JL. Rubb. Res. Inst. Sri Lanka (1990) 70, 11-25

USE OF VEGETABLE OILS AS FUELS FOR DIESEL ENGINES WITH SPECIFIC REFERENCE TO RUBBER SEED OIL

By

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SUMMARY

This paper considers the use of Rubber Seed Oil (RSO) as a diesel fuel substitute / extender for diesel engines. Experiments were conducted using RSO as a fuel in diesel engines. The physical and chemical properties of RSO were measured. High viscosity is one important difference between this material and diesel oil. Processes were investigated to reduce the viscosity, in particular a transesterification process was studied. The effect of viscosity and surface tension on characteristics of sprays from injectors was studied in order to identify differences between RSO and diesel oil. The results of these experiments help to explain the observed differences in engine performance between the two fuels.

INTRODUCTION

Why alternative fuels for Internal Combustion Engine?

Petroleum based fuels have been serving as the major source of fuel for internal combustion (IC) engines, over the past century or so. Development of engines has been based on the properties of petroleum derived fuels which in turn have been tailored to meet the requirement of modern engines. The 1973 oil embargo, however, gave a reminder that the supply of petroleum fuels is not inexhaustible. No one knows for certain when the world's petroleum fuels will run out. However, it is generally believed that economically recoverable reserve of oil will not last very far into the twenty first century, if the present pattern of consumption continues. (McVeigh, 1984).

Choice of alternative fuels:—

Recent concern over the price and availability of liquid petroleum fuels has created substantial interest in alternative sources of fuel for IC engines. In this context biomass based fuels such as alcohols, biogas, producer gas and vegetable oils have been identified as suitable fuels. Fuel properties such as octane and cetane number, self-ignition temperature and calorific value are the

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most important criterions that influence the choice of fuel for Spark Ignition (SI) or petrol engines and Compression Ignition (CI) or diesel engines. These fuel properties are compared in the Table 1.

While alcohol fuels have been found to be more suitable for SI engines, vegetable oils fuels have been proven to be and appropriate fuel for CI engines. Engine modifications to a greater or lesser extent would be required for use of these fuels.

Table 1 Important fuel properties for choice of fuel

Fuel	Octane Number	Cetane Number	Lower calorific Value (MJ/Kg)	Ignition temperature	Type of engine preferred
Petrol	79–98	5–10	45.0	high	SI
Diesel	—	45–55	45.0	low	CI
Ethanol	106–111	0–5	26.7	high	SI
Methanol	106–115	—	20.0	high	SI/CI
Biogas	—	—	25.0 MJ/m3	high	SI/CI
Producer gas	—	—	45–5.0 MJ/m3	high	SI/CI
Vegetable oil	—	35–40	39.0	low	CI

(Source ; Data computed from various sources)

Vegetable oils: Fuels for compression Ignition (Diesel) Engines:

The use of vegetable oil and animal fat as fuels for diesel engines is not a new concept. Dr. Radolph Diesel, who invented the diesel engine, used peanut oil to fuel one of his engines in 1900 (Nitsche and Wilson, 1965). Since then the use of vegetable oils as fuels has occured periodically, usually during petroleum shortages. In most cases, however the interest faltered due to increased availability of more economical petroleum derived fuels. The 1973 very large increase in oil prices signaled the beginning of a new period of petroleum shortage. As a result, the international interest in the use of vegetable oils as a diesel fuel substitute was once again renewed. A large number of researchers have reported engine tests using various vegetable oils such as sunflower, corn, soyabean, coconut etc. These engine tests included measurement of power output, torque, brake thermal efficiency, exhaust temperature, exhaust emissions, etc. They have concluded that vegetable oils give performances comparable to diesel fuel in the short-term. After long - term tests most researchers have reported some or all of the following problems.

Injector nozzle coking and eventual blocking.

Build up of carbon inside the combustion chamber, exhaust values etc, and formation of varnish on combustion chamber surfaces.

Piston ring sticking.

Lubricating oil contamination.

Filter blockage leading to fuel starvation.

Difficulties in starting from cold conditions.

Unacceptable smoke emission levels.

Some of these tests have been run with 100% vegetable oils whereas others have been run using blends of the oil with diesel oil in varying proportions. Use of blends appears to improve injection qualities and combustion performance over that of 100% vegetable oil and to reduce the severity of some of the above problems. (Engelman *et al.,* 1978; Mazed *et al,* 1985).

