Experimental Investigation of Effect of Straight Vegetable Oil Fuel on Engine Performance Parameters

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Abstract

Experimental investigations have been carried out to evaluate the effect of addition of ethanol to vegetable oil on performance and emission characteristics of a compression ignition engine. Use of straight vegetable oil (SVO) for diesel engine is limited due to their higher viscosity and poor volatility. The SVO shows lower thermal efficiency and higher unburnt hydrocarbon emissions, etc. In long term, SVO exhibits injector coking, fuel pump damage and fuel filter clogging, etc. To reduce the viscosity and to increase the volatility of the fuel, an ethanol is added to the vegetable oil so that thermal efficiency and emissions can be improved. During investigation, blends of vegetable oil with different proportions of ethanol are prepared. Blends BSVO-80 and BSVO-70 are prepared using 20% and 30% of ethanol with SVO respectively. Basic properties like viscosity, calorific value, specific gravity, etc. are evaluated for all test fuels. The blends of SVO with alcohol show lower viscosity, improved volatility, better combustion and less carbon deposits as compared to SVO. Improvement in brake thermal efficiency, reduction in oxides of nitrogen, carbon monoxide and smoke emissions are observed with increase in amount of ethanol in blend. The engine performance with the blend BSVO-70 is in closer approximation with diesel fuel. It could be concluded that blend BSVO-70 can be a good substitute for diesel.

Index Terms—Compression Ignition engine, Vegetable oils, Blend, Performance, Emissions, Etherification.

INTRODUCTION

In country like India, majority of population lives in rural areas and they depend on agriculture. In the event of regular electricity failure, diesel engines are used to operate water pump sets and other agricultural implements. If fuel for these diesel engines is prepared locally, it makes the farmers self-sufficient with regard to their energy needs. There are many vegetable oils available, which can be used as fuel for diesel engines. Use of edible oils like sun-flower oil, peanut oil sand soya oil, etc. for diesel engine may cause conflict between food and fuel. The non edible oils obtained from plant species such as Jatropha curcas (Ra-tanjyot),Pongamiapinnata(Karanj),Calophylluminophyl-lum(Nagchampa), Hevca brasiliensis, honge, honne and rubber, etc. can be used as fuel for diesel engine. These non edible vegetable oil plant species can be grown on the land which is not suitable for agricultural purpose. The vegetable oils offer many benefits including sustainability, regional development, reduction in green house gases and reduction on dependency on mineral diesel, etc. Straight vegetable oils have very high viscosity which results in inferior engine performance and higher emissions. One approach to utilization of vegetable oil as fuel is to blend it with conventional diesel oil. These blends fall short of meeting the farmer's goal of energy self sufficiency. Cracking ineffective in upgrading vegetable oils, but add considerably to the expenses and negate direct on farm utilization of the harvested product. Likewise, transestrification with a lower alcohol yields a fuel with lower viscosity and acceptable properties, but reduces the feasibility of direct use of vegetable oil. The concept of diluting vegetable oil with ethanol, another agricultural based energy source being investigated for on the farm preparation of fuel.

Many researchers have tried to use vegetable oils (with or without heating)for diesel engine but they found that the vegetable oils have very high viscosity and low volatility causing poor atomization, slow burning, poor engine performance, higher emissions and in consistent combustion, etc. Tadashi et al.[1] evaluated feasibility of rapeseed oil and palm oil for diesel engine. With vegetable oils, engine gave acceptable performance and emission levels for short term op-elations. However, it caused carbon deposits and sticking of piston rings in long run operations. Vellguth [2] analyzed the performance of diesel engine with vegetable oil;it was ob-served that the vegetable oils can replace diesel oil but un-modified engine coke up. Y.He et al.[3] suggested that cotton seed oil can be directly used for diesel engine without any change in engine structure. In order to obtain highest power and thermal efficiency, engine parameters needs to be readjusted. Barsic et al.[4] tried to reduce the viscosity of vegetable oil by heating it before injection and found that the pre-heated vegetable oil

