ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Investigation of Engine Performance and Emissions of B20 Biodiesel Blend and Effect of EGR on NOx Emissions Reduction

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ABSTRACT

Biodiesel is an alternative option to conventional diesel. The use of biodiesel blends slightly reduces the brake thermal efficiency to that of conventional diesel and emission of pollutants are reduced except emission of NOx. Since NOx causes serious environmental and health issues, it could become an important barrier to the future market of biodiesel. Thus it is important to find solution to eliminate/reduce NOx emissions of biodiesel. In this research work, biodiesel is produced from vegetable oils through transesterification and is mixed with conventional diesel to make B20 biodiesel blend. Engine performance and emissions are tested and compared in a single cylinder direct injection diesel engine under three situations: conventional diesel, B20 biodiesel blend and B20 biodiesel blend with EGR.

KEY WORDS: biodiesel, vegetable oil, NOx reduction, diesel engine, performance, emission, EGR.

1. INTRODUCTION

Global energy demand grows by more than one-third over the period to 2035. Fossil fuels have been used as sources of energy requirements which generate pollutants responsible for global warming, climate change and some incurable diseases. Diesel fuel is a fossil fuel extensively used in agricultural, transportation and industrial sector which contribute to the prosperity of the worldwide economy. The diesel engine is a major contributor to air pollution. Exposure to air pollution becomes the top environmental reason globally for premature deaths overtaking malaria and water quality by 2050. Emissions, such as NOx, CO_2, CO, HC and PM produced by internal combustion engines, have adverse effect on environment and human health; CO_2 contributes to green house effect, CO blocks hemoglobin, NO forms nitric acid with moisture causing acid rain, NO_2 damages the pulmonary functions, and HC, PM and SO_2 are irritants. Depletion of fossil fuel reserves and harmful effects of various emissions made all researchers' attention towards the search of alternative fuels.

Biodiesel is an alternative option to conventional diesel and is a non petroleum based fuel that consists of alkyl esters of vegetable oils or animal fat. The direct use of vegetable oils and its blends in conventional diesel engines is impractical, due to high viscosity, acid composition and free fatty acid content. Transesterification is the process used in order to achieve viscosity and flow properties close to that of conventional diesel. Compared to conventional diesel fuel, biodiesel or diesel blended with biodiesel produce less emissions of particulate matter, hydrocarbons and COx but NOx emissions will usually be increased. However, if the diesel blend contains proper amount of biodiesel, ABE solution and a small amount of water (0.5%), excellent brake thermal efficiency and lower NOx emissions could be achieved.

The use of biodiesel as alternative fuel in diesel engines has been investigated by many researchers. Qi (2010), produced biodiesel from soybean crude oil and the effects of addition of biodiesel with conventional diesel was investigated on the performance, emissions and combustion characteristics of direct ignition CI engine. Murari (2014), prepared biodiesel from canola oil and the performance and emissions of biodiesel–diesel, biodiesel–diesel-additive and kerosene–biodiesel combinational series were investigated. Habibullah (2014), used the feed stocks of palm and coconut to make biodiesel and evaluated their combined effect on engine performance and emissions. Mixture of waste cooking oils was used to make the biodiesel by Ozer (2014), and engine performance and emissions were tested. Engin (2015), investigated the effects of camelina biodiesel blends on engine performance and emissions. Jafar (2015), used the disposed animal fat for the production of biodiesel and investigated the engine performance and emissions of its blends. Senthil (2015), investigated the engine performance and emission characteristics of water emulsified B20 biodiesel of Thevetia Peruviana. Similar research works were conducted by different researchers on various biodiesels. Most of these research works show that the use of biodiesel slightly reduce the brake thermal efficiency but all emissions, except NOx emissions, are reduced. NOx emissions cannot be ignored because it causes environmental effects such as ground level ozone, acid rain, smog and health effects such as asthma, coughing, and nausea. Since the market of using biodiesel blends is increasing rapidly, NOx emissions could become barrier to production of biodiesel. Thus it is important to find ways to eliminate/reduce biodiesel NOx emissions.

NOx is formed at higher temperatures. Exhaust gas recirculation (EGR) is a technique that reduces the combustion temperature by mixing a small portion of exhaust gas with the fresh intake. This dilutes the fresh charge lowering combustion temperature inside the engine cylinder and NOx formation is reduced. In this work, conventional diesel fuel, B20 biodiesel blend and B20 biodiesel blend with 10% EGR are taken and the engine performance and emissions are measured. The results are compared and discussed.

