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Abstract

This paper reports on a 1000 hour EMA alternative fuels test that was performed to evaluate compression ignition engine durability when fueled with methyl ester of winter rapeseed oil and number 2 diesel - methyl ester of winter rapeseed oil blends.

Three engines, one fueled with 100% methyl ester of winter rapeseed oil, one with a 50% number 2 diesel - 50% methyl ester of winter rapeseed oil blend, and one with a reference fuel of 100% number 2 diesel, were investigated in the 1000 hour test. It was found that methyl ester of winter rapeseed oil was equivalent to number 2 diesel when compared on the basis of long term performance and engine wear. The primary factors which were evaluated included engine brake power and torque, injector tip coking, and engine component wear (based on oil analysis). The only noticeable adverse effect of the ester fuel was a slight decrease in engine oil viscosity.

INTRODUCTION

Previous studies on the use of unrefined vegetable oil fuels have revealed their vast potential as an alternative to or extender for diesel fuel as well as many of their handicaps (1).* Tests conducted worldwide have shown that short-term performance indicators (power, torque, and brake thermal efficiency) of numerous vegetable oils are comparable to those of diesel. However, long term usage leads to severe engine deposits, injector coking and ring sticking. These long term effects can be reduced or eliminated through transesterification of the vegetable oil to form a methyl ester (2).

This paper reports the results of a long term engine test designed to asses the durability of compression ignition (CI) engines fueled with methyl ester of winter rape and a 50:50 diesel-ester blend in comparison to 100% diesel. The test was conducted using direct injection, naturally aspirated CI engines. The methyl ester of winter rape used in the test was produced at the University of Idaho using a room temperature batch process developed at Idaho.

LITERATURE REVIEW

The energy crisis of the 1970's sparked a renewed interest in the use of vegetable oils as fuels (1). The most promising form of the vegetable oil for use in CI engines is that of an ester (methyl, ethyl, or butyl) (2 - 12). Research has shown that the transesterification process alters the properties of a vegetable oil in a way which makes it more suitable as a diesel substitute (2). Studies with soybean oil, sunflower oil and winter rape oil have shown significant improvements in viscosity and surface tension (13). The degree of improvement, however, appears to vary with the type of ester and the type of vegetable oil.

SHORT TERM ENGINE PERFORMANCE TESTING - Peterson et al. (14) ran a series of

*Numbers in parentheses designate references at end of paper.

cycles. The comparison factors are as follows:

a) Engine performance
b) Analysis of lubricating oil for wear metals and oil deterioration signs
c) Injector coking

2. To define potential problem areas for prolonged use of methyl ester of winter rape as a substitute for diesel fuel.
3. To establish the ability to produce relatively large volumes of fuel quality methyl ester of winter rape using a batch type transesterification process.

MATERIALS AND METHODS

EQUIPMENT - Three Yanmar 3TN75E-S diesel engines (3-cylinder, 4-stroke, naturally aspirated,direct injection) were selected as the test engines. Each has a bore and stroke equal to 75 mm a displacement of 994 cc, a compression ratio of 17.6:1 and a one-hour power rating of 16 kW at 3000 rpm. These engines were chosen because their design is typical of most diesel engines used in agriculture today.

Three test stands, designed and built at the University of Idaho (24), were used to load and monitor the test engines. Each stand uses a hydraulic dynamometer which consists of a Hydreco gear pump(cradled for torque measurement) coupled directly to the engine clutch shaft. A Sperry-Vickers electronically modulated relief valve (EMRV) was used to control the pressure on the pump and thus the load applied to the engine. A constant volume flowmeter, which measures the time for a known volume of fuel to be consumed, and a magnetic pickup, which measures engine speed at the clutch shaft have been incorporated into each stand. Throttle control was provided by a DC gearhead motor linked to the throttle shaft of each engine's fuel injection pump. Each test stand can be controlled either manually from the stand or remotely with a data acquisition and control system.

The data acquisition and control system consists of an HP 85 microcomputer and a 3054 DL (Data Logger). The system capabilities include control of engine speed and load as well as measurement of engine torque, speed, power output, fuel consumption, and temperatures (exhaust, crankcase oil, fuel,and hydraulic oil).

The esterification plant, also designed and built at the University of Idaho (25), has a 756 L capacity. The components of the system include: a 1096 L conical bottomed, cross-linked polyethylene tank; an R.S. Corcoran model 2000D explosion proof centrifugal pump (75-95 L per minute capacity); a 0.2 kW mixer with a 3.4:1 gear reduction unit (1725 motor rpm).

The polymer tank and system pump are mounted on a 1200 mm by 2400 mm steel platform with caster wheels and forklift eyes. PVC pipe and fittings are used for all system plumbing. A hand operated diaphragm pump is used to prime the system pump. All of the reaction, settling, washing, and separating takes place in the cross-linked polyethylene tank. The methanol and KOH (catalyst) are premixed in a 189 L tank prior to being transferred to the larger system tank.