The severe problems such as rapid build up of carbon deposits, gumming, up of piston rings, lubrication oil contaminating, etc., are believed to be caused by the high viscosity of the vegetable oils which leads to poor atomisation (break-up of fuel into fine droplets) of the fuel which in turn leads to insufficient combustion.

General approaches to the solution of these problems include:

(1). Modification of the vegetable oils in order to reduce viscosity.

(2). Modification of the engine to improve spray atomisation and thereby combustion.

The differences in the spray characteristics (spray angle, penetration, and droplet sizes) of vegetable oil and diesel oil are attributed to their differences in physical properties, particularly the viscosity (Humke and Barsic, 1981). In addition, differences in some of the chemical properties such as unsaturation, are responsible for problems arising from incomplete combustion after the fuel injection. However, only limited work has been carried out to investigate how the differences between the properties of diesel oil and vegetable oil influence the spray characteristics.

Rubber seed oil (RSO) as a fuel for diesel engines:

It has boon ostimatod that approximately 130,000 tonnos of RSO and 200,000 tonnes of high protein rubber seed cake may be obtained annually from rubber plantations in the world. Sri Lanka's contribution to this is 4,500 and 7,000 tonnes respectively.

At present the main potential use of RSO is in the paint industry. Currently it is used for the manufacture of alkyd resins used in emulsion paints. Rubber seed cake could be used either as an animal feed or as a nitrogen rich fertilizer. The largest percentage of the resource, however has not been utilised. This study concerns the possible application of RSO, which is an inedible vegetable oil, for use as an alternative to diesel fuel.

Experimental

The objectives of the experimental work are as follows:

(1). Determination of fuel properties of RSO and methyl ester of RSO (MRSO).

(2). Comparison of engine performance.

(3). Comparison of fuel spray characteristics.

Fuel related properties

Fuel related properties were determined following American Standards for Testing Materials (ASTM) test methods.

Engine performance tests

The engine tested was a single cylinder, four stroke, air cooled, naturally aspirated petter (model AC1) engine giving 4.9KW (6.5php) at 3600 revolutions per minute (rev/min). Tests were carried out at different loads with engine running on conventional diesel oil, RSO and blends of RSO with diesel oil at constant speed setting of 2600 rev/min. Three belends were used having 25%, 50% and 75% RSO by volume.

The performance of MRSO was compared with RSO and diesel oil on a separate engine. The engine used here was a single cylinder water cooled, engine with variable compression ratio developing 9 php at 1800 rev/min, when operating at its design compression ratio of 22:1.

Spray characteristics measurements:

An experimental fig (Fig. 1) was set up to measure the spray tip penetration and spray cone angle. The system consists of the following parts.

Spray chamber.

Injector (Bosch, single hole).

Pump (Bryce) and cam box.

Camera, flash and electronics to trigger the flash.

Storage oscilloscope.

A photographic technique was developed to measure the spray angle and spray tip penetration of the liquid jet produced by the single hole injector. This consists of an electronic mechanism built too triggler an electronic flash to illuminate the spray, when it has emerged from the nozzle. to allow it to be photographed.

An infra – red (IR) emitter and an IR sensor are placed just in front of the nozzle exit, perpendicular to the jet axis, on opposite sides of the jet. The IR beam is linked to the electronic flash circuit in such a way that when the beam is cut by the jet, it triggers the flash. The spray patterns of all the liquid fuels were photographically recorded. Spray cone angle and spray tip penetration measured from the photographs.

The droplet size distribution of liquid fuel sprays were determined by using melvern particle sizer which employs laser diffraction method for particle sizing.

RESULTS AND DISCUSSION

Fuel related properties:—

The results of fuel property tests carried out on RSO Soyabean oil and diesel oils are presented in table 2, It can be seen from these results that the cetane rating of RSO is close to ASTM minimum of 40 for No 2 diesel oil, which is actually encouraging.

RSO is extremely viscous with viscosity of ten times greater than the viscosity of No1 diesel oil at 40°C. When ASTM test D 86 was carried out, RSO cracked into a two phase distallate, when the distillation temperature was raised above 300 °C, showing its thermal instability.

Fuel properties of RSO, MRSO, Soyabean oil and diesel oil.