2. METHODOLOGY

Biodiesel is prepared from vegetable oil by transesterification process by adding methanol and catalyst. The transesterification process was carried out by stirring the ingredients for about two to three hours under 60 to 70 degree Celsius. The mixture is then transferred to a separating funnel and kept aside overnight. The containment is washed-off in distilled water to remove the traces of methanol and catalyst and is dried for use. This biodiesel is proportionally (20% of biodiesel and 80% of conventional diesel) mixed with the conventional diesel to make B20 biodiesel blend.

The engine performance and emissions are measured in a single cylinder, four-stroke, air-cooled, direct injection diesel engine. The diesel engine is attached to a brake drum diameter with spring-loaded adjustments. The engine load can be varied by changing the position of rope adjustments. The exhaust pipe is connected to exhaust gas analyzer. The exhaust gas analyzer could detect emissions of Cox, NOx and hydrocarbons. Flow rate of fuel is measured from burette. In the burette, conventional diesel and B20 biodiesel can be filled. EGR is also attached and the flow control valve is set to allow 10% EGR.

The experiment is started with conventional diesel fuel. The test engine is started with no load and is allowed to run at its rated speed of 1500 rpm. The load is applied from no load to 20 kg with 4 kg increments using rope dynamometer and the measurements are noted. For each load conditions, say 0 kg, 4 kg, 8 kg, 12 kg, 16 kg and 20 kg, fuel consumption per minute, torque and emissions are noted and tabulated. The above mentioned steps are repeated by replacing B20 biodiesel and later by B20 biodiesel with 10% EGR. From the readings observed, brake thermal efficiencies of different load conditions are obtained, and investigations are made whether B20 biodiesel is better than the conventional diesel and the effect of EGR on NOx emissions.

3. RESULTS AND DISCUSSION

In this work, the engine performance and emissions were measured for three situations: (a) conventional diesel, (b) biodiesel mixed with conventional diesel (B20), and (c) biodiesel blend with 10% EGR. The results are compared.

Engine Performance: The following figure shows the variations in brake thermal efficiencies of conventional diesel, B20 biodiesel and B20 biodiesel with 10% EGR, under varying engine load conditions. From the figure, it is clearly observed that the brake thermal efficiencies of B20 biodiesel are higher than to that of conventional diesel. O_2 content in biodiesel increases combustion process and hence increases brake thermal efficiency.

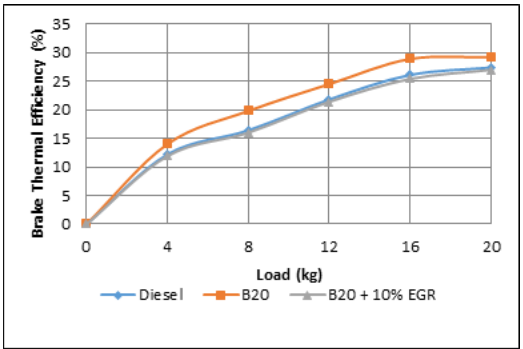

Figure.1. Brake Thermal Efficiency

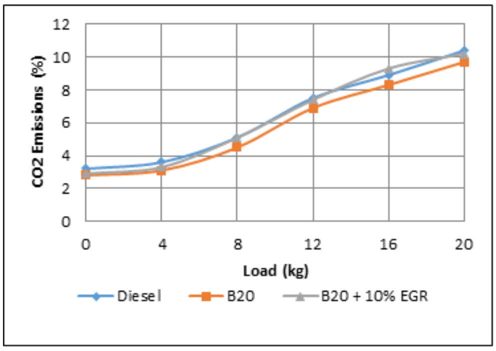

Figure.2. CO_2 Emissions

However, EGR dilutes the fresh air-fuel intake with the exhaust gases which causes lower flame velocity and slightly less availability of O2 and results in incomplete combustion. Hence, brake thermal efficiency is slightly less by introducing EGR than that of without EGR.

CO_2 Emissions: Figure shows the CO_2 emissions level of conventional diesel, B20 biodiesel, B20 biodiesel and B20 biodiesel with 10% EGR. From the figure, it is observed that CO_2 emissions of B20 biodiesel are lesser than that of conventional diesel, due to the fact that biodiesel generally contains low carbon content. The increase in CO_2 emissions, with respect to increased load conditions, is due to higher fuel consumption.

As EGR is introduced with B20 biodiesel, availability of oxygen for complete combustion is low. However, the additional O_2 content in biodiesel reacts with the available carbon content to convert CO into CO_2. Hence, EGR increases CO2 emissions slightly higher than that of B20 biodiesel, but is still less than that of conventional diesel.