solves the problem of filter clogging. Murayama et al. [5] concluded that heating vegetable oil up to 200°C improved the engine performance, reduced the car-bon deposits and sticking of piston rings. With preheating of vegetable oil, the brake thermal efficiency of diesel engine was very close to that of diesel fuel. Can Hasimonglu et al.[6] observed that, there was deterioration of engine power and engine torque with biodiesel due to their higher viscosity. Higher specific fuel consumption was observed due to lower heating values. The in-cylinder combustion temperature was lower due to lower heating values of biodiesel and less heat lost to engine parts. D. Agrawal et al. [7] investigated performance of low heat rejection diesel engine operating with biodiesel of rice bran oil, it was observed that NOx emissions with bio diesel was higher due to presence of molecular oxy-gen. An exhaust gas recirculation was used for controlling the Nox emissions. However, application of EGR resulted in higher BSFC, increased HC, CO and particulate emissions. D.Agrawal et al.[8] compared performance of linseed oil, rice bran oil and mahua oil with diesel. With 50% linseed oil blend with diesel, the brake specific energy consumption was lower. However, the smoke density was higher. 30% mahua oil blend indicated higher thermal efficiency and lower smoke density as compared to diesel. A micro-emulsion is defined as the colloidal equilibrium dispersion of a optically isotropic fluid microstructures with dimensions generally in the range of 1-150nm formed spontaneously form two normally immiscible liquids and one or more ionic or non-ionic amphiphiles . Micro-emulsions are transparent and thermodynamically stable colloidal dispersions. T.K.Bhattacharya et al.[9] used diesel-alcohol micro-emulsions for diesel engine. They reported that with in-crease in percentage of alcohol and ethyle acetate in emulsion, the specific fuel consumption of engine increased due to their lower gross heat of combustion. The carbon monoxide emissions were reduced up to 44.4 percent with different emulsions as compared to diesel. The hydrocarbon emission was marginally higher for all loads. Nitrogen Dioxide emissions were lower. Kerihuel. M et al. [10] investigated performance of diesel engine with micro-emulsions of Animal fat with water and methanol. Lower exhaust gas temperature, higher volumetric efficiency with micro-emulsions was ob-served as compared to diesel. Lower unburnt hydrocarbon, carbon monoxide, Nitrogen oxide emissions were also observed with micro emulsions. Mustafa Canakci et al. [11] conducted experiments on single cylinder diesel engine with methanol-diesel blend to investigate effect of percentage of methanol on engine performance and emission characteristics.
It was observed that with increase in percentage of methanol in blend, BSEC and BSFC decreased with reduction in smoke, CO and HC emissions and increased NOx and CO2 emissions. Prommes K. Wanchareon et al.[12] used diesel biodiesel ethanol blend for running diesel engine. They found that the calorific value, cetane number, flash point, etc. blends containing lower than 10% ethanol was not significantly different than diesel. Use of blends resulted in lower emissions as compared to diesel. In this work, a constant speed diesel engine is operated with diesel, straight vegetable oil (SVO) and its blends (Honge oil with different proportions of ethanol). Experiments are conducted rated speed (at 1500 rpm) under variable loading conditions. The performance parameters like specific energy consumption, brake thermal efficiency, exhaust gas temperature and emission parameters like smoke opacity, oxides of nitrogen, carbon monoxide and unburned hydrocarbon emissions are calculated/measured and com-pared with diesel.

EXPERIMENTAL SETUP:

A straight vegetable oil (SVO) namely Honge oil and its blends BSVO-80 (80% of vegetable oil, 20%ethanol) and BSVO-70 (70% of vegetable oil and 30%ethanol) are pre-pared for investigation. Various physical and chemical properties of diesel, ethanol, vegetable oil and its blends are determined using standard testing procedure and results are tabulated in tableNo.1.Viscosity is measured using red-wood viscometer, calorific value was estimated using bomb calorimeter, flash and fire points are determined by using Marten-penesky closed cup apparatus. It is observed that viscosity of the blends decreased with increase in percentage of ethanol.

Properties	Diesel	Ethanol	Neat Honge oil	BSVO-80	BSVO-70
Viscosity in cSt	4.25	1.2	40.25	24.20	10.08
Flash point(°C)	79	21	190	40	37
Fire point(°C)	85	25	210	47	42
Calorific value(kj/kg)	42700	27569	37258	34312	34105
Specific gravity	0.833	0.78	0.925	0.89	0.86

