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Investigation of Emission & Performance Characteristics of waste cooking oil from diesel engine using Exhaust Gas Recirculation

[#1]M.P. Kumbhare, [#2]M. J. Sable

[1]mpkumbhare@rediffmail.com
[2]mjsable6671@gmail.com

[#1]PG Student,Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Pune, Savitribai Phule Pune University,MH,India.

[#2]Professor,Department of Mechanical Engineering, Rajarshi Shahu College of Engineering, Pune, Savitribai Phule Pune University,MH,India

ABSTRACT

The toxic gases emitted to atmosphere by automobiles are liable to cause harm to human health, other living organisms, plants and environment by entering into bio-logical system." "Diesel engine commonly known as compression ignition (C.I.) engine is widely used as power source. Exhaust gas emitted from compression ignition (C.I.) engine, is a mixture of many undesirable constituents known as pollutants. Diesel engine is better power source due to higher efficiency, performance, reliability and fuel economy than spark ignition (S.I.) engine and hence is preferred over spark ignition engine in commercial application.

One simple way of reducing the NOx emission of a diesel engine is by late injection of fuel into the combustion chamber. This technique is effective but increases fuel consumption by 10–15%, which necessitates the use of more effective NOx reduction techniques like exhaust gas recirculation (EGR). Re-circulating part of the exhaust gas helps in reducing NOx, but appreciable particulate emissions are observed at high loads, hence there is a trade-off between NOx and smoke emission. To get maximum benefit from this trade-off, a particulate trap may be used to reduce the amount of unburnt particulates in EGR, which in turn reduce the particulate emission also.

Keywords— EGR,NOx,Diesel Engine,Emissions.

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I. Introduction

In India diesel engines are widely used for transport and agricultural machinery due to its superior fuel efficiency. The increasing cost of petrol has made people to depend largely on diesel based engines. Due to depletion and higher cost of petroleum based fuels researchers around the world look for alternate fuels. Biodiesel which is mainly mono alkyl esters of long chain fatty acids has been accepted as a suitable alternate to diesel fuel. Moreover, the emission is very much reduced by utilizing biodiesel. Biodiesel blended with diesel fuel showed better performance. Vegetable oils because of their higher viscosity and huge carbon deposits can be used only as a short term fuel in diesel engines. Viscosity of vegetable oils can be reduced and made equivalent to diesel fuel by transesterification. Large number of feedstocks including nonedible oils and wastes from hotels, beef tallow and chicken feather meals are utilized for biodiesel production. In developed countries, used cooking oils are available in plenty and are used as cheap feedstock for biodiesel production.

In India because of huge population and availability of large number of restaurants a huge amount of edible oil is consumed for food preparation. The used oil thus produced is dumped outside resulting in environmental degradation. This could be avoided if these used oils are collected and converted into biodiesel. In this study used palm oil was collected from different restaurants in Tirunelveli region of south India and was converted into biodiesel. The biodiesel thus produced is blended with diesel at different volume proportions and tested in a DI diesel engine to evaluate its performance, emission and combustion profile.

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II. Literature Review

H. Sharon, et. al. (2012) have converted the used palm oil collected from different restaurants into methyl esters (biodiesel) by transesterification. Biodiesel produced from used palm oil was blended with diesel by different volume proportions (25%, 50% and 75%). Biodiesel and its blends were tested in a DI diesel engine at constant speed by varying loads (between 20% and 100%) to analyze its performance, emission and combustion profile. The results obtained were compared with diesel fuel. B25 and B50 showed performances similar to diesel fuel. Combustion profile was smoother and no knocking was experienced while operating with biodiesel blends. B50 produced peak cylinder pressure.

Gerhard Knothe (2009) has discussed in a general and comparative fashion aspects such as fuel production and energy balance, fuel properties, environmental effects including exhaust emissions and co-products. Among the questions that are addressed are if these fuels compete with or complement each other and what the effect of production scale may be.

Yu-Cheng Chang, et. al. (2013)have described a method for reducing the emissions of toxic organic pollutants from heavy duty diesel engines fueled by biodiesel produced from waste cooking oil (WCO). An analytical method was developed to simultaneously measure five pollutants from one exhaust sample, namely polycyclic aromatic hydrocarbons (PAHs), polychlorined dibenzo-p-dixins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs) and polybrominated diphenyl ethers (PBDEs). Even though the chlorine content in the WCO-based biodiesel was five times higher than that of fossil diesel, the reduction in the emission factors of the aforesaid pollutants increased along with the percentage of biodiesel. In conclusion, the use of WCO-based biodiesel not only solves the problem of waste oil disposal, but also reduces the toxic organic pollutant emissions from diesel engines.

