Feasibility Study of Direct Admitting of Pongamia Oil in I.C Engines

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Abstract The increase in global warming, pollution due to the combustion of fossil fuels and its uneven distribution leads for the search of alternative energy source. Only few of them have done research with direct admitting of vegetable oil in C.I engine and this is due to reason of very high viscosity, lower heating value, low volatility and higher freezing point of vegetable oil. While in direct admitting of vegetable oil in C.I engines most of the authors says that the performance and emission characteristics depend on the viscosity, flash point, fire point, calorific value, density, cetane number. This paper reviews the characteristics of various non-edible vegetable oils, its performance and emission characteristics in C.I engines during direct admitting of vegetable oil. The yield of oil from a plant is an important factor in reliability of the fuel so some of the non-edible oil yielding plants, its yield and soil preference are also reviewed. From the review it can be concluded that non-edible oil could be a good alternative fuel which have a good reliability of oil production but direct admitting of vegetable oil for long term may reduce the engine life.

Keywords C.I Engine, Pongamia Oil, Performance, Emission, Non-edible Oil

1. Introduction

The first C.I engine is designed to run with vegetable oil as fuel [1], but Due to the easy availability of fossil diesel fuel the engines produced are designed for the usage of the fossil diesel fuel. Fossil fuels are depleted each and every day and it's not an easy job to regenerate the fossil fuels. Most of the mineral oils produced are being used in I.C engines. Fossil fuels are conventional energy sources but it is non-renewable. After depletion of fossil fuel the demand for it is going to be higher and costlier and it may be used only for aviation purpose. To meet the tomorrow's energy demand vegetable oil could be a good alternative resource.

The carbon produced during the combustion of vegetable oil is recyclable. The vegetable oil used as fuel for I.C engine

should be reliable, easily available and have better enough to run in I.C engine should be reliable easily available, and have better physical and chemical properties.

From various studies of journals and reports it can be found that Pongamia oil is a feasible one to be used in C.I engines. The engine specified below is fueled with Pongamia oil, its performance and emission test were conducted and compared with diesel fuel as base fuel.

2. Literature Review in Direct Admitting of Vegetable Oil in Conventional Engine without any Modification

k.Pramanik[22] used Jatropa oil as fuel and compared its performance with diesel. The result shows that the brake specific fuel consumption for Jatropa oil is higher than diesel because of the relative fuel density, viscosity and heating value. The Exhaust gas temperature for Jatropa oil is higher than diesel. The brake thermal efficiency of Jatropa oil is lesser than diesel, this shows that less fuel is converted into work and the remaining fuel is emitted as heat [22].

During direct admitting of the Jatropa oil at constant speed of 1500 rpm C.I engine, the Brake Specific Fuel Consumption for Jatropa oil is higher than diesel. This is because of the lower calorific value of the Jatropa oil. The higher viscosity leads to poor atomization and larger fuel droplet of Jatropa than the diesel results in lesser Brake Thermal Efficiency. The exhaust gas temperature for Jatropa oil is lesser than diesel. The smoke opacity, CO₂, CO and HC for Jatropa oil is higher when compared to diesel fuel [23].

M.S.shehata, S.M.Abdel Razek[25] uses a constant speed diesel engine and use sunflower oil as fuel. Its performance and emission characteristics are compared with diesel as base fuel .The brake thermal efficiency for sunflower oil is lesser than diesel .The higher density and lower heating value of sunflower oil when compare to diesel leads to lower brake thermal efficiency, so it results in lesser cylinder

pressure for sunflower oil. The CO emission is higher for sunflower oil than the diesel [25].

k.Purushothaman, G.Nagarajan [26] used a single cylinder C.I engine. They used orange peel oil as fuel. The peak cylinder pressure produced during the usage of orange oil is about 75 bar where as diesel have only 71 bar this is because of the higher oxygen content in the orange peel oil. The maximum heat release rate at peak load for orange peel oil is 52J/°CA and for diesel is 39J/°CA. The brake thermal efficiency for orange peel oil is 30.7% and for diesel is 29.3%. The NOx for orange peel oil is 19.99g/kWh and for diesel is 14.99g/kWh. The presence of Oxygen in orange oil leads to higher NOx than the diesel. As the engine load increases the CO increases.

