Performance and Emission Characteristics of Diesel Engines fuelledby Vegetable Oils

R. Sasikumar[1] and Dr. G. Sankaranarayanan[2]
[1] Research Scholar, Department of Mechanical Engineering,
St.Anne's College of Engineering and Technology, Panruti-607110, India,
[2]Research and Dean, Department of Mechanical Engineering,
Sree Sastha Institute Engineering College, Chennai -600123, India

ABSTRACT: Raw vegetable oils can be used successfully in short-term performance test in nearly any percentage as a replacement for diesel fuel. When tested in long-term, blends above 20% always result in engine damage or maintenance problems because, this oil has certain inherent problem like high viscosity and poor volatility. This affects the combustion in diesel engine and deteriorates the whole performance considerably. Hence, turpentine, a resinous extract of pine tree can be chosen as a thinning agent for reducing the viscosity of neat vegetable oil and made suitable for DI diesel engine. A various proportion of turpentine-vegetable oil blends are prepared and fueled into the DI diesel engine test setup for conducting performance test. The performance of kirloskar, AV1model, Single cylinder, Water cooled, Vertical, Direct injection diesel engine is evaluated using modified jatropha oil as fuel. This performance is compared for the same engine using mineral diesel as fuel. The exhaust emission parameters are also compared for these two fuels. From the obtained results, the 50TV blend performs quite similar to that of diesel baseline operation in terms of performance and pollutant emission and it has almost equal combustion characteristics with that of diesel fuel. It offers lower smoke and lower NO_x emission with slightly increased UBHC and CO emission without worsening SFC.

Key words: turpentine, bio fuel, thinning, alternate fuel, emission analysis, vegetable oil and combustion analysis.

I INTRODUCTION

Increasing industrialization and modernization of world lead to steep rise in petroleum cost. Also with the present consumption rate, deplete all petroleum resources within a decade or two. In addition, combustion of fossil fuel accumulates greenhouse gas emissions and leads to rapid rate of global warming. By spending more amount of money we import not only petroleum fuel but also much emission. Considering these disaster effects many alternative fuels were identified and tested successfully in IC engines.

Generally bio fuels are the oils obtained from the living plant sources. These oils may be obtained from resin and plant seeds. Plant oils are renewable and have low sulfur in nature. As the bio fuels are more expensive than fossil fuels, the wide spread use of bio fuel was restrained from its use in I.C engines. The use of vegetable oil in diesel engine has been identified well before. However, despite the technical feasibility, vegetable oils as fuel could not get acceptance, as they were more expensive than petroleum fuels. Also, the vegetable oils were all extremely viscous, with viscosities ranging 10–20 times greater than diesel fuel. This leads to the retardation in scientific efforts to investigate the further acceptability of vegetable oil as fuel.

This fuels take away more carbon dioxide from the atmosphere during their production than is added by combustion. Therefore, it alleviates the increasing carbon dioxide content of the atmosphere. In view of the potential properties, large number of investigations has been carried out internationally in the area of vegetable oils as fuel. Some of the vegetable oils from farm and forest origin have been identified. The most predominantly sunflower, safflower, soybean, cottonseed, winter rape, canola and peanut oil have been reported as appropriate substitute of petroleum based fuels.

Since, the production cost of vegetable oils are slightly lower than those of alcohols and plant oil esters (bio diesel), it can be suggested that direct application of crude vegetable oils would be most advantageous.

The vegetable oils are found to be promising alternative fuels because of their renewable, eco-friendly and can be produced easily in rural areas. The cost of edible oil is some what more. Use of such oil will result in food crises in feature. So that the use of non-edible oil is more significant. The Jatropha curcas grows in all over India irrespective of any climate conditions and areas.

The neat vegetable oil (Jatropha) is not suitable to use as the fuel directly in IC engines. Generally, in diesel engine, straight chain paraffin fuels are preferred for better ignition quality. But due to the large molecular mass and complex chemical structure, vegetable oils are not directly suitable for diesel engine application. This intern leads to problems related to combustion and atomization in the injector systems of a diesel engine. Due to the high viscosity, the long-term operation of the engine with vegetable oils normally introduces the development of gumming, the formation of injector deposits, ring sticking and problems related to the lubricating oils. That is the reason why the diesel oil cannot be replaced by neat vegetable oil without fuel modification and engine modifications. Therefore, the reduction of viscosity of vegetable oils is of prime importance to make it a suitable alternative fuel for diesel engines.

