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The Future of Energy: Vegetable Oils as a Viable Alternative

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Abstract: The rising global demand for petroleum products has intensified imports, causing economic strain and environmental issues, especially for countries like India that heavily rely on imported fuels. To mitigate this, exploring alternative, renewable, and indigenous fuel sources is essential. Vegetable oils, with combustion properties close to diesel, present a viable option for compression ignition (CI) engines. However, their high viscosity and low volatility lead to poor engine performance and high smoke emissions. Methods such as blending, preheating, and transesterification have been employed to improve usability, but these still result in operational problems like filter clogging, nozzle carbon deposits, and elevated emissions. Low Heat Rejection (LHR) engines, which operate at higher in-cylinder temperatures due to insulated components, offer a promising solution. These engines enhance combustion, reduce ignition delay, and lower hydrocarbon, carbon monoxide, and smoke emissions when running on vegetable oils. Ceramic coatings on pistons, liners, and cylinder heads help reduce heat losses and potentially improve thermal efficiency. However, experimental results have been inconsistent, with some studies reporting improved fuel economy and others noting higher consumption. This study aims to modify a standard diesel engine into an LHR configuration using varying levels of ceramic insulation. Performance and emission characteristics will be evaluated using different locally available vegetable oils to identify the most suitable fuel. The research will also explore additional techniques like fuel additives to optimize engine operation. The goal is to develop a more efficient, low-emission engine compatible with renewable vegetable oils.

Keywords: *Combustion Efficiency, vegetable oils, Insulation, Limited Cooled Engines*

INTRODUCTION

The usage of vegetable oil in an engine depends on the properties of the oil. Their properties are almost closer to diesel, particularly cetane rating and heat values. These vegetable oils are renewable and are produced easily in rural and forest areas. Their uses do not require major engine, vehicle or infrastructure modification in existing facilities. Since these oils have slightly longer ignition delay, they are most suitable to use in low heat rejection engines.

In most of the developed countries, biodiesel is produced from soybean, rapeseed, sunflower, peanut, etc., which are essentially edible in Indian context. Among the various vegetable oil sources, non-edible oils are suitable for biodiesel production. Because edible oils are already in demand and too expensive than diesel fuel. Among the non-edible oil sources, Jatropha, karanjan, Mahua, Neems, Sal, Hemp, kusum, hemp, Nahar, Rice bran and Tumba is identified as potential biodiesel source and comparing with other sources, which has added advantages as rapid growth, higher seed productivity, suitable for tropical and subtropical regions of the world. Biodiesel is a chemically modified alternative fuel for use in diesel engines, derived from vegetable oils and animal fats. Biodiesel is produced commercially by the transesterification of vegetable oils with alcohol. These can also be produced from the biomass sources. The direct use of vegetable oil as fuel causes corrosion of various parts in the engine. The transesterification process solves this problem. The carbon cycle of vegetable oils consists of release and absorption of carbon dioxide. Combustion and respiration process release carbon dioxide and crops for their photosynthesis process absorb the carbon dioxide. Thus, the accumulation of carbon dioxide in atmosphere reduces. The carbon cycle time for fixation of CO_2 and its release after combustion of biodiesel is quite small (few years) as compared to the carbon cycle time of petroleum.

FABRICATION OF INSULATED COMPONENTS

Piston

Insulated diesel engine contains a two-part piston; the top crown ,made of invar screwed to aluminum body of the piston, providing a 2mm-air gap in between the crown and the body of the piston. A nickel insert is screwed to the top portion of the liner in such a manner that an air gap of 2-mm is maintained between the insert

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and the liner body. The stainless steel gasket is introduced to minimize the heat loss through gasket. In the first instance, an invar crown was fitted on aluminium piston with 2.0 mm air-gap, in order to investigate the effect of air-gap alone. The total height of the standard aluminium piston was reduced by 9.0mm at the top by machining. An Invar crown of 7.0 mm thickness was turned out of Invar alloy rod of 85 mm to the shape of the standard piston crown. The hemispherical shape was turned using concave and convex turning tool. A thickness of 5mmwas maintained on the flange and bowl area of the crown. The recess for valve clearance is provided by end milling. The crown was separated by gaskets made of copper and stainless steel from the aluminium body. The stainless steel gasket is introduced to minimize the heat loss through gasket.

