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Experimental Studies on a Single Cylinder 4-Stroke Diesel Engine Run with Biodiesel (PaME) at Different Injection Pressures

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Abstract: Petroleum fuels are widely known and utilizing fuels, due to petroleum fuel depletion and environmental degradation. Renewable, carbon neutral, bio-fuels are necessary for environmental and economic sustainability. Biodiesel derived from oil seeds is a potential renewable alternative fuel to petroleum diesel. Chemically, biodiesel is a mono alkyl ester of long chain fatty acids derived from renewable feed stock like edible/non edible vegetable oils and animal fats. It is produced by transesterification process in which, oil is reacted with a monohydric alcohol in presence of a catalyst. Palm methyl ester was chosen for present experimental study. The effect of Palm methyl ester on the performance, emission and combustion characteristics of a single cylinder 4-stroke diesel engine at varying injection pressure was studied through experimental work. It was observed that the fuel penetration distance become longer and the mixture formation of the fuel and air was improved when the combustion duration became shorter as the injection pressure became higher. When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation leads to inefficient combustion in the engine and causes the increase in emissions like NOx and CO. When the injection pressure is increased fuel particles diameters will become small, the mixing of fuel and air becomes better during ignition delay period which causes low CO emission. Maximum brake thermal efficiency of 30.33% was obtained at an injection pressure of 260 bars. Palm methyl ester fuel exhibited lower cylinder gas pressure and higher heat release rate at an injection pressure 260 bar. Palm methyl ester showed reduction in carbon monoxide (CO), carbon dioxide (CO_2) and nitric oxide (NO) but slight increase in the levels of unburnt hydrocarbon (HC) with higher injection pressure.

Keyword: Biodiesel, Palm Methyl Ester, single cylinder 4-stroke diesel engine, emissions, performance.

1. INTRODUCTION

Energy is considered as a critical factor for economic growth, social development and human welfare. With the modernization and industrialization, the energy demand is increasing day by day. Since their exploitation, the petroleum fuels continued as major conventional energy source. On the other hand, they are limited in reserve. Both the factors have contributed to a sharp increase in petroleum prices. Also, petroleum fuels currently the dominant global source of CO_2 emissions and their combustion in posing stronger threat to clean environment. Sharp hike in petroleum prices and increase in environmental pollution jointly necessitated exploring some alternate to conventional petroleum fuels. Among the other possible options of the liquid fuels various kinds of vegetable oils have been considered as appropriate alternate due to prevalent fuel properties. A country like India, having huge agricultural potential vegetable oils proves a promising alternate for petroleum (diesel oil) fuel [2]. In recent years systematic effort have been made by several researchers to use vegetable oils like sunflower, peanut, soybean, rapeseed, olive, cotton seed, linseed, jatropha, coconut, pongamia, rubber seed etc. as alternate for diesel [2]. So far a very few of non-edible vegetable oils have been tried that diesel engine leaving a lot of scope in this area. From previous studies it is evident that vegetable oils offer acceptable engine performance and emissions for short-term operation. While for long-term duration problems like filter clogging, carbon deposits on injector exterior, compression ring grooves, piston lands, etc. have been reported [3]. The high viscosity of vegetable oils is responsible for these problems. Therefore reduction in viscosity of vegetable oils is important to make them suitable for diesel engines. There are several ways available for this task, among them blending or dilution with other oils, preheating and transesterification are predominant. Testing of diesel engines with preheating, blending with diesel and preheating improves the performance and reduce the emissions compared with neat vegetable oil [4]. It also reduces the filter clogging and ensures smooth flow of oil.

Bio-diesel production is a very modern and technological area for researchers due to the relevance that it is winning everyday because of the increase in the petroleum price and the environmental advantages. The most common way of producing bio-diesel is the transesterification of vegetable oils and animal fats. Transesterification is not a new process. It was conducted as early as 1853 by two scientists E.Duffy and J.Patrick. since that time several studies have been carried out using different oils such as cotton seed, soybean, waste cooking, rapeseed, sunflower

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seed, winter rape, frying, different alcohols such as a methanol, ethanol, butaneas well as different catalysts, homogenous ones such as sodium hydroxide, potassium hydroxide, sulphuric acid, and supercritical fluids or enzymes such as lipases [5]. Vegetable oils, also known as triglycerides, have the chemical structure comprise of 98% triglycerides and small amounts of mono- and triglycerides. Triglycerides are esters of three fatty acids and one glycerol. These contain substantial amounts of oxygen in its structure. The fatty acids vary in their carbon chain length and in the number of double bonds. Different types of vegetable oils have different types of fatty acids. Bio-diesel has been produced by transesterification of triglycerides (vegetable oils) to methyl ester with methanol using sodium or potassium hydroxide dissolved in methanol as catalyst, as represented by the following equation:

2. EXPERIMENTATION

2.1. Introduction

The Pure diesel used in the Experimentation is obtained from nearest filling station. The biodiesel prepared from Palm oil by a method of alkaline-catalyzed transesterification. The lower calorific value of biodiesel is approximately 7 % lower than that of pure diesel. The viscosity of Palm methyl ester is evidently higher than the pure diesel. In the experimentation, five injection pressures are provided to injector ie. 220 bar, 240bar, 260bar, 280bar, and 300bar and experiment carried out at constant speed and at varying load conditions. Transesterification of Palm oil was carried out by heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water traces. The PaME so produced was used for the experimentation along with pure diesel at above said injection pressures for comparative study. Fuel properties such as flash point, fire point, kinematic viscosity and calorific value were determined for Palm methyl ester and are compared with the pure diesel.

