1986

EMA Test Cycle Evaluation of a Winter Rape Oil-Diesel Blend with Fumigation

by

C. L. Peterson, W. T. Stibal and P. G. Mora*

ABSTRACT

Following short term injector coking analysis which indicated that propane fumigation may have some benefit in reducing engine deposits, EMA test cycle 200-hour evaluations were conducted. Two different engines were used in the tests. The first two tests were conducted with two-cylinder, air-cooled, direct injection engines and the third test with three cylinder, direct injection, water-cooled engines. Fuels used in each test included two engines operated on a blend of 50 percent winter rape and 50 percent diesel with the third engine having the same main fuel plus a nominal rate of 10 percent propane fumigation.

The air-cooled engine did not satisfactorily complete either test. High levels of deposits, scored cylinder walls and coked injectors were noted in all engines. These engines had mechanical difficulties associated with the EMA test cycle such that even those operated on diesel suffered mechanical breakdowns. The water-cooled engines passed the cycle test with no difficulties. Very low levels of deposits and no ring sticking were observed.

Propane fumigation did appear to reduce the deposits but only by a small amount. No measurable reduction in engine wear nor effect on engine performance at the conclusion of the test was observed.

INTRODUCTION

The use of neat vegetable oil as a replacement for diesel fuel has been the topic of numerous studies in recent years. While it now appears that pressure for alternate fuels has diminished in the United States there is still considerable interest worldwide. It is important that the excellent progress toward utilizing these alternative fuels not be abandoned solely because the energy shortages are no longer in the public limelight.

---

* The authors are Professor, Scientific Aide and former graduate assistant respectively. Department of Agricultural Engineering, University of Idaho, Moscow, Idaho 83843.

This paper will present a brief summary of the results of 200-hour EMA test cycles with propane fumigation as a potential means for reducing engine deposits. Previous short term injector coking studies by Mora and Peterson (1985) indicated some potential benefit to be derived from fumigation at the 10 percent level. It was therefore decided to test the concept further in the longer term tests.

Fumigation, as used in this study, involves the injection of a mixture of liquid fuels through the conventional fuel injection system, and the induction of a gaseous fuel with the intake air. The majority of fuel energy is in the liquid form, with a small percent of the input energy coming from the inducted gas.

LITERATURE REVIEW*

The use of multiple fuels in a CI engine may be accomplished by several methods. Fuel blending mixes the fuels together prior to injection into the combustion chamber by means of the conventional fuel injection system. Fumigation, on the other hand, involves the induction of a portion of the fuel with the intake air while the main fuel charge is injected in the usual manner.

Most previous studies involving the induction of a gaseous fuel into a dual fuel engine were either for the purpose of obtaining additional power from the engine (Miller, 1968; Derry, 1954; McLaughlin et al., 1952), or for utilizing a large quantity of the gaseous fuel (Lalk and Blacksmith, 1982; Bro and Pedersen, 1977; Clark and Bunch, 1962; Mitchell and Whitehouse, 1955). It was usually found that more complete combustion could be obtained with no power increase, or power could be increased with no additional smoke or incomplete combustion.

Carbon monoxide (CO), oxides of nitrogen (NOx), and black smoke in the exhaust gas of a CI engine are indicative of incomplete combustion. Karim et al. (1980) conducted studies involving the fumigation of methane, propane, hydrogen, and ethylene. It was found that the fumigation of these gases resulted in reduced concentrations of CO, NOx, and black smoke at high loads. It was further concluded that propane has "little or no tendency of pyrolisis to liberate soot." Lyn and Moore (1951), and Lyn (1953) found that propane fumigation decreased ignition delay, smoothed engine knock, and allowed fuels of various, non-optimum cetane rating to be used.

---

*The reference list was deleted because of space. Contact the authors for the list of publications cited.

McLaughlin et al. (1952) concluded that propane fumigation of a CI engine reduced smoke and engine deposits through cleaner combustion. Lalk et al. (1982), and Derry (1954) reported similar findings of reduced smoke with fumigation.