Cylinder Head

Ceramic coating is a simpler method of insulation for cylinder head compared with other methods. The head was insulated, by coating the area exposed to the combustion chamber with mullite. The combustion chamber area f the cylinder head was machined to a depth of 0.5 mm. The surface was then sand blasted to form innumerable pores for mullite deposition.

Valves

The bottom surfaces of the valves were machined to a depth of 0.5mm and coated with mullite material of equal thickness. With the valves assembled on the cylinder head the area of the combustion chamber was about 90-92% of the total area

Cylinder Liner

A thin mild steel sleeve was circumscribed over the cast iron liner maintaining a 2mm layer of air in the annular space between the liner and the sleeve. The joints of the sleeve were sealed to prevent seepage of cooling water into the air-gap region. Fig 2 shows the constructional details of the air gap liner. Insulation of the liner brought about considerable reduction in the heat lost to the cooling water and an increase in overall thermal efficiency of the engine.

VEGETABLE OILS

Most suitable vegetable oil can be selected from different vegetable oils by testing them in insulated engine. Their properties are almost closer to diesel, particularly cetane rating and heat values. However their viscosity values are higher but can easily be overcome by heating them. Since these oils have slightly longer ignition delay, they are most suitable to use in insulated engines. The two different vegetable oils, Hemp Oil (HO) and Kusum Oil (KO) are tried in the insulated test engine.

Hemp Oil

Refined hempseed oil is clear and colorless, with little flavor and lacks natural vitamins and antioxidants. Refined hempseed oil is primarily used in body care products. Industrial hempseed oil is used in lubricants, paints, inks, fuel, and plastics. Hempseed oil has found some limited use in the production of soaps, shampoos and detergents. The oil is of high nutritional value because of its 3:1 ratio of omega-6 to omega-3 essential fatty acids,which matches the balance required by the human body.It has also received attention in recent years as a possible feedstock for the large-scale production of biodiesel. There are a number of organizations that promote the production and use of hempseed oil.

Hempseed oil is manufactured from varieties of Cannabis sativa that do not contain significant amounts of tetrahydrocannabinol (THC), the psychoactive element present in the cannabis plant. This manufacturing process typically includes cleaning the seed to 99.99% before pressing the oil. There is no THC within the hempseed, although trace amounts of THC may be found in hempseed oil when plant matter adheres to the seed surface during manufacturing. The modern production of hempseed oil, particularly in Canada, has successfully lowered THC values since 1998. Regular accredited sampling of THC in Canadian hemp seed oil shows THC levels usually below detection limit of 4 ppm (parts per million, or 4 mg/kg). Legal limit for THC content in foodstuffs in Canada is 10 ppm. Some European countries have limits of 5ppm or none-detected, some EU countries do not have such limits at all.

Kusum (Schleichera oleosa)

Schleichera oleosa (Kusum) is a large deciduous (nearly evergreen) tree with a fluted comparatively short trunk and a shade spreading crown. This species occurs in the sub-Himalayan tract from Sutlej Nepal, Chhota Nagpur, Central India and the peninsula generally, apparently absent from Assam. In general, it thrives best on a light well drained gravelly or loamy soil. It is a shade bearer and frost and drought hardy, it is subject to damage by grazing. It produces root-suckers freely and its pollarding and coppicing power is good. The wood is very hard, reddish brown, used for oil and sugar mills, rice pounders, agricultural implements, and other purposes. The fruit is edible and the seeds yield an oil (Macassar oil) of some value. One of the chief uses of the tree is for the propagation of lac, the quality of which is considered better than that produced on any other tree.

Table 1: Properties of Test Fuels

Properties	Diesel	Hemp	kusum
Flash point (°C)	60	47	225
Fire point (°C)	65	55	
Pour point (°C)	-16	-17	-19
Density (kg/m3)	830	858	860
Kinematic viscosity at 40 °C (cSt)	3.7	1.13	40.36
Cloud Point (°C)	-12	-4	-9
Calorific Value(MJ/kg)	43	42.92	38

EXPERIMENTAL INVESTIGATIONS

The engine used for the experimental investigations was a Kirloskar, single cylinder, four stroke, water cooled, vertical and direct injection diesel engine. The standard engine was tested at the recommended injection timing of 27^0 bTDC at various loads. The engine was operated under no load for the first 20 minutes and for each load the engine was operated long enough to stabilize the condition. All the tests were conducted at the rated speed of 1500 rpm. Sets of experiments are conducted with two vegetable oils Hemp(Gongura), Kusum(Schleichera oleosa) to evaluate the performance of engine.