Property	Diesel	Palm methyl ester
Density(kg/m^3) at 27^o c	827	871
Kinematic viscosity(cst) at 40^{o}c	2.26	4.24
Cloud point (^{o}c)	0	11
Pour point (^{o}c)	-6	6
Flash point (^{o}c)	47	161
Fire point (^{o}c)	53	169
Carbon residue test (%wt)	0.02	0.02
Calorific value (MJ/kg)	42.1	39.4

Table 2.1 Properties of Diesel and PaME.

2.2. Experimental setup and Procedure

The experimental set up consists of a single cylinder four-stroke, water-cooled and constant-speed (1500 rpm) compression ignition engine.

The detailed specification of the engine is given below.

Product	Research Engine test setup 1 cylinder, 4 stroke, Multifuel, VCR, Code 240
Engine	Single cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm, 661 cc. Diesel mode: 3.5 KW, 1500 rpm, CR range 12-18. Injection variation:0- 250 BTDC Petrol mode: 4.5 KW@ 1800 rpm, Speed range 1200-1800 rpm, CR range 6-10,
Dynamometer	Type eddy current, water cooled, with loading unit
Fuel tank	Capacity 15 lit, Type: Duel compartment, with fuel metering pipe of glass
Calorimeter	Type Pipe in pipe
ECU	PE3 Series ECU, Model PE3-8400P, full build, potted enclosure. Includes peMonitor & peViewer software.
Piezo sensor	Combustion: Range 350Bar, Diesel line: Range 350 Bar, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple,
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	“Enginesoft” Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Table 2.2 Test Engine Specification

The setup consists of single cylinder, four stroke, Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device as in fig.2.2. The set up which is shown in fig. 2.1 has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo

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powering unit. Rota meters are provided for cooling water and calorimeter water flow measurement. In petrol mode engine works with programmable Open ECU, Throttle position sensor (TPS), fuel pump, ignition coil, fuel spray nozzle, trigger sensor etc The setup enables study of engine performance for both Diesel and Petrol mode and study of ECU programming. Engine performance study includes brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis. at the constant speed. During each trial, the engine was started and after it attains stable condition, important parameters related to thermal performance of the engine including the time taken for 20 cm^3 of fuel consumption, applied load, the ammeter and voltmeter readings were measured and recorded. Also, the engine emission parameters like CO, CO_2, HC, and NO, from the exhaust gas analyzer, which is shown in Fig.2.3 were noted and recorded.


Fig.2.1.Test Engine for this work


Fig.2.2.Computerised data logging system


Fig.2.3.Exaust gas analyzer

3. RESULTS AND DISCUSSIONS

Fig.3.1. shows observations in all cases, the brake thermal efficiency increase with increase in applied load since the heat loss surplus with increase in load cause for increase power develop. It clear that increasing the injector opening pressure from 220 bar to 300 bar significantly increases the brake thermal efficiency. This is because higher injection pressures lead to better spray and combustion. Significant reduction in HC also observed with this change in the injection pressure. At 100% load condition the higher brake thermal efficiency is observed fro 260 bar injection pressure.

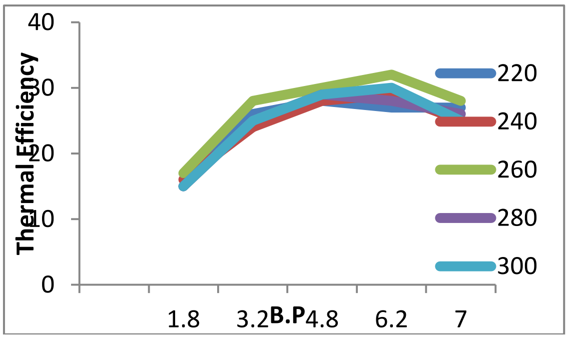

Fig.3.1.Thermal efficiency Vs Load

Fig.3.2. shows the specific fuel consumption with load and it decreases with increase the load from no load to full load. 260 bar compared to recommended injection pressure of 220 bar. Further increase beyond 220 bar has resulted in higher values. This could be due to the fact that with increase in injection pressure, not only the fuel droplet size decreases but also increases the momentum of the droplets but with increase in momentum of the droplets could have got impinged on the cylinder inner wall and to develop same power, the fuel consumption should have increased. At 100% load condition the higher brake thermal efficiency is observed for 260 bar injection pressure.

