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Feasibility Study on Thermal Cracking of Pongamia pinnata Oil for IC Engine Applications

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Abstract— Due to depletion of fossil liquid fuels, research in alternate engine fuel is emerging today. However the conventional route of 'bio-diesel' production is not economical as well as eco friendly. The byproduct like 'glycerin' doesn't have any market value and hence disposal also leads lots of issues. Hence this paper aims in finding out feasibility of using pongamia pinnata oil to CI engines directly by catalytic cracking instead of going for transesterificaiton. Also TGA & DSC studies have been carried out with this oil showing encouraging results.

Index Terms — Pongamia pinnata, cracking, TGA, DSC, Non edible oil, C.I Engine, Nano particles.

1 INTRODUCTION

Cheap and easily available fuel is the most needed fuel for the present day situation and if a major part of a fuel is renewable that would be a great fuel.

The use of Non-Edible oil as an alternative fuel is increasing rapidly. The conventional C.I engines are designed to operate with diesel as fuel and the brake thermal efficiency is lesser. To improve the brake thermal efficiency Non-Edible oil and Nano particles can be used as fuel but the engine is designed to run in diesel fuel. By some modification and proper tuning of conventional C.I engine the Non-Edible oil - nano particles blends can be used in C.I engine and the Brake thermal efficiency can be increased.

The present research is to have a suitable engine for Non-Edible oil -nano particle blend and to have better efficient engine with lesser pollution. To achieve this some modifications have to be done. Generally the viscosity of Non-Edible oil is higher when compared to diesel. Due to the high viscous property the shoot production will be more and it lead to incomplete combustion. So to avoid this non edible oil can be gasified and a very lean mixture of gasified fuel and air can be sent during the suction stroke and a pilot injection of diesel can be done to initiate the combustion. Pilot injection of fuel is also done to compensate the energy density inside the cylinder for different speed and load condition. In order to improve the combustion process metal nano particles can be added along With the gasified biodiesel. The rate of release of energy during the combustion of Metal nano particles is higher so it improves the combustion quality.Since the gasified fuel is sent during the suction stroke a homogeneous combustion process takes place. Turbulence can be introduced before the inlet port so that the gasified Non-Edible oil –nano particles are mixed thoroughly and sent into the combustion chamber during the suction stroke to avoid knocking and to increase combustion quality. So it may lead to raise in peak pressure, increase in brake thermal efficiency and reduced in pollution.

There is various types of raw material like Jatropha curcus L, Pongamia Pinnata (Karanja), Moha, Undi, Castor, Saemuruba, Cotton seed etc. A non- edible oil seeds and various vegetable oils including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce biodiesel fuel and lubricants. Out of these Pongamia pinnata can be a definite source of raw material due to its easy availability in wild.

The experiment result of misin and murthy with soapnut oil as fuel shows that all the blends of oil with diesel have lower break thermal efficiency when compared with diesel fuel. This is due to the higher viscosity of the blends which results in poor combustion. The break specific energy combustion for the oil blends is higher than the diesel because of the higher density of the soap nut oil which leads to more fuel to be injected but due to higher viscosity it leads to incomplete combustion. The carbon monoxide for 10% and 20% of soapnut oil with diesel blend shows lower emission of CO than diesel fuel this is due to the presence of oxygen in the oil. But when the percentage of oil is increased in the blend the CO emission increases than the diesel due to inefficient spray pattern. All the soap oil blends shows higher HC than the diesel which shows incomplete combustion of the blend fuels when compared to diesel. During the combustion of soapnut oil-diesel blends the temperature is lesser when compared to diesel so the NOx emission for soapnut oil-diesel blends is less when compared to diesel.

Pongamia pinnata is drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide.

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Why Pongamia pinnata?