RESULTS & CONCLUSIONS

Experiments are conducted with Diesel and vegetable oils in an insulated engine to evaluate the performance characteristics.

Brake Thermal Efficiency

The variation of brake thermal efficiency of two vegetable oils tested in insulated engine with Brake Power output is shown in Fig. 1. All the oils have more or less equal Brake Thermal Efficiency compared to that of Diesel. The brake thermal efficiency of Hemp oil is higher throughout the load range. The thermal efficiency of Hemp oil is significantly higher compared to Kusum oil. Finally, it may be concluded that insulated is the best choice for vegetable oils from the Brake Thermal Efficiency.

Volumetric Efficiency

The variation of volumetric efficiency with power output is shown in Fig. 2. Relatively due to lower cylinder wall temperatures the volumetric efficiency is higher for Hemp oil. The volumetric efficiency is badly affected in the case of Kusum vegetable oil. The volumetric efficiency drop is more for Kusum oil and less for Hemp oil when observed for a complete power range.

Hydrocarbon Emission

Fig.3 shows the comparison of un-burnt hydrocarbon emissions of the vegetable oils with brake power output. Un-burnt hydrocarbon emissions of all vegetable oils are marginally higher than diesel oil. Poor mixing of these oils with air may be one of the reasons for this. The hydrocarbon emissions are more in the Kusum oil when observed for a complete power range.

Carbon Monoxide Emission

Carbon monoxide emission levels are also lower with Hemp oil as compared to other vegetable oils as seen in the Fig.4.

Exhaust Gas Temperature

Exhaust gas temperature variation with respect to Brake Power output for the vegetable oils are compared in the Fig.5. Exhaust temperature curves of are in close agreement with Diesel. Exhaust temperatures are Lowest for Hemp oil and highest in the case of Kusum Oil when compared with Diesel.

Frictional Loss

The variation of Frictional mean effective pressure with power output is shown in Fig. 6. From the graph, it is evident that Hemp and Kusum oils have more frictional losses when compared with Diesel.

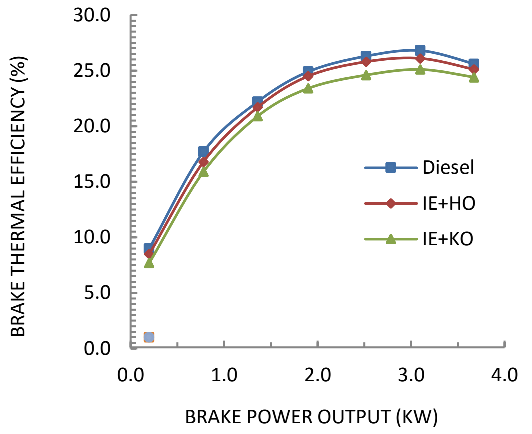

Fig.1 Comparison of brake thermal efficiency with...

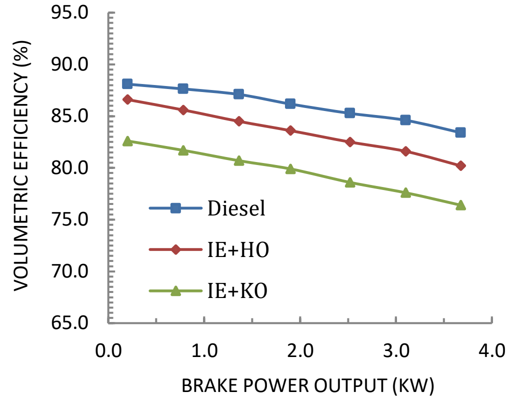

Fig. 2 Comparison of Volumetric efficiency with power...