Alcohol has been widely experimented with both as a means of dual fueling the CI engine, and in conjunction with the use of vegetable oils. Braun et al. (1982) used various blends of diesel fuel, soybean oil, and ethanol to obtain fuels with viscosities approaching that of diesel fuel. Fifty hours of testing resulted in no excess carbon buildup. However, some difficulties were encountered in keeping the fuel blend from separating.

Fujisawa and Yokota (1981) developed an injection system that provided mixing of the fuels in the high pressure line between the injection pump and the injector. The high pressure of the line helped maintain the emulsion. In this set up, mixtures of diesel fuel and vegetable oil can be handled by conventional means, with the alcohol being mixed in after the fuel pump.

Shropshire et al. (1983) used various configurations and types of nozzles to fumigate ethanol into a CI engine. Problems encountered resulted partly from the inability of the intake manifold to uniformly distribute the mixture of air, fuel vapor,and liquid fuel.

Being that fumigation and the problems of using vegetable oil fuels are well documented, it seems a logical step to look at these two fields together. Hence, the topic of study covered within appropriately makes use of these concepts as a means of furthering the progress being made in the field of alternative fuels testing.

OBJECTIVE

The objective of this study was to determine the effect of propane fumigation on injector coking, combustion chamber depoits and ring sticking in 200 hour EMA test cycle engine tests.

MATERIALS AND METHODS

The equipment and procedures in the course of this investigation have been described in a paper by Peterson and Wagner (1982) and will not be described in detail here.

Test Equipment

Six , Wisconsin WD2-1000, 1.0 l, direct injection, air-cooled, twin cylinder engines rated at 15.7 kw at 3000 rpm were used as test engines in the first two tests and will be referred to hereafter as the air-cooled engines.

In the third test, three-cylinder, Kubota D1102-BC engines with a displacement of 1115 cc and rated 14.3 kw at 2800 rpm were used. They have spherical combustion chambers. These engines are referred to as the water-cooled engines.

The gaseous fuel induction system consisted of manual and electrical shut-off valves, and a needle valve for flow regulation.

The auxiliary (gaseous) fuel consumption was measured with a digital scales accurate to 0.02 kg. Gaseous Fuel consumption data was manually recorded.

Fuel Specifications and Description

The diesel fuel used was commercial diesel fuel with a gross heat of combustion of 45,224 kJ/kg. The gaseous auxiliary fuel was a commercially available mixture of propane and butane commonly called propane. It is a member of the paraffin family of fuels, and has a lower heating value of approximately 45,973 kJ/kg.

All liquid fuel blends used consisted of equal portions of the winter rape vegetable oil and #2 diesel fuel. The Winter Rape seed oil was obtained from Dwarf Essex seed. When mixed 50/50 with diesel fuel, the blend had a gross heat of combustion of 42,698 kJ/kg, 5.6% less than the diesel fuel used. The oil was expressed using a CeCoCo expeller operated by the University of Idaho Agricultural Engineering Department. The press processes approximately 55 kg/hr with a mechanical extraction efficiency of about 80%. The oil was stored to allow the particulate matter to settle out and was then subjected to a filtering system with a final mesh size of 4 microns (Thompson, 1983).

The fuels involving fumigation used propane to replace part of the liquid fuel. Percent replacement calculations were based on consumption at 2800 RPM and maximum power.. For example, if a baseline test indicated fuel consumption at 2800 RPM to be 9.0 kg/hr, the auxiliary fuel rate would be set at 9 kg/hr at 2800 RPM. Differences from nominal rates were a result of diminished liquid fuel consumption at lower engine speeds, without a like decrease in the gaseous fuel delivery.

Procedures

Three separate tests will be described, two with the air-cooled engines and one with the water-cooled engines. In each test one engine was operated on a fifty percent blend of winter rape oil and diesel plus 10 percent propane fumigation and two engines were operated on the winter rape-diesel blend without propane.

