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Extraction Diesel Engine Fuel from Waste Ground Nut Oil for Dual Fuel Diesel Engine

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Abstract – **Groundnut is the most important food crop of the world. Groundnut Oil is the major product derived from Groundnut, a major oilseed crop of India. Therefore, waste ground nut oil can been considered as one of the feedstock for biodiesel fuel production in Rayalseema region of Andhra Pradesh. The present work reports on the extraction of diesel fuel from waste ground nut oil (non-edible oil) using transesterification, characterization of fuel, performance & emission characteristics in Duel fuel Diesel Engine. The experiments are carried out on a Single cylinder kirlosker diesel engine which is commonly used in agricultural sector. Experiments are conducted by fuelling the diesel engine with Diesel Engine Fuel with LPG blends. The engine is properly modified to operate under dual fuel operation using LPG as the blended fuel along with Diesel Engine Fuel as an ignition source. The brake thermal efficiency of Diesel Engine Fuel with LPG (2LPM) blend is increased at an average of 5%. HC emissions of Diesel Engine Fuel with LPG (2LPM) blend are reduced by about at an average of 21%. CO emissions Diesel Engine Fuel with LPG (2LPM) blends are reduced at an average of 33.6%. NOx emissions of Diesel Engine Fuel with LPG (2LPM) blend are reduced at an average of 4.4%. The smoke opacity of Diesel Engine Fuel with LPG (2LPM) blend is reduced to an average of 10%.**

Keywords – **Biodiesel, Diesel Engine, Dual Fuel, Ground nut Oil, Transesterification.**

I. INTRODUCTION

Groundnut seeds contain high quality edible oil (50% approx.), easily digestible protein (25%) and carbohydrates (20%). It is grown on 26.4 million ha worldwide with a total production of 36.1 million metric tons, and an average productivity of 1.4 metric tons/ha. Ground Nut oil contains mainly Oleic (C18:1) 52.0-60.0 and Linoleic acid (C18:2) 13.0-27.0. The fatty acid composition of Ground Nut oil is shown in Table 3.2. India produces around 10 lakh MT of Groundnut oil in 2004-05. Groundnut Oil is the major product derived from Groundnut, a major oilseed crop of India. Ahmedabad, Gondal, Junagadh and Rajkot in Gujarat, Adoni in Rayalseema region of Andhra Pradesh, Mumbai and Delhi are the major trading centers for Groundnut Oil. Therefore, Ground nut oil has been considered as one of the feedstock for biodiesel fuel production in Rayalseema region of Andhra Pradesh. Sethi et al (2004) studied the exhaust Analysis and Performance of a Single Cylinder Diesel Engine Run on Dual Fuels. Experiments were done on a 4-stroke 5 hp diesel engine was tested with two different fuel blends. In the first case, diesel kerosene blends (with 10% to 40% kerosene blending by volume) and in the second case, air-liquefied petroleum gas (LPG) mixture (15% to 25 % LPG mixing by volume) along with diesel was tested at constant engine speed of 1700 rpm. With diesel-kerosene blends minimum exhaust emissions were observed at 30% kerosene blend. Exhaust gas emissions, namely, CO, UHC, and SO2 reduced by 40%, 18% and 19%, respectively, when compared with pure diesel emissions. Slight increase in the NOx exhaust emission (2.4%) was observed. With air-LPG mixtures, minimum exhaust emissions were observed at 20% LPG mixing. Exhaust gas emissions, namely, CO, UHC, and SO2 reduced by 80%, 71%, and 21%, respectively. However, 19% increase in NOx exhaust emission was observed. Engine performance improved and specific fuel consumption (SFC) was observed to be minimal at 30% kerosene blending and decreased by 3.7% as compared to pure diesel value at the same brake power output. SFC was also observed to be minimal at 20% LPG mix and decreased by about 20% as compared to pure diesel value at the same brake power output. The fuel operating cost also reduced by 3.6% at 30% kerosene blend and further reduced by 9.6% at 20% LPG mixing with air. Selim et al (2005) analysed the cycle-to-cycle combustion variation as reflected in the combustion pressure data of a single cylinder, naturally aspirated, four stroke, Ricardo E6 engine converted to run as dual fuel engine on diesel and gaseous fuel of LPG or methane. A measuring set-up consisting of a piezo-electric pressure transducer with charge amplifier and fast data acquisition card installed on an IBM microcomputer was used to gather the data of up to 1200 consecutive combustion cycles of the cylinder under various combination of engine operating and design parameters. These parameters included type of gaseous fuel, engine load, compression ratio, pilot fuel injection timing, pilot fuel mass, and engine speed. The data for each operating conditions were analyzed for the maximum pressure, the maximum rate of pressure rise-representing the combustion noise, and indicated mean effective pressure. The cycle-to cycle variation is expressed as the mean value, standard deviation, and coefficient of variation of these three parameters.