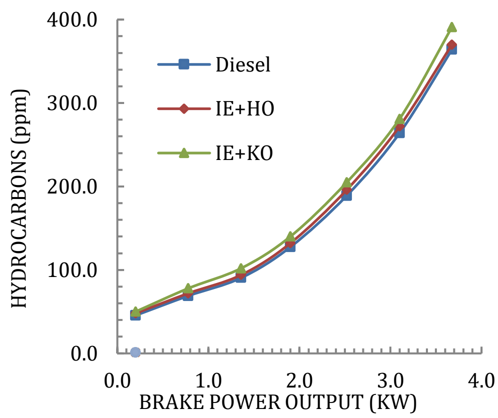

Fig 3 Comparison of Hydrocarbons with power output

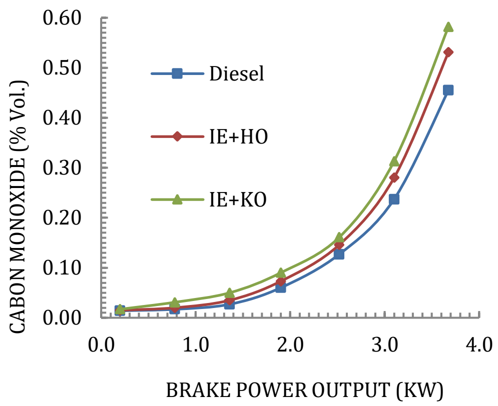

Fig. 4 Comparison of CO emission with power output

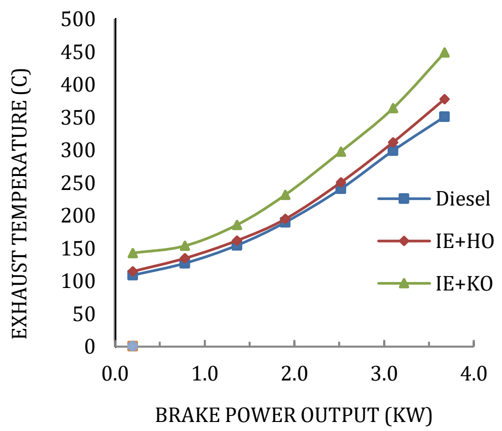

Fig.5 Comparison of Exhaust temperatureency with power output

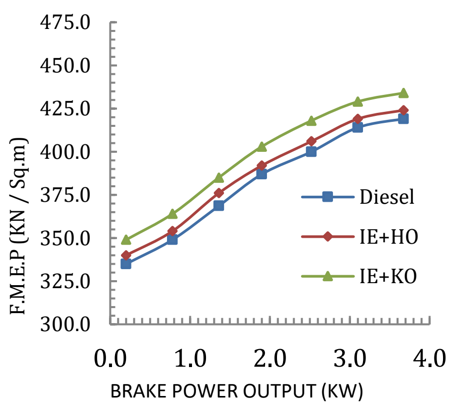

Fig.6 Comparison of Frictional mean effective...

CONCLUSIONS

Based on the experimental results the following conclusions are drawn. These conclusions are drawn based on diesel engine.

1. All the oils have more or less equal Brake Thermal Efficiency compared to that of diesel. The brake thermal efficiency of Diesel, Hemp and Kusum oils are 25.6 %, 25.2% and 24.4% at maximum load condition.
2. The Volumetric efficiency drop is observed in all the vegetable oils. The Volumetric thermal efficiency of Diesel, Hemp and Kusum oils are 83.4 %, 80.2% and 76.4% at maximum load condition.
3. There is slight increase in Hydrocarbon emissions for vegetable oils compared with normal engine. The hydrocarbon emissions of Diesel, Hemp and Kusum oils are 364, 370, 391 ppm at maximum load condition.
4. Carbon monoxide emission levels are also lower with hemp oil as compared to Kusum oil. Carbon monoxide emission of Diesel, Hemp and Kusum oils are 0.455%, 0.531% and 0.582% by volume at maximum load.
5. Among the vegetable oils tested, the exhaust temperatures are marginally higher for vegetable oils. Exhaust gas temperatures of Diesel, Hemp and Kusum oils are 351^0c, 378^0c and 449^0c at maximum load
6. Vegetable oils have higher frictional losses than diesel .Frictional losses of Diesel, Hemp and Kusum oils are 419 KN/mm^2, 424 KN/mm^2 and 434 KN/mm^2 at maximum load.

Insulated diesel engine with Hemp and Kusum vegetable oils performed well without any major modifications of the engine. This modified diesel engine is highly suitable for vegetable oils, due to better turbulence and elevated temperatures to overcome the problems associated with the oils, which are faced by the researchers.

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