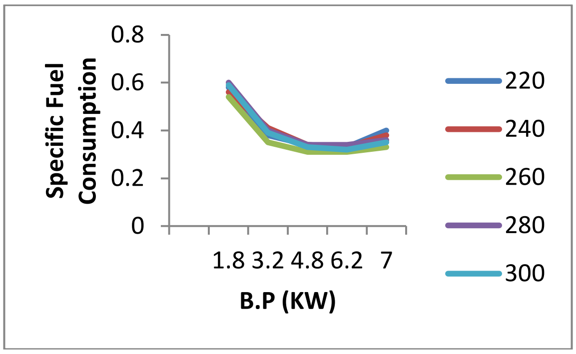

Fig.3.2.Specific fuel consumption Vs Load

The Fig.3.3 – 3.6 shows the comparison of emissions like CO, HC, NO, and CO_2. The CO increases with increase in the load from no load to full load. The lower values of CO are observed for biodiesel is due to oxygen present in the biodiesel which leads to complete combustion in the engine which leads to the tendency of formation of CO_2 rather than CO emissions. The lower CO value is observed for 260 bar because of better fuel atomization and better combustion take place. The CO_2 increases with increases

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in the load from no load to full load. At 100% load condition the higher CO_2 value is observed fro 260 bar .
The NO emission increases with increase in the load from no load to full load. At 100% load condition the higher NO (ppm) value is observed for 260 bar is 529 (ppm). With increases in injection pressure faster combustion take place which result in more amount of heat is released in mixing controlled combustion more amount of heat goes with exhaust gases which result in the higher NO emissions.

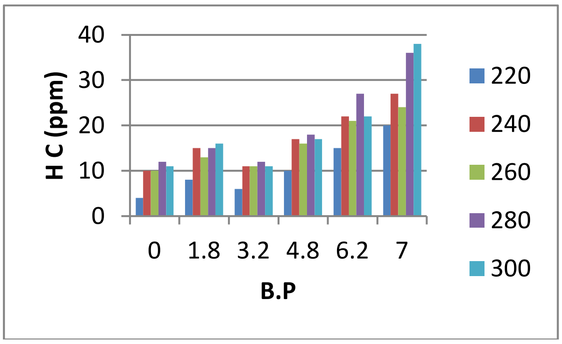

Fig.3.3.Unburned Hydrocarbons Vs Load

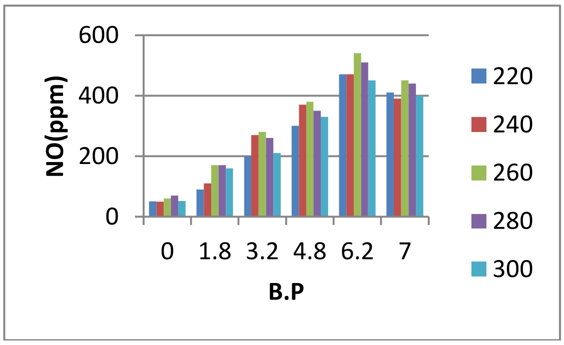

Fig.3.4.Nitric oxide Vs Load

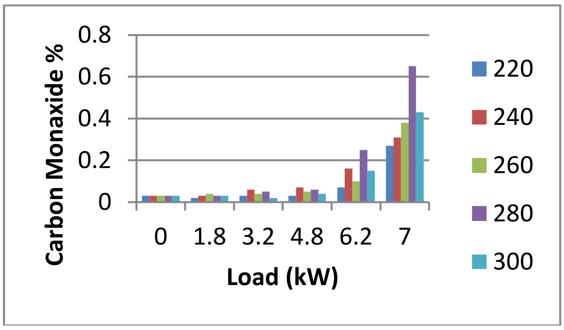

Fig.3.5.Unburned Hydrocarbons Vs Load

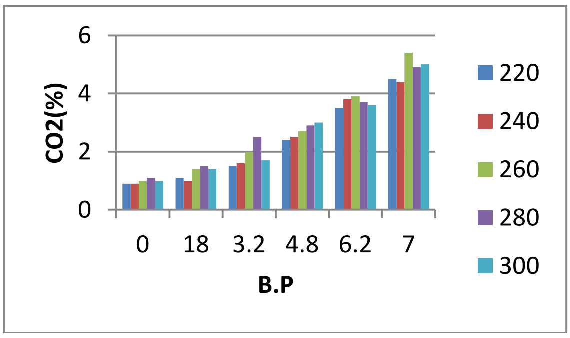

Fig.3.6.Carbon dioxide Vs Load

4. CONCLUSIONS

The fuel penetration distance becomes longer then the mixture formation of the fuel and air was improved when the combustion duration became shorter as the injection pressure became higher. When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion in the engine and causes the increase in NO, CO emissions. When the injection pressure is increased fuel particle diameters will become small. The mixing of fuel and air becomes better during ignition delay period which causes low CO emission. Palm methyl ester fuel on the performance, emission and combustion characteristics of a direct injection diesel engine at varying injection pressure was studied through experimental investigation. Maximum brake thermal efficiency of 30.33% was obtained at an injection of 260 bar. Palm methyl ester exhibited lower cylinder gas pressure and higher heat release rate at an injection pressure 260 bar and Palm methyl ester showed reduction in carbon monoxide (CO), carbon dioxide (CO_2) and nitric oxide (NO) and slight increase in the levels of hydrocarbon (HC) with this injection pressure.

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