Table 2

Fuel property	RSO	MRSO	Soyabean oil	ASTM specification for No 2 diesel oil
Cetan number	40	—	37.1	40 (minimum)
Distillation Temperature °C (90% point)	cracking	—	—	282 (minimum) 338 (minimum)
pour point °C	9.0	—	–12.2	—
cloud point °C	13.0	—	–3.9	6°c above 1/10 percentile minimum ambient temperature
Carbon residue, weight %	1.3	—	0.27	0.35 (maximum)
Ash by weight %	0.54	—	0.01	0.01 (maximum)
Sulphur, copper corrosion	la	—	la	No 3 (maximum)
Sulphur, by weight %	0.003	—	0.01	0.5 (maximum)
Water and sediment, % by volume	0.05	—	trace	0.05 (maximum)
Flash point, °C C	180	05	254	52 (minimum)
Viscosity c st @ 30 °C	31.5	6.5	32.6	1.9–4.1
Calorific value MJ/kg	39.2	38.7	39.7	—
Density kgm $^{-3}$	920	860	910	—
Surface tension X 10^{-3} No.$^{-1}$	32.3	29.6	—	—

Comparisons with properties of No. 2 diesel oil indicate that RSO meets the ASTM limits for total and active sulphur, water and sediment, and fails to meet-the ASTM limits for ash content and carbon residue, reflecting the crude nature of the sample tested (sample was not refined). RSO has higher cloud and pour points, but these low temperature characteristics are not important for tropical countries like Sri Lanka where the ambient day temperature hardly drops below 20 °C. It can be seen that the heating value 3 of RSO is 87% of diesel oil on a mass basis and 94% on a volume basis at 25% C, since RSO is slightly behaviour than diesel oil.

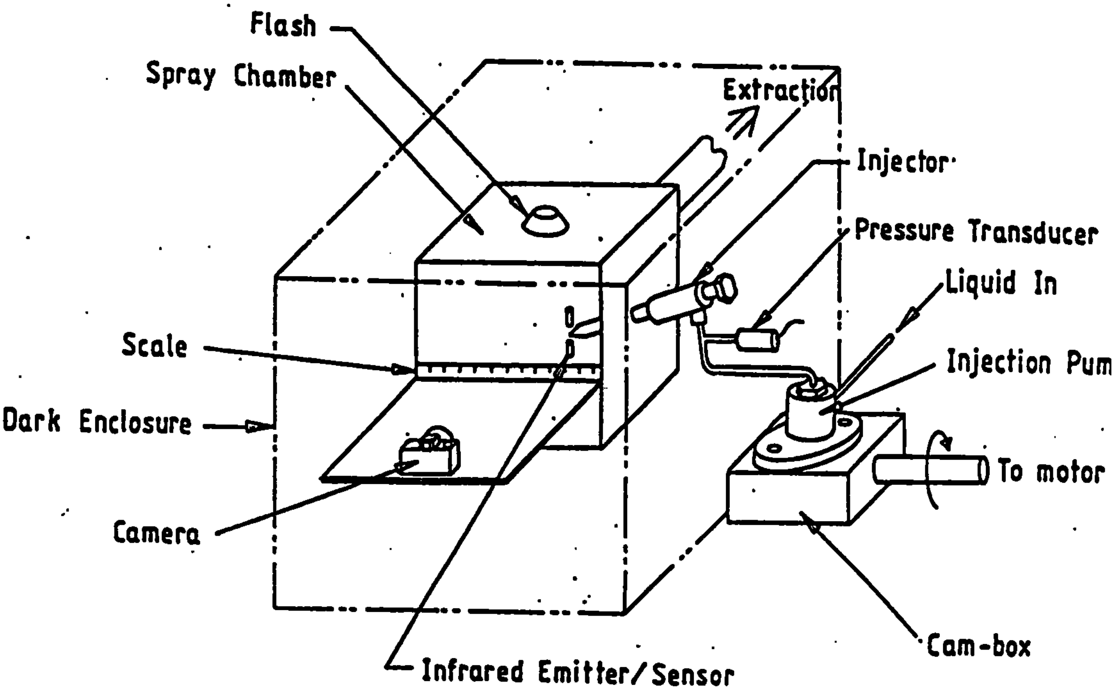

Figure 1 : Lay out of experimental rig built to measure the spray tip penetration a
cone angle.

It is interesting to note that fuel properties of MRSO are comparable to those of diesel fuel, particularly the viscosity is much closer to that of diesel fuel.

Engine performance test results:

Figure 2 shows the variation of specific fuel consumption (SFC), brake power (BP), brake thermal efficiency (TE) and exhaust temperature with brake mean effective pressure (BMEP) for the fuels at 2600 rev/min. As far as above performance parameters are concerned and corresponding values for RSO show a considerable similarity to those of diesel oil. It can be seen that the SFC is slightly higher for vegetable oils due to their low heating value. In most cases the thermal efficiency of vegetable oils is slightly higher.