It was found that the type of gaseous fuel and engine operating and design parameters affected the combustion noise and its cyclic variation and these effects have been studied. Qi et al (2007) conducted experiments on a single cylinder DI Diesel engine, which has been properly modified to operate under LPG-Diesel blended fuel conditions, using LPG-Diesel blended fuels with various blended rates (0%, 10%, 20%, 30%, 40%). It was found that that blended fuel combustion using LPG is a promising technique for controlling both NOx and smoke emissions even on existing DI Diesel engines and requires only a slight modification of the engine structure.

Banapurmatha et al (2008) used Honge oil/Honge oil methyl ester and producer gas as a total replacement for fossil fuels. It was shown that indicated brake thermal efficiency in dual fuel mode of operation to be lesser than single fuel mode of operation at all the injection timings investigated. However, it was observed that the brake thermal efficiency improved marginally when the injection timing was advanced for both Honge oil and Honge oil methyl ester. The smoke emission for producer gas-Honge oil was found to be more than producer gas-diesel oil. The producer gas-Honge oil methyl ester higher brake thermal efficiency and reduced emissions were obtained. With dual fuel operation, smoke and NOx emissions were considerably reduced with increase in CO emissions. Saleh (2008) investigated the effect of variation in LPG composition on emissions and performance characteristics in a dual fuel engine run on diesel fuel and five gaseous fuel of LPG with different composition. It was observed that the exhaust emissions and fuel conversion efficiency of the dual fuel engine are found to be affected when different LPG composition is used as higher butane content lead to lower NOx levels while higher propane content reduces CO levels. Fuel3 (70% propane, 30% butane) with mass fraction 40% substitution of the diesel fuel was the best LPG composition in the dual fuel operation except that at part loads. Also, tests were made for fuel3-diesel blend in the dual fuel operation at part loads to improve the engine performances and exhaust emissions by using the Exhaust Gas Recirculation (EGR) method. Banapurmath et al (2009) studied the utilization of producer gas in CI engine on dual fuel mode. Experiments were conducted on a single cylinder, four-stroke, direct injection, water-cooled CI engine operated in single fuel mode using Honge, Neem and Rice Bran oils. In dual fuel mode combinations of Producer gas and three oils were used at different injection timings and injection pressures. Dual fuel mode of operation resulted in poor performance at all the loads when compared with single fuel mode at all injection timings tested. However, the brake thermal efficiency is improved marginally when the injection timing was advanced. Decreased smoke, NOx emissions and increased CO emissions were observed for dual fuel mode for all the fuel combinations compared to single fuel operation. Vijayabalan et al (2009) tested a single cylinder vertical air cooled diesel engine was modified to use LPG in dual fuel mode. The primary fuel, liquefied petroleum gas (LPG), was mixed with air, compressed, and ignited by a small pilot spray of diesel. Dual fuel engine showed a reduction in oxides of Nitrogen and smoke in the entire load range. It was shown that poor brake thermal efficiency and high hydrocarbon and carbon monoxide emissions at lower loads and to improve the performance at lower loads, a glow plug were introduced inside the combustion chamber. It was found that the brake thermal efficiency improved by 3% in the glow plug assisted dual fuel mode, especially at low load, and also reduced the hydrocarbon, carbon monoxide, and smoke emissions by 69%, 50% & 9% and the presence of glow plug had no effect on oxides of Nitrogen.

Yusaf et al (2009) investigated the use of artificial neural network (ANN) modeling to predict brake power, torque, break specific fuel consumption (BSFC), and exhaust emissions of a diesel engine modified to operate with a combination of both compressed natural gas CNG and diesel fuels. It was found that the mixtures of CNG and diesel fuel provided better engine performance and improved the emission characteristics compared with the pure diesel fuel. It was also found that the ANN model is able to predict the engine performance and exhaust emissions with a correlation coefficient of 0.9884, 0.9838, 0.95707, and 0.9934 for the engine torque, BSFC, NOx and exhaust temperature. Hariprasad et al(2010) conducted experiments on Diesel.

