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EFFECTS OF PROLONGED USE OF VEGETABLE OIL ON DIFFERENT ENGINE PARTS AND PERFORMANCE

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Abstract The awareness for the environment and concern over the limited crude oil reserves have led many researchers to explore and utilize renewable energy resources. Originated from plants, biofuel has the potential to become an alternative fuel for diesel engines. Biofuel, such as methyl ester has proven to be compatible with conventional diesel fuel and has already gained popularity in Western Europe. However, the costly process of converting vegetable oil into methyl ester has discouraged its use. Considering this, attempts were made to use a variety of crude vegetable oil, such as crude palm oil, sunflower oil, rice brain oil, soybean oil, as well as waste cooking oil in diesel engines. Nevertheless, the use of vegetable oil in its original form in diesel engines poses a few challenges, ranging from filter clogging, deposit build up in combustion chamber, injector choking, to deteriorating engine performance, especially after prolonged use. In this study, the engine was dismantled to inspect the various parts, after running with crude palm oil (CPO) for a cumulative period of 500 hours. Different parts of the engine were tested in a new identical engine, to quantify the wear and tear by individual parts. The study showed that valve sticking was the main cause of power deterioration, while other parts like the injector, fuel pump and cylinder contributed less.

Keywords: Vegetable oil, prolonged use, engine performance, wear

INTRODUCTION

In the year 2000, the world suddenly experienced a surge in petroleum price. For countries that rely on imported petroleum as the main source of energy, the surge increased the energy cost tremendously, and brought to light the issue of energy security. Looking at the current reserve over production ratio of 39.51 years for world petroleum [Nurul, 2000], there is a real need to intensify the use of alternative fuels.

Biofuel is one potential alternative fuel for engines. Originated from plants, biofuel is renewable and gives a zero net CO_2 green house gas contribution. In Brazil, ethanol derived from sugar cane has been used for many years in petrol engines [Rickeard and Thompson, 1993]. In Europe, rapeseed methyl ester (RSME) is gaining popularity in recent years [Schröder, 1999]. Meanwhile, in Malaysia, oil palm is a major plantation crop, with total production of palm oil estimated to reach 11.2 million tonnes in the year 2001. A biofuel derived from palm oil through the transesterification process, palm oil methyl ester (POME), has been studied and trial tests have been successfully conducted [Schäfer,1998].

However, the high capital and conversion costs are setbacks to the commercialisation of POME. There are also attempts to use raw vegetable oil directly in diesel engines [Bari and Roy, 1995; Nwafor and Rice, 1995] and in multifuel engines [Ahmad, 1995]. Many had reported the problems of difficulty of fuel flow, deposit build up in combustion chamber, injector choking and degraded engine performance after prolonged use [Rickeard and Thompson, 1993; Choo, *et al*., 1995].

The aim of this study is to determine the effects of prolonged use of CPO on engine parts and to examine the significance of the affected parts to the overall engine performance deterioration.

METHODOLOGY

The engine used was a Yanmar L60AE-DTM, a direct injection, air-cooled diesel engine with a capacity of 273 cc. The rated power of the engine was 4.0 kW at 3600 rev/min. The engine was coupled to an electric dynamometer to provide brake load. In addition to the diesel tank, a fuel tank with heater was provided for CPO. The fuel flow rate was measured with the help of a burette and a stopwatch. In-cylinder pressure measurements were taken with a piezo pressure transducer while a shaft encoder supplied the crank angle data. These analogue signals were converted to digital signals and fed to a computer for combustion analysis. The experimental set-up is shown in Fig. 1. The engine was started with only diesel. This was to prevent choking by CPO solidification in the cold parts

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of the fuel system, e.g. the injector nozzle. Switching to CPO was only carried out after the engine had completely warmed up. The fuel was switched back to diesel before shutting down the engine to flush out the at various loads and speeds. After a cumulative 500 remaining CPO in the fuel system. The engine was run operating hours with CPO, the engine was dismantled to examine the various parts. The parts were then interchanged individually into a new identical engine to evaluate the performance.