Plots of variation of SFC, thermal, efficiency and BP with BMEP obtained with the blends of RSO and diesel oil were used to produce fig. 3. This show the variation of SFC, thermal efficiency and BP with the percentage of RSO in RSO/diesel oil blend at 2600 rev/min.

There has been a general trend of a slight increase in SFC and thermal efficiency as the percentage of RSO is increased.

In all engine performance tests MRSO also behaved very much similar to diesel oil.

Fuel spray characteristics:

Figure 4 shows the variation of spray tip penetration with the time from commencement of spray from the nozzle. It can be seen from these results that except RSO, all liquids have a similar penetration during the first millisecond or so of the injection., Comparable penetration results have been presented by Burt and Troth (1969) for gasolene and diesel oil. All the liquids, however, tend to show different penetration values sometime after injection. It is clear form these results that the spray penetration increases as the viscosity increases. In other words, sprays of low viscosity liquid slow down more rapidly than high viscosity sprays of low viscosity liquid slow down more rapidly than high viscosity sprays. Two reasons can be given for the viscosity effect on penetration; the reduced spray cone angle and increase in droplet size. More compact sprays will suffer less resistance form the surrounding air, while bigger droplets will have a smaller decleration.

Another important observation in the present study lies in the effect of surface tension on spray penetration. If can be seen form the penetrations results that the surface tension of liquids has no any noticeable effect on penetration curves.

Figure 5 shows the variation of measured spray cone angle with liquid viscosity. It can be seen from this curve that spray angle decreases as the viscosity of liquid increases (the measured spray angle values are in reasonable agreements with tho values calculated using the aerodynamic surface wave theory) The high viscosity RSO, gives only half of the value of spray angle of diosel oil.

Tho mean droplet size measured from a distance of 7.5 cm from the nozzle is plotted against the viscosity of fuel in Figure 6. It can be seen from this figure that thoro is an increase in sauter. Mean diameter (SMD) with increaso in liquid viscosity. THo true SMD of MRSO, RSO and RSO/ diesel mixture must be higher than the recorded value. This is because these three liquids would appear to give droplets of diameter greater than 564 mm which is the maximum daimeter for which the laser instrument can respond. The deviation of MRSO from true droplet size can be assumed to be small and much less than RSO and RSO/ Diesel.

Conclusions and Recommendations for further work:

RSO has fuel properties very similar to other vegetable oils. Comparisons with fuel properties of diesel oil indicate that crude RSO meets ASTM limits for cetan number, flash point, total and active sulphur, and water and sediment. However it fails to meet the ASTM limits for viscosity, ash content, carbon residue, cloud and pour points. properties such as ash content, carbon residue, cloud and pour points can be improved by refining the oil.

Amongst the fuel properties of RSO tested, the crucial factors must be high viscosity and distillation characteristics. The high viscosity is found to affect the characteristics of the fuel spray and thereby cause a number of detrimental effects. Tho higher distillation temperature (i. e. low volatility) might have an effect on vaporization and combusition characteristics. Fuel properties of MRSO were found to be much more closer to those of diosel oil.

Short term engine performance tests indicate that RSO, MRSO and blends of RSO and diesel fuel are very much similar to diesel oil in terms of power productivity, thermal efficiency, and specific fuel consumption.

Spray penetration, come angle and droplet size measurements show that RSO sprays are markedly different from those of diesel oil in the following ways.

RSO has a higher penetration than diesel oil.