FUELS - The fuels used in this study were 100% methyl ester of winter rape oil (100RE), 100% number 2 commercial grade diesel (100D2), and a 50:50 (by volume) blend of number 2 diesel and methyl ester of winter rape oil (50RE-50D2). The methyl ester used in the test was all produced by the University of Idaho Agricultural Engineering Department in the batch esterification plant described above. The number 2 diesel, used as a control, was obtained from a local commercial dealer. The fuel properties determined by a commercial lab are displayed in Table 1.

TABLE 1.
PHYSICAL PROPERTIES OF FUELS
BASED ON ANALYSIS OF SAMPLES SENT TO PHOENIX CHEMICAL LAB. INC., CHICAGO, ILLINOIS.

PROPERTIES	100RE	100D2	50RE-50D2
Flash Point (C)	-- *	72.2	86.7
Cloud Point (C)	-1.1	-10.0	-7.8
Viscosity @ 40C, cs	5.65	3.17	4.34
Sulfur, %	0.031	0.360	0.204
API Gravity, 15C	29.6	32.7	31.0
Heat of Combustion kJ/kg (gross)	40721	45333	42914

* No flash was observed.

engine.

All engine service and maintenance was performed as specified in the manufacturers service manual.

The methyl ester of winter rape oil used in the test was produced as described by Peterson et al (25).

RESULTS AND DISCUSSION

FUEL CONSUMPTION - The engine fueled on 100D2 consumed 3607 liters of fuel while the engines fueled on 100RE and 50RE-50D2 consumed 3701 and 3589 liters of fuel, respectively. These differences in fuel consumption reflect the differences in heat of combustion and density of the individual fuels. A complete listing of fuel properties can be found in table 1. The 5496 liters of methyl ester fuel used in this test were produced in the batch esterification plant with no problems of significance. The total volume of methyl ester that has been produced in this plant is 8782 liters to date. The methyl ester production capability with the current plant is 757 liters per week.

ENGINE PERFORMANCE - The observed performance trends are shown in Figures 1 and 2. Figure 1 shows maximum engine power at each 100 hour interval for the three fuels 100D2; 100RE and 50RE-50D2. A least squares quadratic curve was fit to the data with R^2 (coefficient of determination) values of 0.78, 0.82 and 0.23 respectively. Figure 2 is engine torque at 2550 RPM for each 100 hour interval, R^2 values for the quadratic curves of 0.53, 0.79 and 0.15 respectively were found.

The test began with the 100D2 providing the most power and the 50RE-50D2 coming in second and the 100RE having the lowest power output. The 100D2 fueled engine reached its peak power output after 200 hours and gradually declined from there. The 100RE fueled engine reached its peak output at 500 hours while the 50RE-50D2 fueled engine reached its peak at 800 hours. It was noted that from the 500 hour mark on the 100RE fueled engine produced more power than the 100D2 fueled engine and from the 800 hour point on the 50RE-50D2 fueled engine also produced more power than the 100D2 fueled engine. (The 100RE fueled engine produced more power than the 50RE-50D2 engine from the 200 hour mark on.)

The torque output followed the same general trend as the power output with the only major difference being that the 100RE fueled engine started out with a slightly higher torque producing ability than the 50RE-50D2 fueled engine.

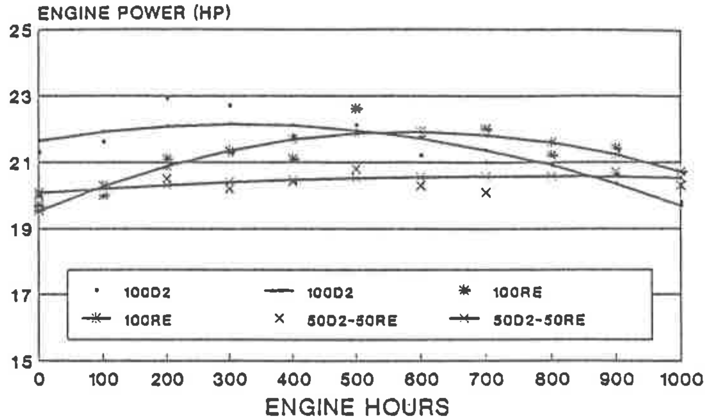

Fig. 1 - Maximum engine power at 100 hour intervals during the 1000 hour endurance test.

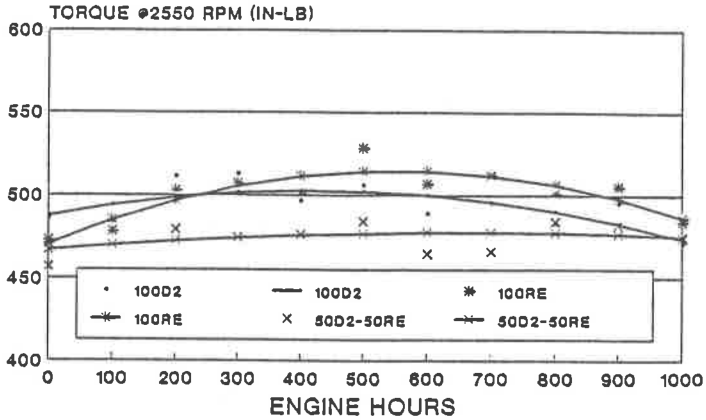

Fig. 2 - Engine torque at 2550 rpm for 100 hour intervals during the 1000 hour endurance test.