The CO emission for orange oil is lesser than diesel because orange oil has 3% of oxygen content by weight. The HC emission for orange peel oil is lesser than diesel. The combustion quality is better for orange peel oil than the diesel so the smoke level is lesser for orange peel oil.[26]

The direct admitting of karanja oil in diesel engine leads to lower brake thermal efficiency than the diesel fuel. It's because of the larger droplet size of the fuel. The brake specific fuel consumption of karanja oil is higher than Diesel where Brake specific energy consumption for karanja oil is almost equal to that of diesel. CO emission is higher for karanja oil than diesel. HC for karanja oil is lower than diesel at lower load , higher than diesel at higher load. NOx is significantly lower for karanja oil but the gap decreases at higher load. The exhaust gas temperature is higher for karanja oil but the NOx is lower than diesel because large amount of heat is released at late combustion phase.

The poor atomization of karanja oil leads to higher smoke opacity than diesel. With increase in load the smoke opacity increases [27].

With the direct admitting of mustard oil in C.I engine the smoke opacity, CO emission, Hydrocarbon emission and NOx for mustard oil is lesser than diesel. The Particulate matter is lesser for diesel than the mustard oil[28].

Table 1. Properties of various Non-Edible Plants and Its oil properties

Plant Name	Rubber	Soapnut Oil	Neem	Eucalyptus Oil	Poon Oil	Pongamia Pinnata	Rape Seed Oil
Rain Fall (mm)			750-1000[2]			500-2500[2]	
Temperature (°C)			15-45 [2]				
Soil Preference		Deep Loamy And Leached	Deep Clay[2]			Wide Range[2]	
Height (m)	34[2]		20 [2]			8-10[2]	
Seed Yeild (Kg/ha/year)	150[2]		12 to 20[2]			900-9000[2]	
Oil Content In	40-50[3],	51[3],	33-45[3]			30 to 40[2], 33[3]	
Seed (%)	40-50 [2]	23[2]					
Calorific Value MJ/Kg	37.5[4,5] 37.25[6]	38.207[7]	29.27[2]	43.27[10]	39.65 [11,12]	34[4],[13],[5]	40.11[17,12] 3762[18],
Cloud Point (°C)		14.2[7]					
Poure Point (°C)		6.5[7]			-5[11]	-3[14]	
Fire Point (°C)	210 [6]					258[27,12], 230[14]	
Flash Point (°C)	198[4,5,6]	232[7]		54[10]	158[11], [12]	205[4],242[13], 237[27][12], 263[5],225[14], 215[15]	234[17], 280[5], 234[12], 246[33]
Viscosity	66.2[4,5],	46.42[7]		1.6-2.1[10]	49.7[11,12]	27.84[4,13],35.98[27],	31.23[17,12]
@40 °C cSt	66[6]					37.12[5],35.98[12]	
Density Kg/m ³		904 [7]			9264[11]	938[27], 924[14], 0.926[15]	914[18]
Cetane Number			31[9]			46[13],42[14],31.8[15]	37.6[18]
Specific Gravity	0.91[4,6,5]		0.968[9]		0.9264[12]	0.913[4],0.912[5], 0.93[12],0.925[14]	0.903[12]

Table 1. (Continues) Properties of various Non-Edible Plants and Its oil properties

Plant Name	Jojoba	Honne	Polanga	Croton	Mahua	Jatropha	Cotton
Rain Fall (mm)					550-1500[2]	480-2400[2], 250-1200[2]	
Temperature (°C)						20-28[2]	
Soil Preference					Deep Clay[2]	Any Type[2]	
Height (m)					18-20[2]	3-5[2], 5-7[2]	
Seed Yield (ton/hac/year)						0.1 to 8 [2]	
Oil Content In Seed %					30-40 [3]	43-59[2], 30-50[3]	
Calorific Value (MJ/Kg)		39.11[12]	39.25[4]	36.98[20]	37.614[12]	38.5[4,22], 39.7[21]	39[4]
Cloud Point (°C)	16[19]						
Pour Point (°C)	-6[19]					3 to 5[30]	
Fire Point (°C)					246[12]	271 to 277	
Flash Point (°C)	186[12,19]	224[12]	221[4]		230[12]	174[4], 210[22], 240[21]	210[4]
Viscosity @40°C cSt	52[12,19]	32.47[12]	71.98[4]	33.38[20]	39.45[12]	49.93[21]	50[4]
Density Kg/m ³						932.9 [22], 918.6 [21]	
Cetane No.	55[19]			40.7[20]		38[22], 40-45[21]	
Specific Gravity	0.920[12]	0.910[12]	0.896[4]		0.924[12]	0.920[21]	0.912[4]

N.R.Banapurmatha, P.G. Tewaria, R.S. Hosmathb[29] used a constant speed C.I engine with injection timing of 27°C and with 80% load it is found that the ignition delay for diesel is 10°CA and for honge oil is 12°CA. Were the cylinder pressure for diesel is about 71.5bar and 65 for honge oil. The combustion duration for Honge oil is higher than the diesel. Increase in the quantity of fuel injection leads to increase in power output but the duration of the combustion also get increases.