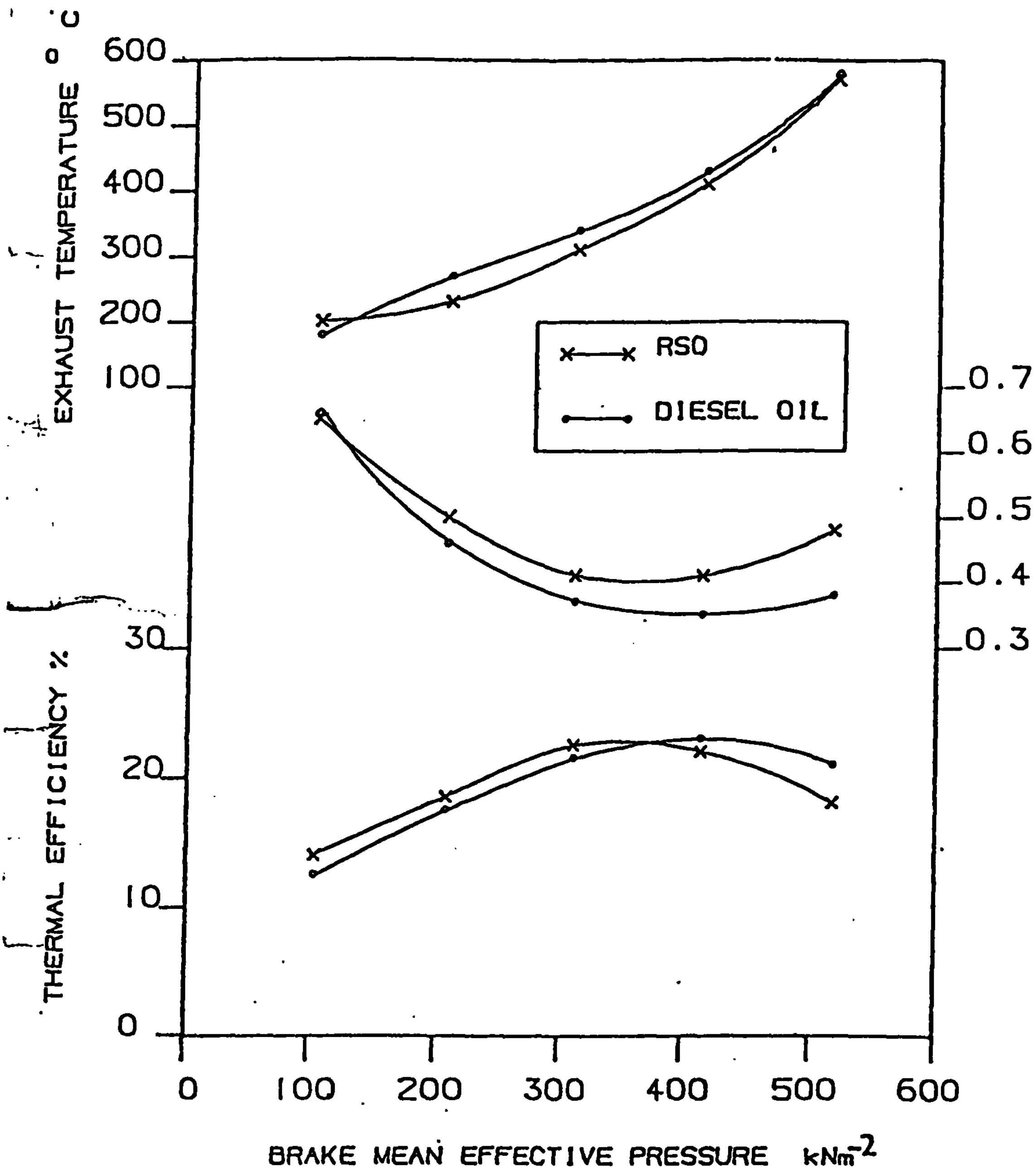

FIGURE 2. : PERFORMANCE OF RSO AND DIESEL OIL AT 2600 RPM

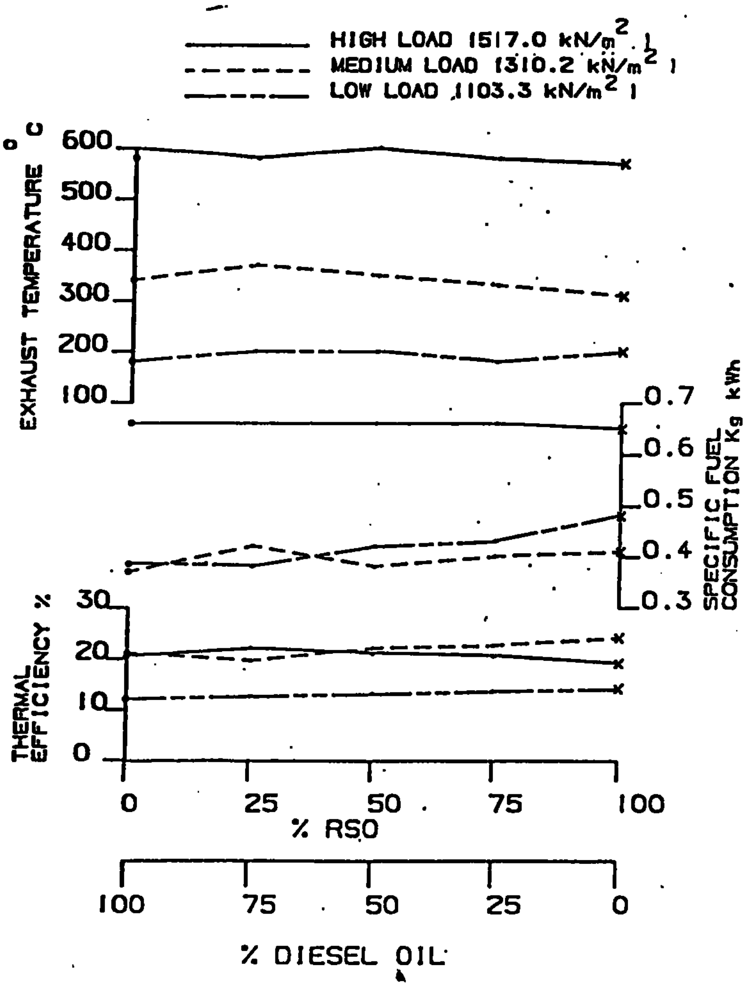

FIGURE 3 : VARIATION OF THERMAL EFFICIENCY, SPECIFIC FUEL CONSUMPTION AND EXHAUST TEMPERATURE WITH THE COMPOSITION