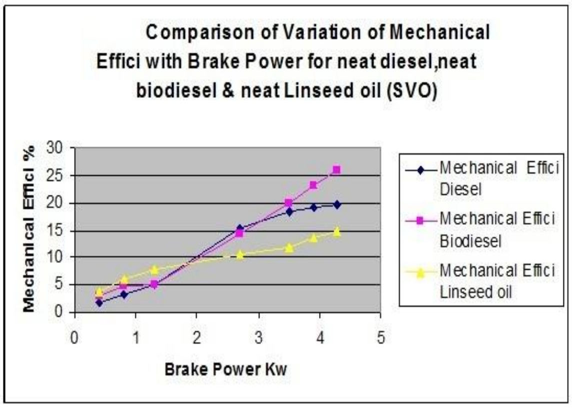
The experiments are conducted on a single cylinder, four stroke, direct injection, and naturally aspirated compression ignition engine. The technical details of the engine are given in Table .This type of engine is primarily used for agricultural purpose in India. The computerized diesel engine test rig supplied by Apex Innovations is used for investigations. The test setup consists of electrical dynamometer for loading the engine. The load on the dynamometer is measured using strain gauge load sensor. An air cooled piezoquartz pressure sensors supplied by piezotronics Ltd, USA are mounted in cylinder head and between injection pump and injector to measure cylinder pressure and fuel injection timings respectively. The pressure sensor signals are obtained at every 1◦crank angle. These signals are passed to charge amplifier for amplification. The crank shaft position is measured by using Kublar-Germany encoder. The Coolant temperature, exhaust temperature and air temperature are measured using thermocouples. The fuel flow rate is measured on volumetric method using differential pressure transducer. Figure 1 shows the schematic diagram of experimental setup. Exhaust gas analyser is used for measuring carbon monoxide, unburnt hydrocarbon and oxides of nitrogen emissions. A smoke meter is used for measurement of smoke opacity. Initially, experiment is carried out with injection pressure and injection timing set by manufacturer (200 bar and 23deg btdc) and diesel fuel at different loads. With same settings, experiments are repeated with blends BSVO-80 and BSVO-70. Variation in humidity and ambient temperature is neglected because all tests are performed for short duration. During all experiments, engine is allowed to run at rated speed of 1500 rpm and at 25%, 50%, 75% and 100% load Conditions. After completing tests on every test fuel, fuel lines, fuel filters are drained and sufficient new test fuel is allowed to flow so that no trace of previous test fuel remains in injection system. After this again engine is allowed to run for 10 min on new fuel so it can be ensured that engine is operating with required fuel.

RESULTS AND DISCUSSION:
PERFORMANCE PARAMETERS:

The performance parameters like Brake thermal efficiency, Specific energy consumption and Exhaust gas temperature are calculated for different fuels and discussed in following paragraphs.

BRAKE THERMAL EFFICIENCY:

The Variation of brake thermal efficiency with different fuels is presented. In all cases, the brake thermal efficiency increases with increase in load. It is noticed that at full load, the brake thermal efficiency with SVO, BSVO-80, BSVO-70 and diesel is about 21.12%, 23.93%, 24.60% and 31.85l % respectively. The reason for lower thermal efficiency with SVO is its higher viscosity, lower calorific value and poor volatility which results in poor atomization and spray pattern. The poor spray pattern results in non homogenous fuel distribution in combustion chamber, resulting in poor combustion and lower thermal efficiency. The addition of ethanol to vegetable oil reduces the viscosity and increases volatility of the fuel. This results in improved combustion phenomenon and higher thermal efficiency. Further, presence of inherent oxygen in ethanol improves the combustion phenomenon.



BRAKE SPECIFIC ENERGY CONSUMPTION:

The Brake Specific energy consumption is an ideal parameter for comparing fuels with different densities. Be-cause it gives an idea of amount of heat energy supplied to develop the same power irrespective of fuel properties. The decreases with increase in load due to better combustion and lower heat losses. The brake specific energy consumption with straight vegetable oil(SVO)is highest among all test fuels due to its lower calorific value and poor atomization because of its higher viscosity. With blends, the BSEC is improved as compared to straightedge-table oil due to reduction in viscosity, improvement in volatility and better atomization. Also micro-explosion of ethanol and traces of water in blend leads to secondary atomization which reduces the mean diameter of injected fuel. It is observed that improves with increase in percentage of ethanol

CONCLUSIONS

Following conclusions are drawn from above investigation:

1. The brake thermal efficiency with vegetable oil blends is higher than straight vegetable oil due to better combustion characteristics.

2. The brake specific energy consumption with blends is lower as compared to SVO on account of better atomize-blends resulted in lower BSEC. As discuss about the SVO , this is the better option for the substitute of fuel on the diesel engine.

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