Engine Using Methyl Esters of Fish Oil and Pongamia Oil and simulated the results by developing models in Artificial Neural Network. By reviewing these literatures on Duel fuel engine, most of the researches were emphasis on the fuel properties of biodiesel such as viscosity, pour point, cetane number and oxidation stability and also very few research was done on LPG with along with diesel as fuel in diesel engines. However, the researches related to the effect of fatty acid composition on the combustion characteristics of biodiesel are rare. Also using LPG with biodiesel as fuel in diesel engine is rare. Therefore more researches are required to understand the effect of fatty acid composition on the combustion characteristics of biodiesel and also on Duel fuel system for diesel engines. The main objective of this work is to extraction diesel engine fuel from waste ground nut oil for using in Dual Fuel Diesel Engine.

II. Experimental Setup

A. *Transesterification Set Up*

The design and fabrication of transesterification equipment for methyl ester preparation are discussed in the fallowing section. The main components of transesterification equipment are stainless steel cylindrical vessel with necessary modifications, Heater and stirrer with baffles. Heater is used to heat the required vegetable oil present in the cylindrical vessel to a temperature in the range of 50-60ºC.

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Fig. 1. Shows Transesterification reactor

Fig. 2. Shows the Methyl Esters of Ground Nut oil used

From the fuel properties of FME; the viscosity of was measured according to JIS K 2283 by using Redwood viscosity meter and Engler viscosity meter. The density was measured according to JIS K 2249 by using a hydrometer. The pour point was measured according to JIS K 2269 by using a rapid pour point tester. The carbon, hydrogen, oxygen contents were calculated from FAME composition.

TABLE I: FAME composition of GME

Fatty acid	C:N	Content (%)
Caprylic	8:0	6.0
Capric	10:0	4.9
Lauric	12:0	52.4
Myristic	14:0	16.9
Palmitic	16:0	8.6
Stearic	18:0	2.3
Oleic	18:1	6.5
Linoleic	18:2	1.4
Linolenic	18:3	0.3
Others	-	1.0

TABLE II:PROPERTIES OF LPG

Property	Content (%)
Calorific value, kJ/kg	50 000
Self ignition temperature, °C	525
Boiling point range, °C	-34
Flame propagation rate, cm/s	83.7
Flame temperature, °C	1985
Specific gravity at 32°C	0.43
Sulphur content by weight, %	0.0112

TABLE III:PROPERTIES OF GME

Property		Content (%)
Cetane number		50 000
Net calorific value	(MJ/kg)	525
Density@288K	(kg/m^3)	-34
Kinematic viscosity@313K	(mm^2/sec)	83.7
Pour point	(°C)	1985
C	(% mass)	0.43
H	(% mass)	0.0112

TABLE IV: PROPERTIES OF DIESEL

Property	Content (%)
Cetane number	56
Net calorific value	43.12
Density@288K	832
Kinematic viscosity@313K	4.7

B. Test Fuels

Waste ground nut oil was selected for this study and transesterified to ground nut oil methyl ester (GME). GME was used as one of the test fuels in the engine experiments. In transesterification reaction, the molar ratio of methanol to Ground nut oil was 6:1 and 1% mass of KOH to Ground nut oil was used. The reactions were taken for two hours at reaction temperature 60?C. After the end of the reaction, the mixtures were kept at the ambient temperature 20-25?C for eight hours and then the settled glycerin layer was drained off. At last the residual methanol in methyl ester mixtures was evaporated. Then the finished product is Ground nut oil biodiesel or GME. The ester conversion rate of GME was over 95%. From fatty acid composition, GME can be said a saturated fatty acid type biodiesel. The FAME composition of GME measured by gas chromatograph and the properties of GME are expressed in table 3.3 and 3.4.

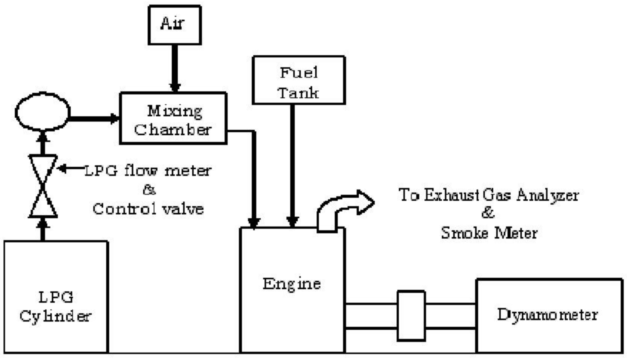

Fig. 3. Schematic of Experimental set-up

Fig. 4. Pictorial view of Schematic of Experimental set-up

C. *Experimental set up*

Experiments were conducted in single cylinder diesel engine. The engine is modified to operate on dual fuel mode. The engine has a compression ratio of 16.5 and a constant speed of 1500 rpm controlled by a governor. The engine is run at a specified load with various LPG-flow rates. At each flow rate, performance parameters namely engine speed, air, diesel, water flow rates, brake and thermal efficiency, exhaust gas temperature, Emissions and smoke levels were determined under steady state conditions.