Idris Saad and Saiful Bari (2013)were performed IC engine simulations to determine the effect of Guide Vane Swirl and Tumble Device (GVSTD) on the air flow using 3D computational fluid dynamics (CFD) software. The effects of various vane heights by means of parametric optimization were investigated. The results of average in-cylinder pressure, turbulent kinetic energy (TKE) and velocity were analyzed before the optimum vane height to the pre-set values of vane angle, number and length were decided. Interestingly, the highest vane height failed to improve all the analyzed parameters.

NOx formation mechanisms are complex and affected by several different features (e.g., size, operating points, combustion chamber design, fuel system design, and air system design) of internal combustion engines. The slight differences in properties between biodiesel and petroleum diesel fuels are enough to create several changes to system and combustion behaviors of diesel engines. Combined, these effects lead to several complex and interacting mechanisms that make it difficult to fundamentally identify how biodiesel affects NOx emissions. Instead, it is perhaps better to say that several parameters seem to most strongly influence observed differences in NOx emissions with biodiesel, thus introducing several possibilities for inconsistency in the trends. These parameters are injection timing, adiabatic flame temperature, radiation heat transfer, and ignition delay. Jiafeng Sun et. al. (2010) provided a review of the rich literature describing these parameters, and provides additional insight into the system responses that are manifested by the use of biodiesel.

The combustion characteristics and emissions of compression ignition diesel engine were measuredbyWail M. Adaileh and Khaled S. AlQdah (2012)using a biodiesel as an alternative fuel. The tests were performed in Chemical and Mechanical Engineering department laboratories at steady state conditions for a four stroke single cylinder diesel engine loaded at variable engine speed between 1200-2600 rpm. The waste vegetable oil (cocking oil) used in this investigation transferred from restaurant collected and disposed in a suitable way. The testing results show without any modification to diesel engine, under all conditions dynamical performance kept normal, and the B20, B5 blend fuels (include 20%, 5% biodiesel respectively) led to satisfactory emissions at variable load. The experimental results compared with standard diesel show that biodiesel provided significant reductions in CO, and unburned HC, but the NOx was increased.

III. Waste Cooking Oil

A. Introduction

Fried food items are very popular in the coastal regions of India. Generally cooking oil used for frying are sunflower oil, palm oil, coconut oil etc. as they are easily available, and especially so of the coconut oil which is abundantly available in south India. It is well known fact that, when oils such as these are heated for an extended time, they undergo oxidation and give rise to oxides. Many of these such as hydro peroxides, peroxides and polymeric substances have shown adverse health/biological effects such as growth retardation, increase in liver and kidney size as well as cellular damage to different organs when fed to laboratory animals [10]. Thus, used cooking oils constitute a waste generated from activities in the food sectors (industries and large catering or community restaurants), which have greatly increased in recent years. Most of the waste (overused /abused) cooking oil are disposed inappropriately, mostly let into the municipal drainage, leading to water pollution. The primary end use of WCO in existence now is to utilize it as a fuel in residential and industrial heating devices. An alternative to prevent inappropriate disposal of WCO is by recycling it. The main use of recycled WCO is in the production of animal feeds and in a much smaller proportion in the manufacture of soaps and biodegradable lubricants. Some health risks can be traced from the use of recycled cooking oils in animal feeding, such as undesirable levels of contaminants, particularly PAHs (Polycyclic aromatic hydrocarbons), PCBs (Polychlorinated biphenyls), dioxins and dioxin related substances [11]. By consumptions of animal origin foodstuffs like milk, meats, poultry and other products, these undesirable contaminants enter the human body and cause serious long term health hazards. As these contaminants are lip soluble, they accumulate in organic lipids and finally in the body, and thereby their concentration increases gradually over the years. In other words, the body is exposed not only to a single acute action, but also to a chronic action of bioaccumulation of these hazardous compounds over the years [11]. Hence utilizing the recycled WCO in any way is not advisable from health standpoint.

