replacement. It has been found that the vegetable oils are promising fuels because their properties are similar to that of diesel and are produced easily and renewably from the crops. Vegetable oils have comparable energy density, cetane number, heat of vaporization and stoichiometric air–fuel ratio with that of the diesel fuel. None other than Rudolph Diesel, the father of diesel engine, demonstrated the first use of vegetable oil in compression ignition engine in 1910. He used peanut oil as fuel for his experimental engine [1]. So the use of vegetable oils as alternative fuels has been around for one hundred years when the inventor of the diesel engine Rudolph Diesel first tested peanut oil, in his compressionignition engine. Biodiesel is a renewable fuel which is free from sulfur and aromatic compounds.

Biodiesel does not overburden the environment with CO_2 emission as CO_2 from the atmosphere is absorbed by the vegetable oil crop during the photosynthesis process, while the plant is growing. Hence biodiesel offers net CO_2 advantage over conventional fuels. The use of biodiesel in diesel engines does not require any hardware modification [2]. Exhaust gas recirculation is an effective method for NOx control. The exhaust gases mainly consist of inert carbon dioxide, nitrogen and possess high specific heat. When recirculated to engine inlet, it can reduce oxygen concentration and act as a heat sink. This process reduces oxygen concentration and peak combustion temperature, which results in reduced NOx. EGR is one of the most effective techniques currently available for reducing NOx emissions in internal combustion engines.

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However, the application of EGR also incurs penalties. It can significantly increase smoke, fuel consumption and reduce thermal efficiency unless suitably optimized. The higher NOx emission can be effectively controlled by employing EGR [3]. Results indicated higher nitric oxide (NO) emissions when a single cylinder diesel engine was fuelled with JBD, without EGR. NO emissions were reduced when the engine was operated under HOT EGR levels of 5–25%. However, EGR level was optimized as 15% based on adequate reduction in NO emissions, minimum possible smoke, CO, HC emissions and reasonable brake thermal efficiency. Smoke emissions of JBD in the higher load region were lower than diesel, irrespective of the EGR levels. However, smoke emission was higher in the lower load region. CO and HC emissions were found to be lower for JBD irrespective of EGR levels. Combustion parameters were found to be comparable for both fuels [4]. The aim of this study mainly was to quantify the efficiency of exhaust gas recirculation (EGR) when using JME fuel in a fully instrumented, two-cylinder, naturally aspirated, four-stroke direct injection diesel engine. The tests were made in two sections. Firstly, the measured performance and exhaust emissions of the diesel engine operating with diesel fuel and JME are determined and compared. Secondly, tests were performed at two speeds and loads to investigate the EGR effect on engine performance and exhaust emissions including nitrogenous oxides (NOx), carbon monoxide (CO), unburned -hydrocarbons (HC) and exhaust gas temperatures. Also, effect of cooled EGR with high ratio at full load on engine performance and emissions was examined. The results showed that EGR is an effective technique for reducing NOx emissions with JME fuel especially in light duty diesel engines. A better trade-off between HC, CO and NOx emissions can be attained within a limited EGR rate of 5–15% with very little economy penalty[5]. A single cylinder diesel engine was converted to operate on hydrogen-diesel dual fuel mode. Hydrogen was injected in intake port and diesel was injected directly inside the cylinder. The injection timing and injection duration of hydrogen were optimized initially based on the performance and emissions. It was observed that start of injection at 5° before gas exchange top dead center (BGTDC) and injection duration of 30° crank angle gives the best results. The flow rate of hydrogen was optimized as 7.5 lpm for the best start of injection and injection duration of hydrogen. Cold exhaust gas recirculation technique was adopted for the optimized injection parameter of hydrogen and flow rate. Maximum quantity of exhaust gases recycled during the test was 25% beyond this the combustion was not stable resulting in increase in smoke [6]. An experimental study has been conducted on a 2.0 l HSDI automotive diesel engine under low-load and part load conditions in order to distinguish and quantify some effects of EGR on combustion and NOx / PM emissions. For a purely diffusion combustion the ROHR is unchanged when the AFR is maintained when changing incylinder ambient gas properties (temperature or EGR rate). At low-load conditions, use of high EGR rates at constant boost pressure is a way to drastically reduce NOx and PM emissions but with an increase of brakespecific fuel consumption (BSFC) and other emissions (CO and hydrocarbon), whereas EGR at constant AFR may drastically reduce NOx emissions without important penalty on BSFC and soot emissions but is limited by the turbo charging system [7].