III. Results and Discussion

A. *Brake Thermal Efficiency*

The variation of brake thermal efficiency with Brake Power, when diesel and GME were used as pilot fuel is shown in Fig. 5. At higher LPG flow rate, the higher flame speed of LPG might have resulted in better combustion of the fuel.

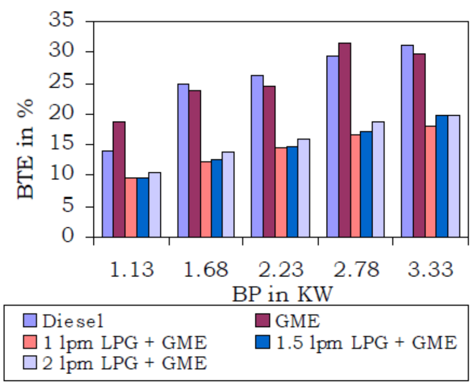

Fig. 5. Brake Thermal Efficiency of GME and its blends with LPG

Variation of brake thermal efficiency with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 5. .At full load, for the injector opening pressure of 180 bar, 200 bar and 220 bar, the LPG flow rate of 0.3 kg/hr, 0.3 kg/hr and 0.5 kg/hr respectively, results in higher brake thermal efficiency. Since the viscosity of the biodiesel is high, it requires large heat source for the combustion of fuel at lower injector opening pressure. But at higher injector opening pressure, atomization and penetration of pilot fuel is good and hence the injector opening pressure of 220 bar results in higher brake thermal efficiency at the LPG flow rate of 0.5 kg/hr.

B. *Brake Specific Energy Consumption*

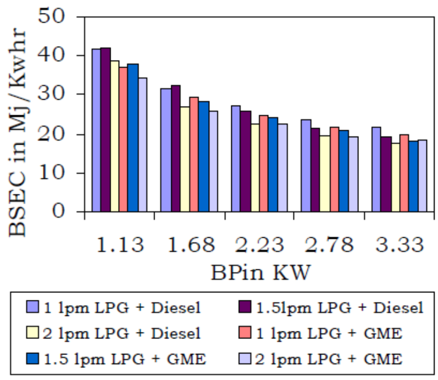

Fig. 6. Brake Specific Energy Consumption Diesel blend with LPG and GME blend with LPG

C. *Exhaust Gas Temperature*

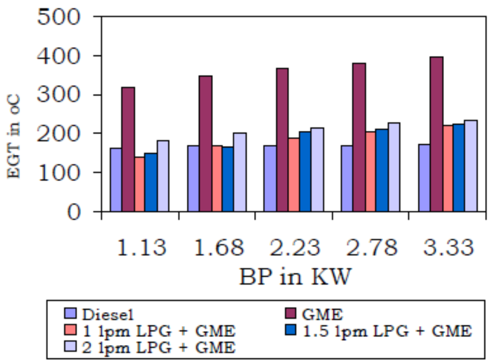

Fig. 7. Exhaust Temperature of Diesel, GME and its blends with LPG

D. *Hydrocarbon Emissions*

HC emissions levels slightly increase with increase of LPG mass fraction in the blended fuel. HC emissions increase with increase of the LPG mass fraction at low engine load and are almost the same at high engine load. The main reason is that the cylinder gas temperature is lower for blended fuel operation at low engine load with increase of LPG mass fraction, and LPG contains more aromatic hydrocarbons, which are too stable to burn out entirely. On the other hand, a good spray can reduce blended fuel close to the combustion chamber wall, thus greatly