B. Affect In Human Health

In terms of the health implication of WCO reuse, continued heating and consumption of WCO was reported to be very dangerous to human health. By continuing reuse of WCO for food preparation one increases the risk of cardiovascular diseases, liver problem, and cancer. [12]If WCO is not properly strained and stored after it cools, bacteria feeds on food particles left in the oil. Unrefrigerated oil becomes anaerobic and leads to the growth of Clostridium botulinum, which causes botulism, a potentially fatal food poisoning. Refrigerating or freezing oil retards bacterial growth. Rancid meaning old and stale oil contains free radicals, molecules that can damage cells and lead to increased cancer risk, as well as affect the quality of your food. The good news is that your nose can easily identify rancid oil. Waste cooking oil management aims at preventing the general environmental and health effects associated with its improper disposal and continuing consumption among consumers. It entails any legal and practical measures employed in ensuring that WCO is handled in a manner that has not in one way or the other affect the environmental and human welfare. Waste cooking oil collection and recycling programme is among the most common practice in developed countries or regions like the EU, Japan, United States, and Taiwan [13].

IV. Material and Method

Waste cooking oil collected from the restaurants is considered as feedstock for the biodiesel production. Transesterification is a chemical process of transforming large, branched, triglyceride molecules of Waste cooking oils and fats into smaller, straight chain molecules, almost similar in size to the molecules of the species present in diesel fuel. The process takes place byreacting the vegetable oil with an alcohol in the presence of catalyst. In general, due to high value of free fatty acids (FFA) of waste vegetable oils, acidcatalyzed transesterification is adopted. However, FFA of the feedstock used in this work is less and hence alkali catalyzed transesterification process is employed for the conversion of Waste cooking oil into ester. The Waste cooking oil is preheated in a reactor to remove the moisture. Potassium methoxide is prepared by dissolving potassium hydroxide in methanol. Various concentration of KOH in the methoxide was prepared and the process is optimized for the maximum yield. For the optimized KOH concentration, alcohol proportion also optimized to obtain the maximum yield. Methoxide is mixed with preheated oil and the reaction carried out under nominal speed stirring by a mechanized stirrer and at a constant reaction temperature of 55°C for 2 hours. During that time period the chemical reaction takes place between raw WCO oil and the methanol. At the end of completion of reaction, the mixture was drained and transferred to the separating funnel. The phase separation was taken place in the funnel in two layers. Upper layer was the biodiesel and lower phase was Glycerine. Finally, washing was made with water.

TABLE I
PROPERTIES OF OIL

Sr. No.	Property	Diesel	WCO
1	Density (kg/m^3)	850	885
2	Kinematic Viscosity (cSt)	2.44	4.76
3	Heating Value (kJ/kg)	41000	40200
4	Cloud Point (^0C)	3	16
5	Pour Point (^oC)	-6	19
6	Flash Point (^0C)	70	145

V. EXPERIMENTAL SETUP

A naturally aspirated single cylinder diesel engineis selected for experimentation. Modifications are made to the original engine set up to work with option EGR. A heat exchanger is used to cool the exhaust gas while entering the inlet. The control valve is provided to recirculate exhaust gas into the inlet pipe. Table I gives the details of the experimental setup. Smoke meter is used to measure emissions. The emission concentrations are measured after engine has attained steady state for each set of readings. A schematic of experimental set up is shown in figure 1.

Figure 1:

Waste Cooking Oil

↓

Heating on Magnetic Stirrer (65-75^{0}C)

Alcohol (CH_3OH)
+
Catalyst (NaOH)

'ransesterification — Glycerin

Settling Down — Purification

Biodiesel Washing — Soap/Pears/Candle

Heating (110^{0}C)

Pure Biodiesel

Fig. 1 Flow Chart of Biodiesel Production Process

Fig. 2 Experimental Setup

TABLE II
ENGINE SPECIFICATIONS

Sr. No.	Specification	Value
1	Maximum Engine Output	3.7 kw
2	Maximum Engine Speed	1500 rpm
3	Bore x Stroke	87 x 110 mm
4	Compression Ratio	16:1

VI. RESULTS AND DISCUSSION

The nature of variation of Carbon Monoxide withBrake Power is shown in Fig. 3. At part loads the engine isoperated at higher air fuel ratios, these lean mixturesleft unburnt leads to higher CO emissions. At higher Brake power rich mixtures leads to increase in CO formation. CO emissions increases with EGR rate at a given load of engine operation.