Due to pressure on edible oils like groundnut, rapeseed, mustard and soybean etc. non-edible oil of jatropha curcas and karanja (PongamiaPinnata) are evaluated as diesel fuel extender. Pongamia pinnata is a species of family Leguminasae, native in tropical and temperate Asia including part of India, China, Japan, Malaysia and Australia. Commonly it is called as karanja. Karanja is drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide. The leaves are soft, shiny burgundy in early summer and mature to a glossy, deep green as the season progresses. Flowering starts in general after 4-5 years. Cropping of pods and single almond sized seeds can occur by 4-6 years and yields 9-90 kg's of seed. The yield potential per hectare is 900 to 9000 Kg/Hectare. Pongamia pinnata has been recognized as a viable source of oil for the burgeoning biofuel industry.The tree may be planted with a spacing of 3x3m^2 . The seed oil content ranges between 30 and 40% Weight. The oil is reddish brown and rich in unsaponifiable matter and oleic acid. As per statics available pongamia oil has got a potential of 135000 million tones per annum and only 6% is being utilized. The tree is well suited to intense heat and sunlight and its dense network of lateral roots and its thick long tap roots make it drought tolerant.

Literature studies shows that by reducing the viscosity of oil, by using proper catalyst, heating to certail temperature will have same proper spray characteristics the efficiency can be increased and emission can be decreased.

2. Physical Properties of Non Edible Oils:

Table 1 gives agro-climatic preferences of some promising tree-borne oil seeds.

Table .1 Agro Climatic Performance

Non-edible vegetable source	Rainfall (mm)	Temperature (^oC)	Soil preference	Tree height (m)
Jatropha curcas	480–2400	20-28	Any type	3–5
Pongamia	500–2500	38	Wide range	8–10
Neem	750–1000	15-45	Deep clay	20
Mahua	550–1500	46	Deep clay	18-20
Calophyllum	750–5000	48	Sand/Loamy	10-25
Simarouba	1000-4000	25-45	Well drained	15

Table 2 gives Physico-chemical Properties of Pongamia Pinnata with chemical treatment.

Table 2. Properties of Pongamia pinnata

Property	Diesel fuel	Pongamia pinnata
Chemical Formula	C3 to C25	$C_{18}H_{34}O_2$, $C_{18}H_{32}O_2$, $C_{22}H_{44}O_2$, $C_{16}H_{32}O_2$
Fire point (^{o} C)	56	354
Freezing point ^{o} C	-40	-3
Cetane Number	40–55	42
Calorific Value (MJ/kg)	42.21	34.00
Ash Content %	0.01	0.07
Density	0.846gm/cc	0.924gm/cc
Kinematic Viscosity at 50^{o}C(mm^2/s)	2.60	27.84
Boiling point ^{o} C	190-345	316

3. Methods of usage of Non Edible Oils in IC Engines:

Major Rout for usage of non-Edible oil for Engines and the problems:

3.1. Straight Usage of non-edible Oils in Diesel Engine.

Myth: Just put in the tank—any inline injection pump is happy on cold veg-oil, they don't mind starting on cold oil, Especially with an older Mercedes.

In the 1930s the British Institute of standards, Calcutta had examined, over a 10 year period, a series of eleven non edible oils as potential 'diesels' , among them one of the oil is pongamia pinnata .

The central problem in using vegetable oil as diesel fuel is that vegetable oil is much more viscous than conventional diesel fuel. It is 11 to 17 times viscous. Vegetable oil also has very different chemical properties and combustion characteristics to those of conventional diesel fuel. If the fuel is too viscous incomplete combustion takes place , the injectors get coked up, leading to poor performance, higher exhaust emission and reduced in engine life.

3.2. Micro emulsification

Micro emulsification is defined as transparent, equilibrium thermodynamically stable colloidal dispersion of microstructure with diameter ranges from 100to1000 ˚ A. Micro emulsion can be made of vegetable oils with anester and dispersant (cosolvent), or of vegetable oils, and alcohol such as ethanol, ethanol, buthanol, hexanol and a surfactant and a cetane im-

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prover, with or with out diesel fuels. Micro emulsification has been considered as a reliable approach to solve the problem of the high viscosity of vegetable oils.

3.3. Dilution

Most of the oil is extremely viscous. Their viscosity varies about 10 to 17 times greater than diesel. The viscosity of the oil can be reduced by diluting the oil with diesel. Non-edible oil can be diluted with diesel to reduce the viscosity and improve the performance of the engine. This method does not require any chemical process. It has been reported that substitution of 100% vegetable oil for diesel fuel is not practical. Therefore, blending of 20–25%vegetable oil to diesel has been considered to give good results for diesel engine.