The EMA test cycle used has been widely reported; it consists of one hour at maximum power, one hour at 85% rated rpm at maximum torque, 30 minutes at 25% power and 30 minutes at idle. The cycle is repeated 5 times and then the engine shut down for a minimum of 8 hours before it is repeated.

RESULTS AND DISCUSSION

In the first test, at 21.8 hours a ring seized on the #1 cylinder of the fumigated engine. It was assumed to be a mechanical problem and not fuel related so the engine was replaced and the test resumed. After an additional 33.8 hours a fire in the test facility casued extensive damage to the building, test stands and engines ending the test.

The second test was started after moving to a new building, reconstructing the test facility and completely reworking the test stands. Newly rebuilt engines were placed on the stands and the tests started. These engines had a tendency to pull the head bolts, a problem which had also been experienced in earlier tests. After 69.9 hours the fumigated engine would no longer start. The non-fumigated engines experienced similar difficulties at 107 hours. Cylinder number 2 always froze first; this cylinder is furtherest from the cooling fan. All 3 engines had frozen rings in the hot cylinder. Only the fumigated engine had frozen rings in the cylinder closest to the cooling fan. The fumigated engine had serious cylinder scoring on the hot cylinder and lesser amounts on the cooler cylinder. That engine also had very hard coking compared to softer deposits on the heads of the other two engines. Problems associated with failure were worse on the hot cylinder of all engines.

Test number 3 was conducted with the water-cooled engines; these engines have spherical pre-combustion chambers. All of these engines successfully completed the test.Disassembly of the engines revealed very low levels of deposits. No ring sticking was apparent and very little polymerization was noticed below the top piston land. Differences in wear were negligible and all engines were within specifications on major wear components. The propane fumigated engine did have slightly lower amounts of deposits in the combustion chamber, on the pistons and on the rings than did the non-fumigated engines although these differences were slight and had not noticeably affected engine performance at the end of the 200 hour cycle. At the conclusion of the test one engines had gained 1.67 % and the other two lost 6.23% and 1.75 % power compared to their starting values all within acceptable limits for the expected accuracy of measurement. The engines used approx. 760 l of vegetable oil blend and the fumigated engine an additional 56 kg of propane. The propane engine was loaded slightly heavier during the test which would account for the increased fuel consumption.

One factor which may account for part of the improvement in ability to operate on vegetable oil in addition to the pre-combustion chamber the water cooled engines have a much higher lubricating oil capacity. For example , the Kubotas have almost a 6:1 ratio between engine displacement and crankcase capacity, whereas the air-cooled engines have a 2:1 ratio between crankcase capacity and displacement. This may be an important factor in the life of an engine when used with vegetable oil fuels. Earlier studies have shown that the lubricating oil can have a very sudden and disasterous increase in oil viscosity that often is the cause of a sudden failure of the engine. As a result it has been recommended that oil condition be monitored at regular intervals at least daily. Reduced oil change intervals may be required depending on the crankcase capacity of a particular engine.

CONCLUSIONS

The objective of this study was to determine the relative effectiveness of propane fumigation in reducing combustion chamber deposits. The following conclusions are based on the data collected and presented in this paper.

1. There was a dramatic difference between engine types in there ability to satisfactorily utilize the vegetable oil blend as a fuel.
2. Propane fumigation reduced engine deposits by a small amount in the water-cooled engine; but, did not significantly extend engine life compared to the non-fumigated fuels.
3. The cylinders furtherest from the cooling fan on the air-cooled engines suffered more serious ring sticking and deposits than did the cylinders adjacent to the cooling fan.
4. The water-cooled, spherical combustion chamber engine suffered no apparent ill effects from using any of the fuels. There was only minor benefits due to fumigation.
5. The water-cooled engine had a large lubricating oil capacity compared to the air-cooled engine which may have improved performance on vegetable oil. Required oil change intervals may be a function of oil capacity;, daily monitoring (more frequent under high use or severe engine operating conditions) of the lubricating oil is recommended.