CO Emissions: Figure shows CO emissions of conventional diesel, B20 biodiesel, B20 biodiesel and B20 biodiesel with 10% EGR. CO is formed when the presence of O_2 is not adequately present to convert all carbon into CO_2. As biodiesel is oxygen-rich, CO emissions is lesser in B20 biodiesel compared to that of conventional diesel. However, when the load is increased, CO emission is significant as the fuel consumption is more.

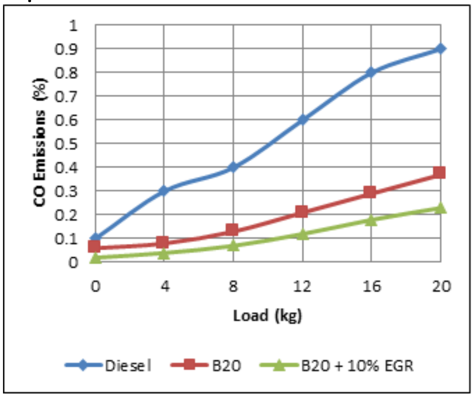

Figure.3. CO Emissions

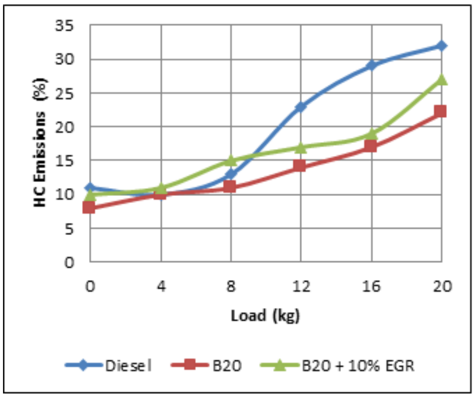

Figure.4. HC Emissions

CO emissions increase with the introduction of 10% of EGR due to reduction in the availability of oxygen for complete combustion.

HC Emissions: Figure shows HC emissions of conventional diesel, B20 biodiesel, B20 biodiesel and B20 biodiesel with 10% EGR. The presence of oxygen in the biodiesel increases the combustion process and hence the HC emission is less in B20 biodiesel compared to that of conventional diesel. However, increase in load increases HC emissions, may be, due to varying air-fuel ratio or incomplete combustion.

NOx Emissions: Figure shows the variation of NOx emissions level of conventional diesel, B20 biodiesel, B20 biodiesel and B20 biodiesel with 10% EGR. While all other emissions are lesser than conventional diesel, B20 biodiesel shows higher NOx emissions at all load conditions. NOx is formed at high temperatures and higher NOx emission happens because of higher exhaust gas temperature.

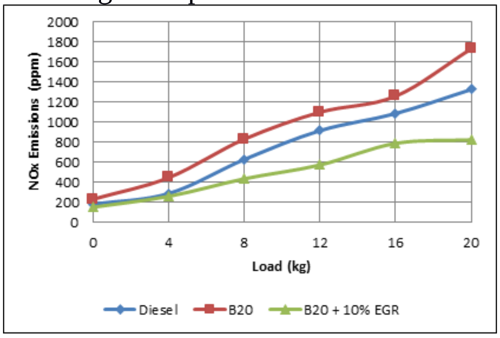

Figure.5. Nox Emissions

Nox emission depends on combustion temperature and oxygen availability inside engine cylinder. As EGR decreases the combustion gas temperature as well as the availability of oxygen content, NOx formation is considerably reduced compared to that of both conventional biodiesel and B20 biodiesel.

4. CONCLUSION

In this work, biodiesel is produced from vegetable oil and the engine performance and emission characteristics were investigated. Experiments were conducted in a single cylinder diesel engine using conventional diesel fuel, B20 biodiesel blend and B20 biodiesel blend with 10% EGR. The brake thermal efficiencies and emissions are determined. The following conclusions are made from the obtained results:

- Brake thermal efficiency is improved in both B20 biodiesel and B20 biodiesel with 10% EGR. However, the introduction of EGR slightly reduced the brake thermal efficiency in B20 biodiesel.
- CO_2, CO and HC emissions are reduced with the use of B20 biodiesel compared to conventional diesel. When EGR is introduced, these emissions are slightly increased due to low availability of oxygen content to form these emissions.
- NOx emission of B20 biodiesel is higher than that of conventional diesel due to high combustion temperature. This emission is reduced due to the decrease of combustion temperature due to low availability of O_2 for combustion process.

Finally, it is concluded, from the results, that NOx could be reduced effectively by introducing EGR in biodiesel obtained from vegetable oil. The B20 biodiesel with 10% EGR can be used as a better alternative fuel, in diesel engines, with reduced environmental and health effects than conventional diesel.

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