Figure 1. Experimental Setup

3. Experimental Setup and Procedure

3.1. Instrumentation

- 1) Digital temperature indicator to measure exhausts gas temperatures sensed by respective thermocouples.
- 2) Digital RPM indicator to measure the speed of engine.
- 3) Glass to measure the rate of fuel consumed during running through three way valve system.
- 4) Handheld stop clock for measuring quantity of fuel flow from burette.
- 5) Flue gas analyzer and gas analyzer used to measure the various emissions like NO, NO₂, CO, CO₂.

3.2. Experimental Set Up

The engine used for the investigation is a single cylinder, four stroke, constant speed, vertical, water cooled, direct injection diesel engine.

3.3. Engine Specification:

Table 2. Specification of Engine

Manufacturer	Gujarat Forgings Pvt Ltd..
No of Cylinders	1
Maximum Power	8 HP (5.9 KW)
Compression Ratio	17.5:1
Speed	1500 RPM
SFC	240 g / KWh
Lubrication oil	HD-30
Lubricating System type	Splash Type

3.4. Valve Timing:

Table 3. Valve Timing

Inlet valve opening	12° Before TDC
Inlet valve closing	33° After BDC
Exhaust valve opening	38° Before BDC
Exhaust valve closing	13° After TDC
Injection timing	28° Before TDC

3.5. Emission Analyzer Specification:

3.5.1. Flue gas analyzer Make: Landcom SeriesIII

Table 4. Specification of flue gas analyzer

Sensor	Standard Range	Max. Range	Accuracy	Resolution
Oxygen, O ₂	0 to 25% Vol.	0 to 30% Vol.	±1%	±1% vol.
Carbon Monoxide, CO(low)	0 to 2000 ppm	0 to 100000 ppm	±2%	±1%
CO(H ₂) Compensated	0 to 2000 ppm	0 to 4000 ppm	±2%	±1%
Carbon Monoxide, CO(high)	0 to 4%	0 to 10%	±2%	±1%
Sulphur Dioxide, SO ₂	0 to 2000 ppm	0 to 50000 ppm	±2%	±1%
Nitric Oxide, NO	0 to 1000 ppm	0 to 5000 ppm	±2%	±1%
Nitrogen Dioxide, NO ₂	0 to 100 ppm	0 to 1000 ppm	±2%	±1%
Hydrogen Sulphide, H ₂ S	0 to 200 ppm	0 to 1000 ppm	±2%	±1%
Carbon Dioxide, CO ₂ **	0 to 25% vol.	-	±5% Vol.	±0.1% Vol.
Hydrocarbons, C _x H _y	0 to 5% Vol. (Application dependent)			
Flue gas Temperature	0 to 1000°C			
Ambient Temperature	Measured			
Flow (Velocity)	1 to 50m/s			

Note: Special ranges are available

3.5.2. Gas Analyzer

Make: Electronic System tech Model: PGA 13/ Portable Specifications:

Table 5. Specification of Gas analyzer

Gas Range	CO --0-50% CO ₂ -0-25% CH ₄ ---0-10% H ₂ ---0-50%
Data logging	Yes

3.6. Experimental Procedure

The engine used in this experiment was a single cylinder direct injection diesel engine with a compression ratio of 17.5:1. The rated power was 3.7 kW at 1500 rpm. Test was carried out at constant speed of 1500 rpm. A drum brake dynamometer was coupled to the engine and measured the engine power.

The engine is allowed to run at constant speed and the experiment is conducted for different loads of 0%, 20%, 40%, 60%, 80% and 100%. First the engine is fueled with diesel, its performance and emission characteristics were

analyzed, then the Pongamia oil is used as fuel and the performance and emission characteristics were analyzed. For both the diesel and Pongamia five set of readings were taken and the average reading was taken for performance and emission and it is plotted.

Exhaust gases were measured on line by a flue gas analyzer, in which CO, CO₂, NO_x were analyzed with a non-dispersive infra-red (NDIR).

The engine was run to gain uniform speed after which was gradually loaded. The experiments were conducted for 0%, 20%, 40%, 60%, 80% and 100% load.

The engine was tested at constant speed for diesel and neat pongamia. The time taken for 10cc fuel was noted using stop watch. The CO, CO₂ and NO_x emission were noted by using analyzer for each fuel. Finally the performance and emission characteristics were plotted in graph.