The problem of high viscosity of vegetable oils can be reduced in several ways, such as transesterification, micro emulsification, preheating the oils and blending with other fuels such as diesel, oxygenated organic compounds, and methanol.

Usually, Essential oils (Turpentine) are offering good fuel characteristics and this is the only fuel offering high calorific value than that of other bio fuels and its calorific value almost equal to that of diesel fuel.

As the Turpentine, resinous extract of pine tree possess good fuel value, it could be considered as a one of the possible alternative fuel for diesel engine. Oil of turpentine is a colourless, oily, odorous, flammable, water-immiscible liquid with a hot, disagreeable taste. Chemically, oil of turpentine is a mix hydrocarbon, the predominant constituent being pinene. The turpentine used in this study was distilled from resin obtained from pine trees.

The objective of the present work is to investigate the performance and emission characteristics of the C.I Engine fueled with turpentine-thinned vegetable oil. During this investigation, the C.I engine was fueled with the different TV blends in proportions varying from 30TV to 50TV (30:70, 40:60 and 50:50). The performance and emission characteristics of turpentine - vegetable oil blends are then compared to diesel fuel. The regulated emission species and particulate matters are measured and its variation in the engine exhaust has been compared with the diesel base line operation.

I. DETAILS OF EXPERIMENTAL SET-UP

A single cylinder, 4- stroke, water-cooled, diesel engine coupled with electrical dynamometer as shown in figure 1 was used as experimental set-up.

The specifications of engine & dynamometer are given in table 1 & 2. The measuring instruments used in this project is listed in table 3.

The suction side of the test engine is attached with anti-pulsating drum to measure air inflow quantity. The inlet temperature of air is measured with inlet air thermometer. The exhaust side of the engine consisting of series of devices such as Exhaust Gas Thermometer (EGT), gas analyser probe and smoke meter probe.

A combustion analyser is also attached with the test rig to study the combustion behavior of engine.

The set-up also consists of fuel flow measuring device to measure the fuel consumption of the engine. The output side of the engine consists of an electrical dynamometer and followed by a loading rheostat.

The output is measured in terms of watts using digital wattmeter mounted in the panel. An 8 bit Data Acquisition System (DAS) is also connected with the test rig to acquire the combustion pressure and crank angle,pressure – volume, MFB and HRR data for a stipulated number of cycles.

The schematic diagram and photographic view of the experimental setup are shown below:

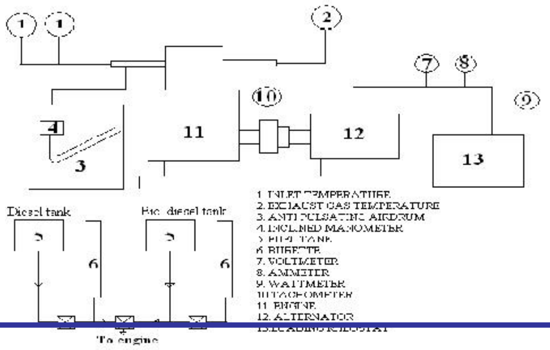

Table 1
Engine Specification

Make	Kirloskar AV 1 model
Type of Engine	Vertical, 4 – Stroke cycle, single acting, High speed, compression ignition, diesel engine
Number of Cylinder	One
Speed	1500 rpm
Maximum power output	5 Hp (= 3.7kW)
Bore	80 mm
Stroke	110mm
Cubic capacity	0.553 litres
Norminal compression ratio	16.5 : 1
Fuel timing by spill	23 Deg. BTDC
Lubrication	Forced Full pressure lubrication
Type of cooling	Water cooled
BMEP at 1500 rpm	5.42 bar

Table 2
Alternator Specification

Make	Kirloskar
Power	5 KVA
Speed	1500 rpm
Voltage	230 v
Ampere	21.7 amps
Frequency	50 Hz
Power factor	0.8

Table 3
Measuring Instruments Used

S.No.	Measuring Parameters	Instruments Used
1	HC,CO,NO_x, CO_2 and O_2	Exhaust gas Analyser
2	Smoke	Bosch Smoke meter
3	Cylinder pr, and Crank Angle	Data aquisition system
4	Exhaust gas temperature	Digital Thermometer
5	Air flow rate	Orifice & manometer

RESULTS AND DISCUSSION

Based on the objectives and methodologies mentioned in the earlier chapters, the experimental investigations were conducted and the results are presented and discussed in this chapter. From the results, the respective graphs for the parameters such as brake thermal efficiency, volumetric efficiency, exhaust gas temperature, peak cylinder pressure, ignition delay, heat release rate, rate of pressure rise and the emission parameters such as carbon monoxide, hydro carbon, NOx and smoke emission were drawn against the engine load.