OF RSO/DIESEL BLEND AT THREE DIFFERENT LOADS WITH THE ENGINE RUNNING AT CONSTANT SPEED OF 2600 RPM

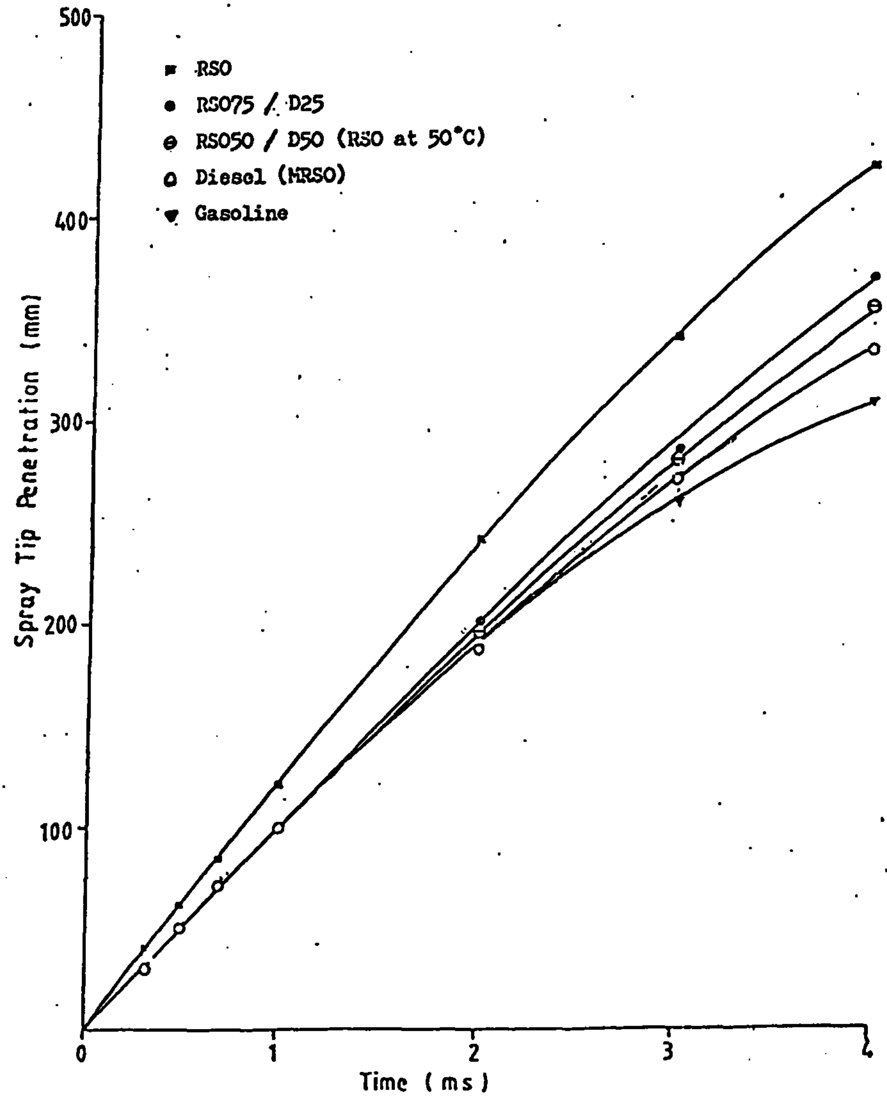

Figure 4: Variation of spray tip penetration of liquids with the time from commencement from the nozzle