4. Results and Discussions

4.1. Performance Characteristics

The fig.2 compares the Brake thermal efficiency of Diesel and Pongamia. The Brake Thermal Efficiency increases with increase in load. The similar trend of plot is seen for both the Pongamia and diesel. For Pongamia oil 80% to 100% load there is drop in efficiency. To maintain the speed of the engine more amount of fuel is injected at higher loads. The higher viscosity and lower volatility of Pongamia oil leads to lesser combustion quality than diesel so that the conversion rate of the fuel into energy is reduced, this leads to lesser BTE at 100% load than 80% load [16].

Brake Specific fuel consumption is the consumption of unit mass of fuel for producing unit power in a unit time. The fig.3 shows sharp decrease in specific fuel consumption with increase in load because the need of fuel with the increase in brake power is considerably lesser due to lesser heat loss at higher load [24]. Because of the lower calorific value of Pongamia oil to maintain the constant speed for the particular load when compared to diesel it, requires more amount of fuel so the governor adjust and send more amount of fuel to the injector and hence more amount of fuel is injected. Specific Fuel Consumption for

Figure 2. Variation of Brake Thermal Efficiency with load for Diesel and Pongamia oil

Figure 3. Variation of Specific fuel consumption with load for Diesel and pongamia oil

Figure 4. Variation of Total Fuel Consumption with Load for Diesel and Pongamia oil.

Pongamia is greater than diesel because the combustion character is lesser than diesel. Higher viscosity of Pongamia leads to poor atomization during injection of the fuel which results in larger droplet size of the fuel. The larger droplet size results incomplete combustion and the whole particle can't take place in combustion. When the fuel particle size is large the surface contact area with the air is lesser so it leads to lesser participation of the fuel in combustion. This may leads to higher SFC for Pongamia than diesel.

Total fuel consumption is the unit mass of the fuel consumed for unit time. From total fuel consumption the quantity of fuel consumed can be understood. The fig.4 shows the total fuel consumption for both diesel and Pongamia oil. To maintain constant engine speed the governor is designed in such a way that it supplies fuel according to the engine load such that it supply more amount of fuel at higher load and lesser fuel at lower load.

4.2. Emission Characteristics

The CO emission for neat Pongamia is higher than diesel for all loads. The CO formation is due to the insufficient oxygen during the combustion process.

Figure 5. Variation of Carbon monoxide with Load for Diesel and Pongamia oil

Figure 6. Variation of Carbon dioxide with Load for Diesel and Pongamia oil

Figure 7. Variation of Nitrous oxide with Load for Diesel and Pongamia oil

Figure 8. Variation of Exhaust Gas Temperature with Load for Diesel and Pongamia oil

The insufficient oxygen during the combustion leads to the formation of CO [8]. Even though the vegetable oil contains oxygen, the higher viscosity of vegetable oil leads to poor atomization therefore the inner layer of the fuel droplet may not have sufficient oxygen during the combustion, this may leads to the higher CO in vegetable oil.

The CO₂ emission for Pongamia is higher than diesel due to the presence of oxygen content in the Pongamia oil. The NO_x is lesser for Pongamia oil than the diesel. This is because of higher viscosity of Pongamia which results in poor combustion. NO_x formation depends on the temperature during the combustion.

Even though the NO_x for Pongamia is lesser than diesel, the exhaust gas temperature for Pongamia is higher than diesel. This indicates that the combustion takes place at controlled combustion phase. The heat released cannot be significantly used for raise in pressure because the release of heat takes place almost during the middle of the expansion stroke of the engine.

5. Conclusions

The engine can be successfully operated using Pongamia oil as fuel. The efficiency at 80% load is 24.65% and for 100% load is 21.59%. From the experimental study we can conclude that the combustion of Pongamia oil is better around 80% load. A slight higher vibration and knocking is seen while using Pongamia. The performance and emission characteristics while using Pongamia may be Slightly inferior in direct admitting but it can be used in rural areas and pumping applications. By slight modifications of fuel or the engine, Pongamia can be used for long term and the vibration and knocking can be reduced. Pongamia is a nitrogen fixing plant so the commercial oil production leads to a source of income for rural people and the quality of life will be improved.

Nomenclature

BTE-Brake Thermal Efficiency
 SFC- Specific Fuel Consumption
 TFC- Total Fuel Consumption
 CO-Carbon monoxide
 CO₂-Carbondioxide
 NO_x- Nitric oxide
 TDC-Top Dead Center
 BDC-Bottom Dead Centre

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