The engine is tested and its performance is evaluated by using different fuels and blends. The results are found out and analysed one by one as follows.

This chapter consists of the results and discussions of the following fuels while used in engine.

1.Pure diesel(for base line test.
2.Turpentine-Diesel blend.
3.Turpentine- Neat jatropha oil blend.
4.Jatropha biodiesel.

the variation of brake thermal efficiency of various turpentine-diesel blends (TD blends) with respect to engine load. From the figure, it is observed that the brake thermal efficiency of TD blends increases with respect to increase in turpentine fraction in the blend. This is due to improved volatility, increased heat content and remarkable change in viscosity of the blend.

Basically, turpentine possess larger fraction of cyclic compound- terpens (approximately 90% by volume). It has four carbons in its molecule; hence the fuel has low viscosity and higher volatility (usually, number of carbon and chain length of molecule determines the viscosity and volatility of the substance). In addition, turpentine decomposes very easily at lower temperature and releases more volatile intermediate compounds.

It also possesses unstable molecular structure, which helps to combust the mixture faster than the neat diesel fuel. Hence, the combustion duration of higher turpentine blends shortens with respect to increase in turpentine fraction in the blend.

Higher turpentine blends react faster than lower turpentine blends. This is due to finer spray, improved air entrainment and improved oxidation ability. The release of lighter fraction from the higher turpentine blends during combustion is more rapid and abundant due to the presence of higher proportion of cyclic compounds (turpentine). The increased heat content and higher density are also other reasons for higher brake thermal efficiency.

The maximum brake thermal efficiency obtained with 40T blend is 31.5% and it is 2.5% higher than that of DBL operation. Though the blends beyond 40T (50T and 60T) contains higher heat content, these are not considered for analysis because these blends offered poor cold starting and misfires during idling. Hence, the maximum blend proportion was limited to 40T.

the variation of specific energy consumption (SEC) of TD blends with respect to engine loads. The SEC of TD blends decreases with respect to increase in turpentine fraction in the blend. Addition of turpentine in diesel oil not only changes the physical properties but also improves the combustion behavior of the blend. The higher turpentine blends are more reactive than lower turpentine blends and diesel fuel. Hence, in higher turpentine blends the combustion occurs at relatively higher temperature and pressure resulting in lower SEC. Improved spray characteristics, improved volatility, increased heat content and shorter burn duration are some of the additional reasons for lower SEC of higher turpentine blends.

it is observed that the EGT of TD blends are closer to that of diesel base line operation except at higher loads. This is mainly due to higher latent heat of turpentine. Therefore, during evaporation the higher turpentine blends reduces the cylinder temperature considerably lower than diesel operation. However, during combustion, it sufficiently raises the cylinder temperature and keeps it closer to that of DBL operation.

EMISSION ANALYSIS

the CO emission of TD blends with DBL operation at various load conditions. It shows only a small variation in CO emission up to 75% load for all TD blends. Normally, higher turpentine blends are having higher heating value, improved volatility, low cetane number and more cyclic compounds. Hence, the combustion of TD blends is occurring at comparatively higher temperature resulting in lower CO emission. This trend persists up to 75% load beyond which, there is remarkable change in CO emission. This is mainly due to more fuel admission and poor fuel utilization. one of the reasons for rapid production of intermediate volatile compounds, resulting in lower HC emission. the variation of NOx emission of various TD blends with respect to the load. From the figure it is observed that the NOx emission of all TD blends is higher than that of DBL operation. The cetane suppressing property of turpentine is the main reason for higher NOx emission. Usually, low cetane fuels offer longer ignition delay, which promotes more heat release during first stage of combustion and resulting in higher combustion temperatures. The higher combustion temperature provides a conducive ambient for reacting oxygen with nitrogen and yielding more NOx compounds. However, this can be resolved by adopting suitable NOx reduction technique. The maximum NOx emission obtained with 40T blend is 1380ppm.