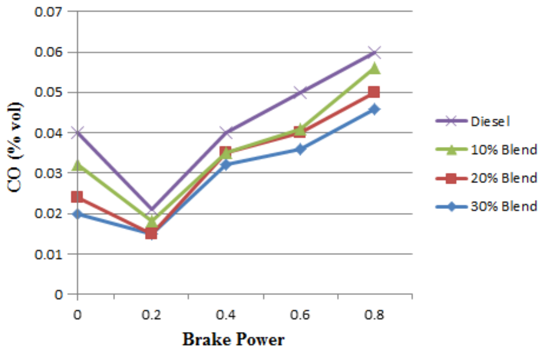

Fig. 3 Variation of CO with Brake Power

The nature of variation of CO_2 with Brake power is shown in Fig. 4.The emission of CO_2increases with increase in Brake power.

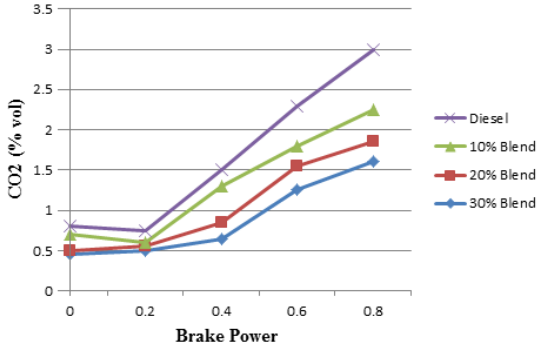

Fig. 4 Variation of CO_2 with Brake Power

It was observed that as EGR rate increases a rise UHC emission occurred in the exhaust. UHC emissions are lower for biodiesel diesel blends are much reduced in comparison to diesel for all the loads of engine operation. Effect of EGR is to increase the HC emissions in the exhaust. Pure diesel observed to be giving higher UHC emissions with EGR rate in comparison to biodiesel.

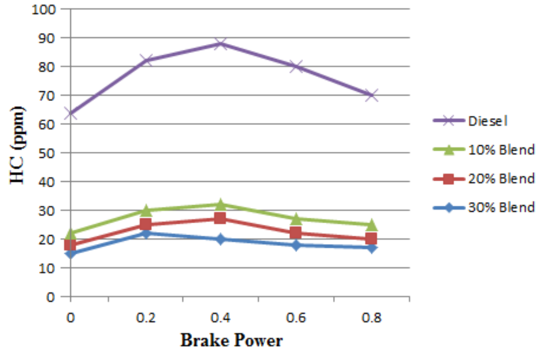

Fig. 5 Variation of HC with Brake Power

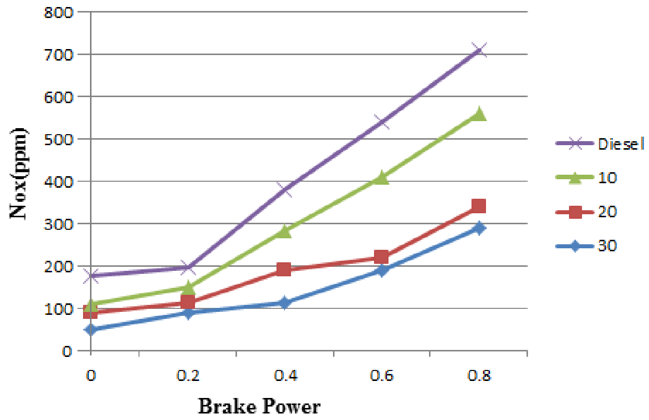

Fig. 6 Variation of NOx with Brake Power

Nitrous oxide formation is a temperature dependant phenomenon along with residence time of fuel and air. Biodiesel combustion emits more NOx in comparison to diesel. The reason can be due to quantity of nitrogen present in the fuel. Figure 5 gives the variation of NO with Brake power. It is evident that as the Brake power increases NO emissions increased, due to rise in temperature leads to more NO formation

VII. CONCLUSIONS

1.Brake Specific fuel consumption increases forpure biodiesel, and decreased for B10, B20 incomparison to

diesel. The main cause of theincrease in BSFC values for pure biodiesel itshigh value of viscosity when compared with
diesel.
2. Effect of EGR is to increase the fuelconsumption of the engine. Unburnthydrocarbon emissions seem to reduce with biodiesel-diesel blends and with pure biodiesel,however with EGR the hydrocarbon emissionsincreased. With increase in EGR rate thecarbon monoxide emissions also increased.
3. Nitrous oxide emissions are considerablyreduced with the rise in EGR rate. When theengine is operated with biodiesel EGR wouldbe best pre treatment method to reduce theNOx emissions at the cost of little fuel penalty.

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