Experimental results showed higher oxides of nitrogen emissions when fueled with waste plastic oil without EGR. NOx emissions were reduced when the engine was operated with cooled EGR. The EGR

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level was optimized as 20% based on significant reduction in NOx emissions, minimum possible smoke, CO, HC emissions and comparable brake thermal efficiency. Smoke emissions of waste plastic oil were higher at all loads. Combustion parameters were found to be comparable with and without EGR. Compression ignition engines run on waste plastic oil are found to emit higher oxides of nitrogen [8]. When similar percentages (% by volume) of exhaust gas recirculation (EGR) are used in the cases of diesel and RME, NOx emissions are reduced to similar values, but the smoke emissions are significantly lower in the case of RME. The retardation of the injection timing in the case of pure RME and 50/50 (by volume) blend with diesel results in further reduction of NOx at a cost of small increases of smoke and fuel consumption [9].

Exhaust Gas Re-Circulation System

In exhaust gas recirculation process, a fraction of the engine out exhaust gas is recirculated to the engine. Oxides of nitrogen are formed when the temperature inside the combustion chamber exceeds the critical temperature so that the molecules of nitrogen and oxygen combine [9]. Intermixing the incoming air with re-circulated exhaust gas basically cuts off some percentage of the oxygen going into the combustion chamber and lowers the adiabatic flame temperature. The exhaust gas increases the specific heat of the mixture and lowers the peak combustion temperature. NOx formation progresses faster at higher temperatures. EGR serves to limit the formation of NOx. There is no doubt that EGR is very effective in reducing oxides of nitrogen, but it also has adverse effects on the engine efficiency. As it contains a lot of particulate matter, it may also contaminate the lubricating oil and can also foul the intake manifold [9].

Experimental Setup

The engine used for the investigation is a four stroke, water cooled, single cylinder, direct-injection (DI), vertical diesel engine running at a rated power of 5.2 kW and at a rated speed of 1500 rpm shown in fig 1. The specifications of the test engine are shown in Table 1. In the experimental is work conducted two phase. The first phase is to analysis of the performance, combustion and emissions of the diesel. In second phase with EGR is using Biodiesel (papaya fruit seed oil) are studied. The engine was run by using papaya fruit seed oil as biodiesel with B20, B50, B75 and B100. In both phase readings are taken in 20%, 40%, 60%, 80% and 100% load. The emissions like HC, CO, NOx are measured in the AVL DI gas analyzer and smoke density is measured by smoke meter. The exhaust gas temperature is measured using thermo couple. Using AVL combustion analyzer the combustion parameter such as cylinder pressure, heat release and cycle to cycle variation are with pure diesel and bio-diesel.

Table 1: Specifications of the DI- Diesel Engine

1	Rated Horse power	5 hp (3.73 kW)
2	Rated Speed	1500rpm
3	No of Strokes	4
4	Mode of Injection and injection pressure	Direct Injection, 200 kg/cm^2
5	No of Cylinders	1
6	Stroke length	110 mm
7	Bore	80 mm
8	Compression ratio	16.5

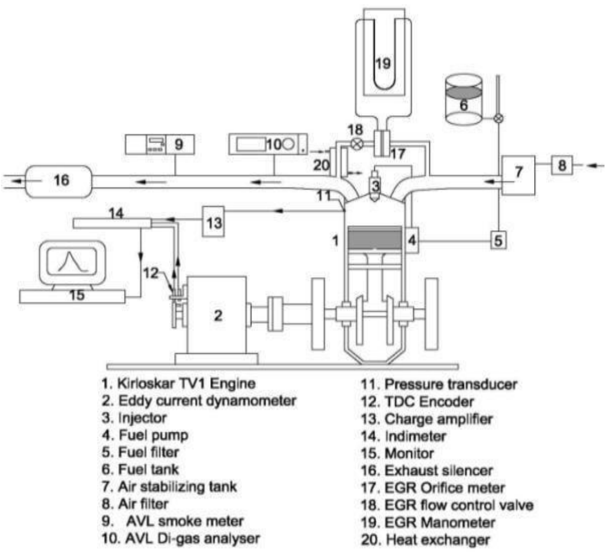

Figure: 1 Experimental Setup

Experimental Procedure

For experimentation, the engine is run at a rated speed of 1500 rpm and an injection advance of 24.9 ˚ .The engine is allowed to run till the warm-up period is reached. Then the engine is loaded in terms of 0%, 25%, 50%, 75% and 100% corresponding to the brake mean effective pressures of 0.9, 1.8, 2.7, 3.62 and 4.52 bars. At each load, the engine is run at a constant speed of 1500 rpm and an injection advance of 24.9 ˚ with different EGR conditions. The exhaust gases are tapped from exhaust pipe and connected to an inlet airflow passage. A system is devised consisting of a control valve and a manometer set up to control the rate of EGR by manually operating the control valve. After attaining the steady state, the observations are made for various parameters such as exhaust gas temperature, airflow rate, fuel consumption, brake specific fuel consumption, combustion characteristics like pressure rise that are recorded through the data acquisition system which converts analog to digital at various loads. The flue gas analyzer records exhaust emissions CO, HC and NOx simultaneously while smoke density was measured with smoke meter. The effect of fuel blends (with DTBP) and EGR on engine performance and emissions are evaluated at an engine speed of 1500rpm. At each load, the experiment is conducted by varying EGR rates such as 0%, 10% and 20%.