3.4. Transesterification (Alcoholysis)

Transesterification or alcoholysis is defined as the chemical reaction of alcohol with vegetable oils. In this reaction, methanol and ethanol are the most commonly used alcohols because of their low cost and availability. This reaction has been widely used to reduce the viscosity of vegetable oil and conversion of the triglycerides into ester.

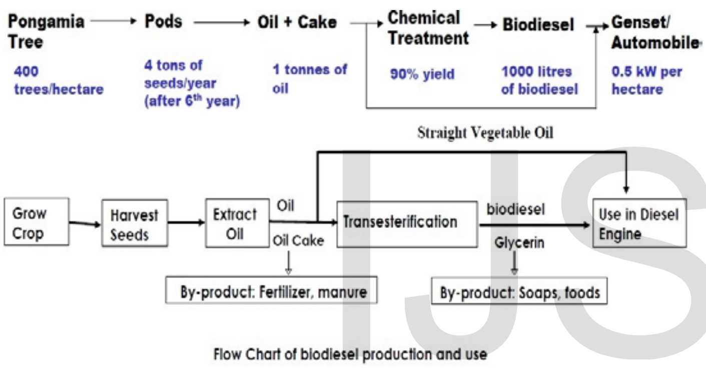

Fig. 1 Flow Chart of Biodiesel Production and Use

Transesterification can be carried out by two ways:

(i) Catalytic transesterification and

(ii) Non-catalytic transesterification

It is widely known that catalytic transesterification is confronted with two problems. The main problem is the processes are relatively time consuming and needs separation of the vegetable oil/alcohol/catalyst/saponified impurities mixture from the biodiesel. Furthermore, the waste water generated during biodiesel purification is not environment friendly. Under such condition, the super critical alcohol transesterificationis one option to solve the problems by employing two phased methanol/ oil mixtures by forming a single phase as result of the lower value of the dielectric constant of methanol in supercritical state. As a result, the reaction was found to be complete in a very short time.Moreover, purification of biodiesel is much easier as no catalyst is required during supercritical transesterification process, thus preventing soap formation or saponification to occur. However, the drawbacks of supercritical alcohol transesterification process are due to the high temperature and pressure that result in the high cost of the apparatus.

3.5. Pyrolysis (Thermal cracking)

Pyrolysis is the thermal conversion of the organic matters in the absence of oxygen and in presence of a catalyst. The paralyzed material can be vegetable oils, animal fats, natural fatty acids or methyl esters of fatty acids. Thermal decomposition of tri glycer- ides produces alkanes, alkenes, alkadines, aromatics and car- boxylic acids.The liquid fractions of the thermally decomposed vegetable oils are likely to approach diesel fuels. The pyrolyzate had lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values.

However, cetane number of the pyrolyzate was lower compared to diesel fuel. The pyrolyzed vegetable oils contain acceptable amounts of sulfur, water content, copper corrosion values and sediments but unacceptable ash, carbon residual and pour point.

4. TGA & DSC Characterization

Thermochemical conversion route for power and thermal applications is a proven method. Pyrolysis and Gasification are thermochemical conversion process, the temperature and rates of heating have pronounced effects on the weight loss of biomass. Thermo gravimetric analysis (TGA) measures and records the weight loss of sample biomass as the temperature is raised at desired uniform rate. In addition to the effect of environment such as inert and reacting atmosphere with and without flowing can be studied. For determining the characteristics of pyrolysis and also kinetic parameters, TGA is used extensively. Kinetic parameters are calculated using the net weight loss with simplifying assumptions which do not necessarily correspond to the complex chemical reaction in the thermal degradation. The Thermogravimetric / Differential Scanning Calorimetric study of Pongamia pinnata oil reveled the following:

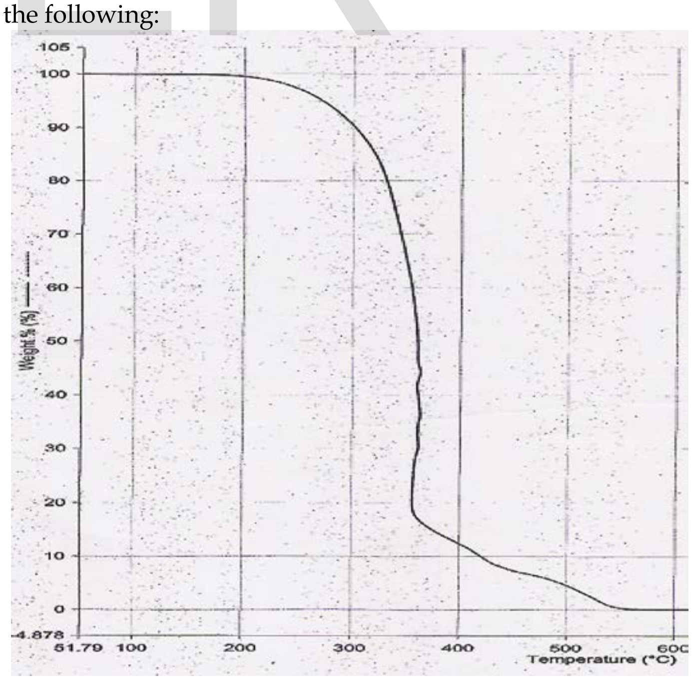

Fig.2. TGA Curve of Pongammia Pinnata Oil

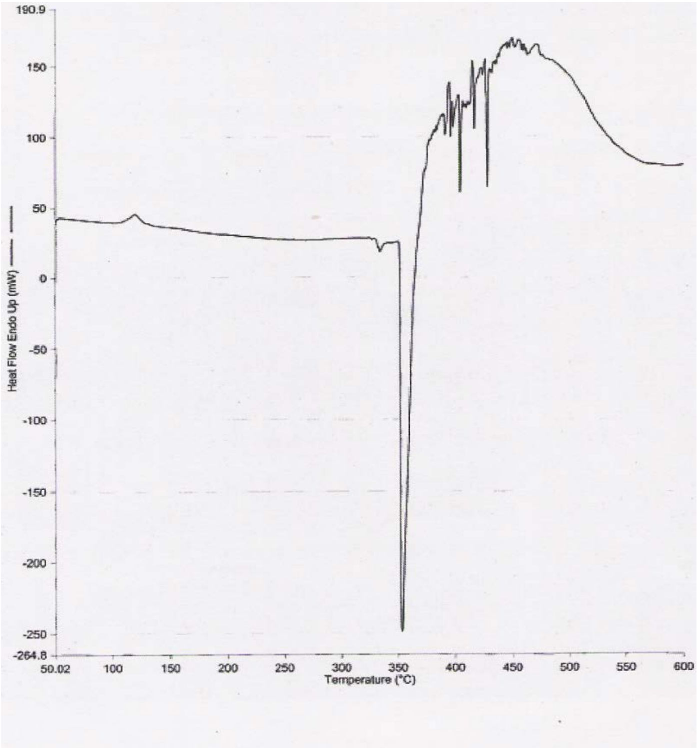

Fig.3. DSC Curve of Pongammia Pinnata Oil

- ✓ No weight reduction upto a temperature of 200°C
- ✓ Major weight reduction is in the temperature of 350°C and DSC studies shows there is a exothermic peak at 350°C
- ✓ Upto 85% weight reduction has been achieved in the temperature range of 350°C
- ✓ Complete weight reduction has been achieved in 550°C

From the above data, it is evident that

- ✓ 95% conversion will be possible at 450°C itself.
- ✓ Thermal degradation of non edible oils at low temperature is feasible.
- ✓ Auto Gasification is found to be a viable route.

5. Conclusion:

It is found that thermal cracking is feasible for the Pongammia Pinnata oil. From the TGA and DSC experiment it is revealed that 95% conversion of oil to gas is feasible at 450°C. Once it is completely converted in to gaseous product it is very well suited for the CI Engine. The complexity faced by the direct admission of oil into the engine is overcome from this thermal cracking. Hence the thermal cracking is well suited method for the engine fuel for the pongammia Pinnata Oil.

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