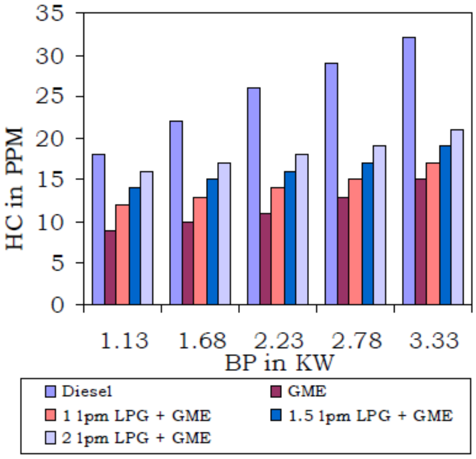

Fig. 7. HC emissions of Diesel, GME and its blends with LPG

E. *Carbon Monoxide Emissions*

CO emissions slightly increase at low engine load but considerably decrease at high engine load with increase of LPG mass fraction. The rate of CO formation is a function of unburned gaseous fuel availability and mixture temperature, both of which control the rate of fuel decomposition and oxidation. It is obvious that the CO emissions slightly increase at low engine load and evidently decrease at high engine load with increase of the LPG mass fraction. The main reason is that the cylinder gas temperature is low at low engine load, and at high load, the flash boiling injection enhances the mixing efficiency of fuel and air and gives the blended fuel more Opportunity to contact air.

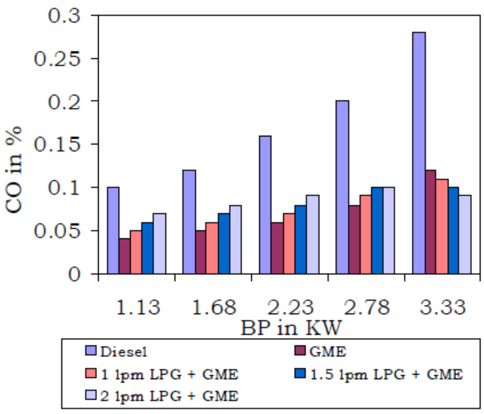

Fig. 8. CO emissions of Diesel, GME and its blends with LPG

F. *Nitrogen Oxide Emissions*

With increase of the LPG mass fraction in the blended fuel, NOx concentration decreases and is lower compared to Diesel operation. The results show that the concentration of NOx decreases with increase of the LPG mass fraction in the blended fuels, and the difference is amplified with increase of the engine load. The main reason is that an increase in the heat of evaporation of the LPG-Diesel blended fuels with increase of the LPG mass fraction will decrease the temperature of the cylinder gases due to the fuel evaporation.

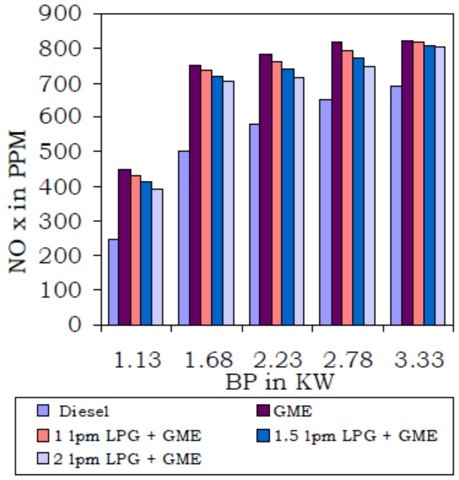

Fig. 9. NOx emissions of Diesel, GME and its blends with LPG

G. *Smoke Emissions*

It is obvious that the light absorption coefficient (Kvalue) decreased with increase of LPG mass fraction, especially at high engine load. The reason is that the boiling temperature of LPG is lower and LPG is easier to evaporate. Once injected as a free jet, LPG will vaporize rapidly because of the pressure reduction. This flash boiling injection can enhance gas perturbation with fluctuation pressure in the spray field [11], and the gas perturbation will definitely promote the spray process [12]. Spray can, thus, improve, and the droplets of blended fuel become smaller than those of Diesel. The longer hold-up time of the droplets lowers the particle pollution due to splitting fuel. The possibility of producing smoke is reduced due to reduction in the possibility that oxygen is absent at high temperature for diesel. The combustion velocity increases and the burning is shortened, which helps to restrain smoke production. Therefore, the LPG-diesel dual fuel engine's emission is reduced.

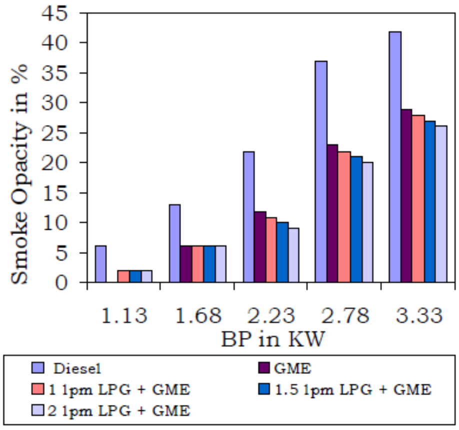

Fig. 10. Smoke emissions of Diesel, GME and its blends with LPG

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