Results and Discussions

The experiment was carried out in a four stroke single cylinder, water cooled diesel engine using diesel and papaya fruit seed oil as biodiesel at 1500 rpm and different EGR rates to study the effect of EGR on the performance of the engine like brake thermal efficiency and specific fuel consumption and emission characteristics like HC emission smoke density and NOx concentration in the tail pipe emissions. Higher amount of smoke emission is observed in the exhaust when the engine is operated with EGR. Smoke emissions increases with increasing engine load and EGR rates.EGR reduces availability of oxygen for combustion of fuel, which results in relatively incomplete combustion and increased formation of PM and reducing NOx emissions from diesel engine. Using biodiesel in diesel engine, smoke is decreased with increase in NOx. Thus, biodiesel with EGR can be used to reduce NOx and smoke intensity simultaneously.

Brake thermal efficiency

This is due to re-burning of hydrocarbons that enter in to the combustion chamber during suction with the recirculated exhaust gases. Brake thermal efficiency of diesel fuel is higher than papaya fruit seed oil as biodiesel at all loading conditions with EGR operations due to higher heating value of the diesel fuel. At full load operation the brake thermal efficiency marginally decreases in both cases with the increase of the EGR rate.

Specific fuel consumption

The variations of SFC with brake power for diesel and biodiesel (papaya fruit seed oil) respectively with EGR at constant speed of the engine. The specific fuel consumptions are lower for diesel at all loading conditions when operated with EGR and without EGR when compared to papaya fruit seed oil. So, for papaya fruit seed oil more mixtures are required for constant power output.

Oxides of nitrogen emission (NOx)

The variations of NOx emissions with brake power of diesel and papaya fruit seed oil respectively with EGR at constant speed of the engine. It is observed from that the bio-diesel emits higher NOx than diesel fuel at all loading conditions due to higher oxygen content of bio-diesel provide high local temperature and complete combustion of the bio-diesel. The emission of NOx tends to decrease significantly with the increase of EGR rate for all loading conditions for both the fuels due to reduction of oxygen concentration for the presence of inert gases such as CO_2 and H2O in the cylinder that decreased the flame temperatures in the combustion chamber. At full load condition NOx emission for diesel and papaya fruit seed oil are respectively 798ppm and 880ppm at constant speed of the engine with EGR.

Smoke density (HSU)

The variations of smoke emissions with brake power of diesel and papaya fruit seed oil respectively with EGR at constant speed of the engine. Higher amount of smoke emission is observed in the exhaust when the engine is operated with EGR. Smoke emissions increases with increasing engine load and EGR rates. EGR reduces availability of oxygen for combustion of fuel, which results in relatively incomplete combustion and increased formation of PM and reducing NOx emissions from diesel engine. papaya fruit seed oil showed 5.5% lower smoke compared to diesel oil at full load condition when operated with EGR due to the oxygen content of the bio-fuel molecules resulting more complete combustion of the bio-diesel. At full load condition almost same smoke emission is observed for both the fuels with EGR.

Hydrocarbon emission (HC)

The variations of hydrocarbon (HC) emissions with brake power of diesel and papaya fruit seed oil respectively with EGR at constant speed of the engine. it is observed that hydrocarbon emission increases with the increase with load in the engine due to insufficient amount of oxygen in the combustion chamber resulting incomplete combustion. Due to presence of molecules of oxygen papaya fruit seed oil emits lower HC than diesel fuel. At full load condition papaya fruit seed oil emits 12% and7.5% lower HC than diesel.

Conclusion

An experimental investigation was carried out on a single cylinder four stroke, water cooled diesel engine operated on diesel fuel and papaya fruit seed oil with exhaust gas recirculation. The effect of EGR on the performance and exhaust emissions of the diesel engine were analyzed.

The results of this study may be concluded as follows:

1. When the engine was operated with papaya fruit seed oil, the brake

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thermal efficiency decreases due to the lower calorific value of biodiesel compared to net diesel fuel. The brake thermal efficiency increases at low EGR rates for both the fuels. However, increasing EGR flow rates to high levels resulted in decrease in brake thermal efficiency for both net diesel fuel and papaya fruit seed oil.

2. It is observed from the Figure: that the biodiesel emits higher NOx than diesel fuel at all loading conditions. The NOx emissions were decreased with increase in EGR flow rate for both net diesel fuel and papaya fruit seed oil.
3. The emissions of smoke and HC were found to be lower with papaya fruit seed oil. However, with the increase of EGR flow rates resulted in considerable rise in smoke and HC emissions for both net diesel fuel and papaya fruit seed oil.
4. The specific fuel consumption for papaya fruit seed oil was slightly higher than diesel fuel at all loading conditions when operated with and without EGR.

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