The shift of peak pressure of TD blends is not much distinguishable and the occurrence of peak pressures is not far away from the DBL operation (within 5 degrees). Hence, the power loss due to longer ignition delay is insignificant.

Compares the heat release rate of 40T blend with that of DBL operation at full load. From the figure it is seen that the two phase of combustion is clearly visible and distinguishable. The height of premixed phase of combustion is increasing with respect to increasing turpentine fraction in the TD blends. This is attributed to low cetane number of turpentine. This is also one of the reasons for higher brake thermal efficiency and higher peak pressure of 40T blend.

Terpens possesses only four carbons hence the fuel has low viscosity and higher volatility. In addition, turpentine decomposes very easily at lower temperature and releases more volatile intermediate compounds. These gaseous products combust rapidly and releases heat energy in shorter duration. This is the major reason for higher brake thermal efficiency of 40T blend.

4. NOx emission of 50TJ blend is slightly lower than that of diesel base line operation.
5. The CO and UBHC emission of 50TJ blend is very closer to DBL operation.
6. Based on the net heat release rate, Pee Theta diagram and ignition delay, 50TJ blend does not deviate much more than the diesel base line operation.
7. As the combustion and emission performance of operation, it is proposed to be the best blend than that of other TJ blends and NJO. In addition the following observations were also made while running the engine under biodiesel mode.

9. Higher thermal efficiency.
10. Less EGT.
11. Lower CO and CO_2
12. Slightly increased Nox emissions.

REFERENCES

[1] Achten W.M.J, Maes W.H, Aerts R, Verchot L, TrabuccoA, Mathijs E, Singh V P and Muys B(2009) Jatropha: From global hype to local opportunity. Journal OF Arid Environments xxx(2009) 1-2.

[2] Alamu O J, Akintola Ta, Enweremadu C C and Adeleke A E (2008) Characterization of palm-kernel Figure 1 Comparison of SFC of DBL, 50TJ,NJO and oil biodiesel produced through NaOH catalyzed transesterification process. Scientific Research and Essay vol.3 (7),pp 308-311.

[3] Amba Prasad Rao G, Rama Mohan P (2004) Performance Evaluation of DI and IDI Engines with Jatropha Oil based Bio-diesel. IE(I) Journal-MC, p72-76.

[4] Anjan Kumar Prusty B, Rachna Chandra and Azeez P A, Biodiesel: Freedom from Dependence on Fossil Fuels?

[5] Bacon, D. M., F. Brear, I. D. Moncrieff, and K. L. Walker. 1981. The use of vegetable oils in straight and modified form as diesel engine fuels. Beyond the Energy Crisis -- Opportunity and Challenge Volume III. Third International Conference on Energy Use Management. Berlin (West). Eds. R. A.

[6] Fazzolare and C. R. Smith, 1525-33. Pergamon Press, Oxford.

[7] Bartholomew, D. 1981. Vegetable oil fuel. J. Am. Oil Chem.

BIODIESEL

The variation of SFC with brake power output is shown in Figure 1.

The SFC of TJ blends varies with respect to turpentine proportions in the blend. Usually, higher turpentine blends are offering lower SFC and lower turpentine blends are offering higher SFC. From the Figure it is clear that the 50TJ blend offers lower SFC than NJO, other TJ blends and it is very closer to DBL. Hence, the 50TJ blend could be suggested as a replacement fuel for petro diesel. The reasons for lower SFC of 50TJ blend are increased calorific value, improved spray performance, better air entrainment, reduced soughter mean diameter and improved volatility. EGT

CONCLUSIONS

From the detailed test conducted with turpentine- thinned jatropha oil and biodiesel the following conclusions have been derived.

1. The 50TJ blend offers maximum brake thermal efficiency of 30.6% at full load. It is around 5% higher than that of DBL and 8.5% higher than that of NJO and 2.6% higher than biodiesel.
2. The SFC of turpentine-jatropha oil blends found decreases with respect to increase in turpentine fraction in the blend. The 50TJ blend has the SFC very closer to DBL operation. But SFC of biodiesel is lowest among the all.
3. The EGT of 50TJ blend is slightly higher than that of diesel base line operation due to higher turpentine content in the blend. At the same time EGT of biodiesel is less than the DBL mode.