Vegetable Oil Engine

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INTRODUCTION

Fossil energy raw materials are limited and have a negative CO_2 cycle balance. Its use will be reduced through renewable energy. The utilization of vegetable oil as a renewable raw material will improve the CO_2 cycle balance.

There are definitely advantages for the environment by using vegetable oil versus fossil energy carriers, for example diesel fuel:

- long-term securing of energy through renewable raw material and the saving of fossil energy carrier.
- Almost closed CO_2 cycle, therefore less pollution.
- Almost complete and fast biological decomposition.
- Negligible emission of sulphur compositions.
- High safety regarding storage and transportation due to the high flame point.

Vegetable oils will not completely replace the needs of our motorised society for gasoline, diesel and mineral oils, but will prolong the energy reserve and relieve the environment.

Therefore there are many reasons to use vegetable oil as fuel instead of fossil fuel. Let's have a look on the material cycle of renewable raw materials as almost closed carbon dioxide (CO_2) cycle. The CO_2 produced in the combustion machinery by using vegetable oil as fuel will be converted to oxygen after photosynthesis.

The use of vegetable oil instead of fossil fuel is possible, on the one hand with biodiesel and on the other hand with original unprocessed vegetable oil.

- biodiesel is fatty acid methyl ester gained through a chemical process from vegetable oil and which could be used without problem as fuel for diesel engines.
- Unprocessed vegetable oil fuel can be easily pressed from oilseeds and oil pits; however the combustion engine need to be adapted.

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Elaeis Special Issue, November 1995, pp. 50-51

DMS Dieselmotoren-und Geratebau GmbH (DMS) in Schonebeck, Germany have adapted the diesel engine to the vegetable oil fuel, preliminary to achieve the maximum efficiency of the energy conversion.

Comparing the specific characteristics of the rapeseed oil with the diesel fuel we noticed that the vegetable oil has:

- higher viscosity,
- higher density,
- lower heat value,
- 11 % more oxygen content than the diesel fuel and practically neither sulphur or aromatic hydrocarbon.

There is a considerable difference regarding the boiling characteristics between the rapeseed oil and the diesel fuel. High temperature is required for the rapeseed oil.

The build-up of combustion deposits in the injection nozzles, on the piston walls, piston rings and exhaust valves can be avoided through an adaptable combustion procedure. The fuel system need to be adjusted in relation to the filtration of the vegetable oil for its high viscosity. Another adjustment needed was the cold starting system.

THE VEGETABLE OIL ENGINES MODEL

In 1991 DMS started to develop a family of 3, 4 and 6 cylinders vegetable oil engines. Besides vegetable oil as a renewable, raw material, animal fat, biodiesel and diesel are suitable for these engines. We called these engines MULTI-FUEL engines (MF).

It was important that at the layout of the combustion procedure of the raw vegetable oil the consideration that the vegetable oil does not evaporate. When direct injected on the combustion chamber walls should be taken into account. The conventional fuel injection system with a multi-hole nozzle is not suitable to inject the vegetable oil. Therefore the heat density of the combustion chamber has been raised to improve the combustion of the vegetable oil through new design and different materials, which is close to the results of adiabatic engines. The special high value of the heat density produces the required high temperature of the charged air, which is essential for the combustion of the vegetable oil.

Two single-hole nozzles are placed on the side of the combustion chamber to inject the vegetable oil to the centre (not at its wall). The most important characteristics of the adjusted combustion procedure are:

- Direct injection of the fuel in the combustion chamber of the piston through 2 oppositely placed single-hole nozzle
- Direct injection through a conventional in-line injection pump with injection pipe and a T-connection to the 2 nozzles
- Air/fuel mixture occurs in the combustion chamber with the insulated cold air skirting around the hot centre of the combustion area
- With bare contact of the injected fuel with the wall, the build-up of polycondensation, and deposits can be avoided
- Minimizing the damaging gap areas usage of material with same expansion coefficient and lower heat transfer in the cylinder piston area
- cylinder liner cooling only in the upper area of the piston rings.

DESIGN CHARACTERISTICS

For the new DMS vegetable oil engines the air-cooled diesel engines have been reinforced in the area of the cylinder seat. Four long bolts connect the individual cylinder head together with the cylinder liner of each cylinder unit. Three-cylinder element has a bore of 128 mm and a stroke of 145 mm. The divided piston is being cooled through 2 cooling nozzles located in the lower part of the crankcase. The engine is cooled by its own lube oil. The lube oil is being externally cooled. To lower its high viscosity the vegetable oil is being preheated by a heat exchanger located in the engine oil pan.

One unit of the vegetable oil engine model has been tested for 600 hours at an independent research institute in RoBlau, Germany. Raw, hot-pressed rapeseed oil with a phosphorus content of 152.8 mg/kg has been used for this particular test. According to the test results, the engine is suitable for operation with raw rapeseed oil. The phosphorus content in the vegetable oil did not show any damaging effect to the engine.

It is necessary to note that the heat value of rapeseed oil is lower than that of normal diesel fuel. Assuming the heat value of the rapeseed oil is 37.2 MJ/kg and that of the diesel fuel is 42.4 MJ/kg, the rapeseed oil has only 88 % energy to that of diesel fuel at the same unit mass. This means that the best specific consumption of 229 g of rapeseed oil per kWh represents an equivalent energy consumption of 201 g of diesel fuel per kWh. These values confirm the high efficiency of the energy conversion of the DMS vegetable oil engines. The endurance test has showed that the lube oil does not get so dirty as with conventional diesel fuel engine and the oil change interval could be increased to 600 hours. The emission test with a DMS vegetable oil engine, has shown that the measured values are below the limited values in Germany.

The 6-cylinder DMS vegetable oil engine for the automotive application has met the emission requirements of the European Union regulation 49, well known as EURO-Norm. Due to the technical level and experience achieved with the tested engines we are expecting that the emission, requirements of the EURO-NORM 11 can also be met.

Therefore these DMS multi-fuel engines are the first engines with direct injection, which, with the use of unprocessed vegetable oil fuel without the use of the diesel oil, have met the emission requirements. As long as the fuel is liquid and will be pumped in the fuel system, these Multi-Fuel engines do not need any diesel fuel to start. In the event the vegetable oil becomes solid fat, a start device is needed. This device will switch the fuel system at cold temperature from vegetable oil to diesel oil during the engine shut down and flushes the fuel lines for a predetermined period of time. At the cold start the engine will start with the diesel fuel until the vegetable oil has been sufficiently warmed up. At extreme cold temperature (below -15 °C), this device will be combined with a glow plug.

The engines have been successfully tested in tractors, harvesters, trucks and generator sets.

CONCLUSIONS

DMS has developed this engine family of 3-,4- and 6-cylinder multi-fuel engines only within a time period of 3 years. These engines have been released for production in the second half of 1994. The displacement of each cylinder is 1.87 dm^3 (litre) and the power output of these engines are 88-240 kW.

These new engines have a direct injection system and are specially suitable for the use of all raw vegetable oils, but could also be used with biodiesel, liquid fat and of course with normal diesel fuel. The DMS vegetable oil engines meet the emission requirements of Germany and the EURO 1. These new engines represent a start of a new generation of non-polluting engines, which do not need to depend on the limited resources of the fossil fuels.