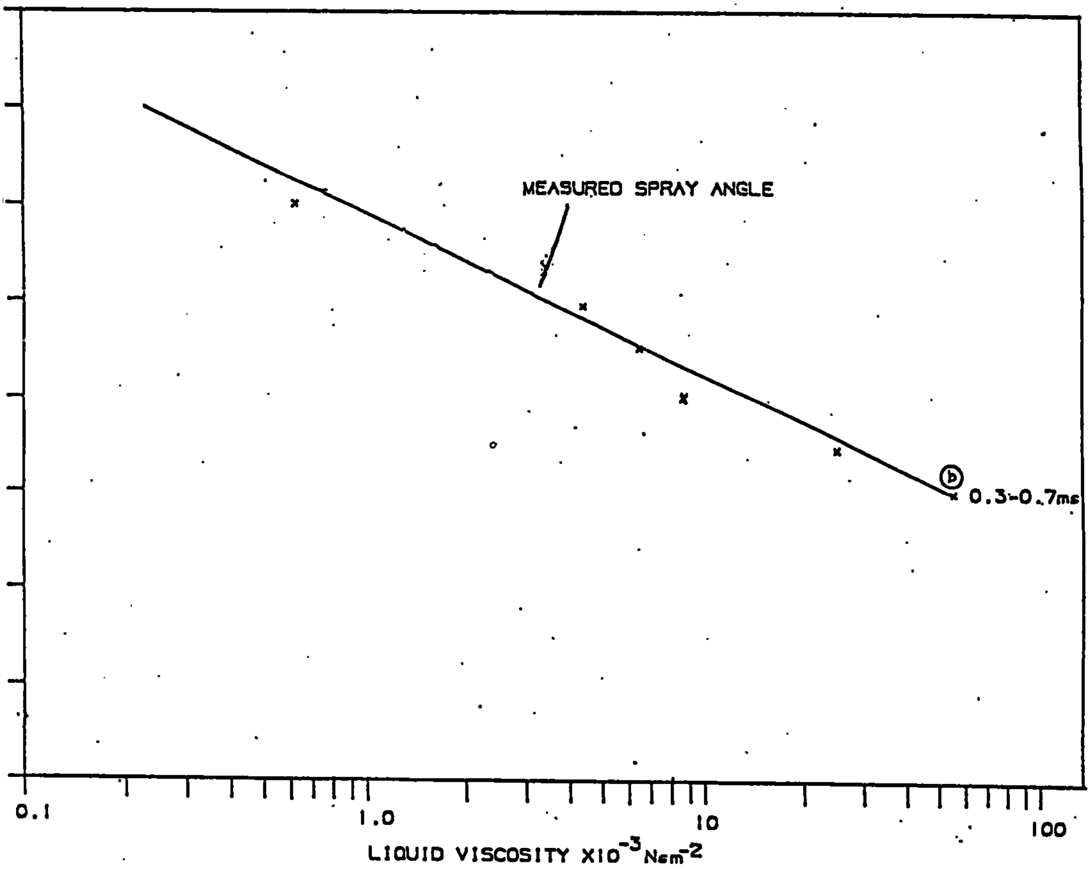

FIGURE . 5 : VARIATION OF SPRAY ANGLE WITH LIQUID VISCOSITY

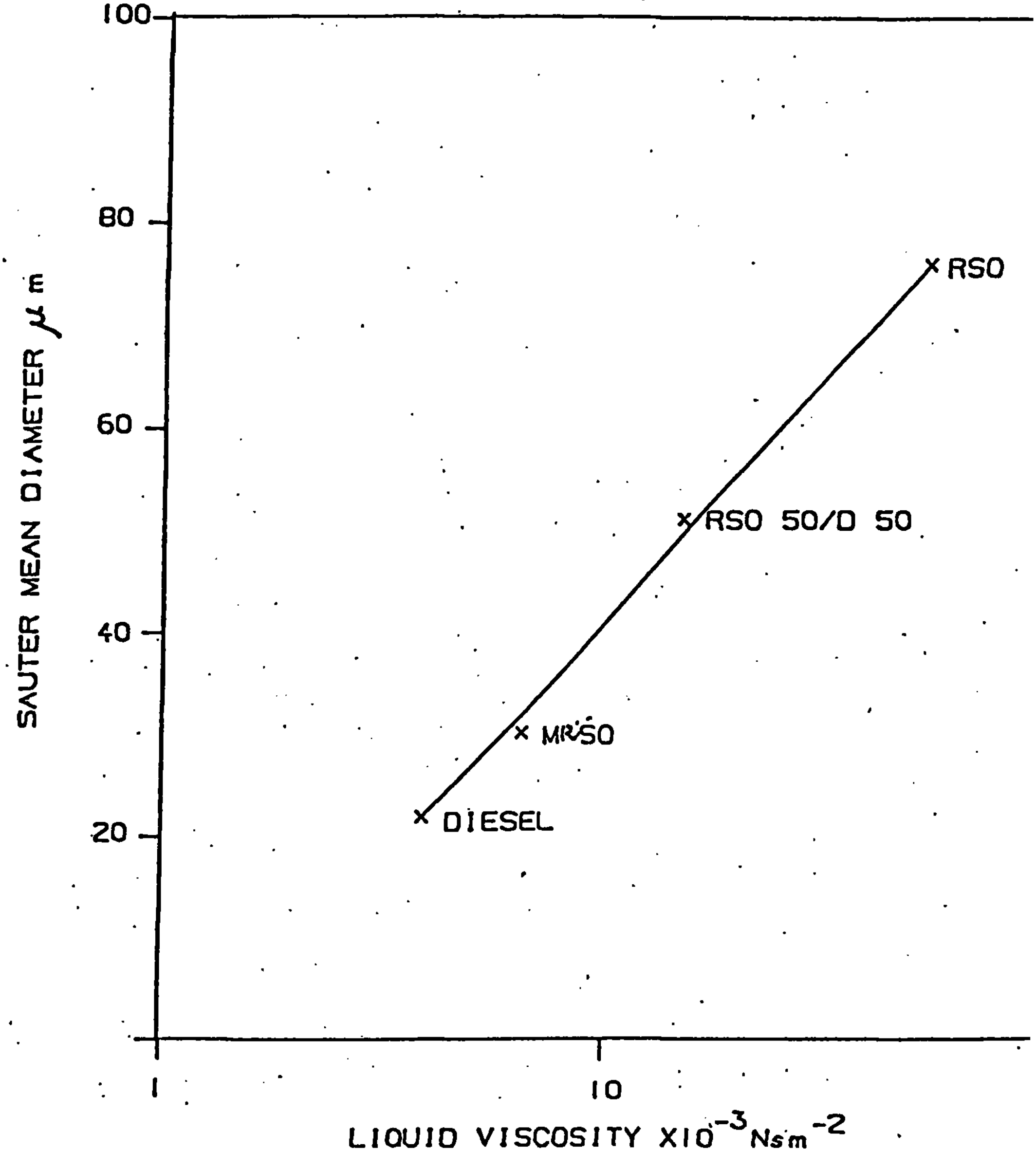

FIGURE 6·2· VARIATION OF SAUTER MEAN DIAMETER WITH LIQUID VISCOSITY

RSO has a spray cone angle of about half of the cone angle of dried oil.

RSO has a SMD of more than three times that of diesel oil.

The spray experimental results show that high viscosity oils such as RSO produce sprays of small angle which tend to penetrate further when compared to diesel oil sprays. Further the sprays from RSO contain bigger droplets than from diesel oil, making combustion difficult. Large droplets also tend to penetrate to a greater distance before they are vapourised. Therefore some oil may actually impinge on cylinder walls before it is combusted resulting in increased blow – by into the crankcase causing lubrication oil contamination or gum forming on the walls.

It is clear that the poor atomisation of high viscosity vegetable oils such as RSO is responsible for problems associated with the long term use of vegetable oils in diesel engines. To overcome these problems one of the following steps should be followed;

Reduce the oil viscosity:

(a) Use of heated fuel.

(b) Use of blends of vegetable oils with diesel oil.

(c) Use of chemically modified oil (eg. Transesterified oil).

Modify the engine, specially the injector system to improve the spray atomisation.

Research in these fields are required to enable the use of vegetable oil fuels in diesel engines and overcome current problems.

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