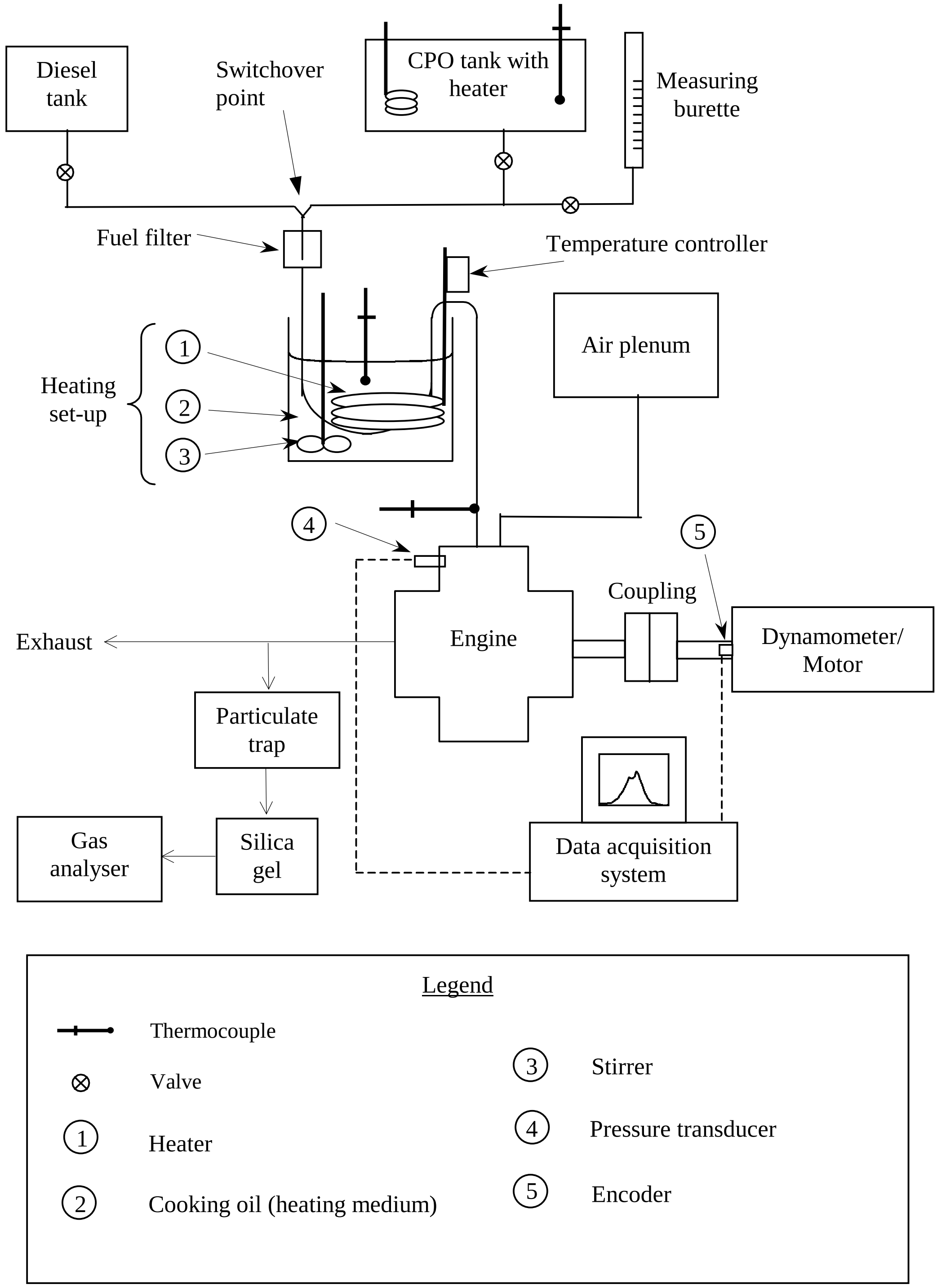

Fig. 1 Experimental set-up

RESULTS

Combustion Analysis

Figs 2 and 3 show the in-cylinder parameters of the engine at 70% of full load. In Fig 2, the peak pressure produced by CPO combustion was higher than that of diesel by about 7%, and this occurred about 4° earlier. The earlier combustion of CPO due to shorter ignition delay (Fig. 3) in a smaller combustion chamber volume compared with that of diesel resulted in a higher peak pressure for CPO. The chemical reaction of vegetable oil at high temperature could have contributed to shorter ignition delay of CPO as compared to diesel [Ryan and Bagby, 1993; Ziejewski *et al., 1996*].

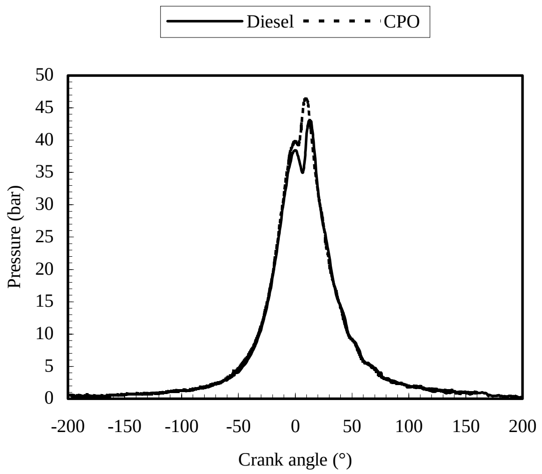

Fig. 2 Pressure – crank angle comparison

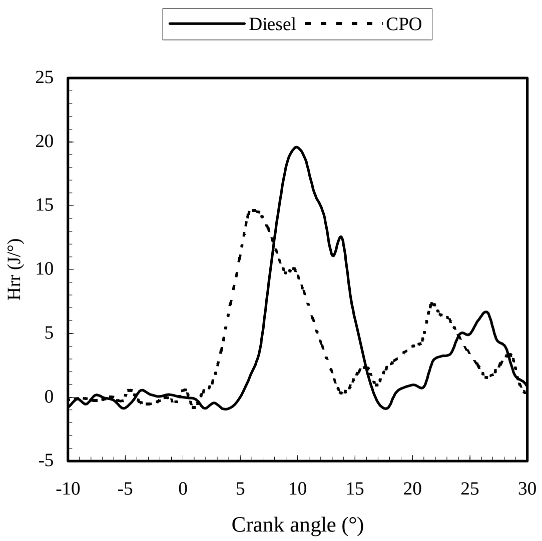

Fig. 3 Heat release rate – crank angle comparison

Fig 3 compares the heat release rates of diesel and CPO. As shown, CPO has a lower heat release rate compared with diesel, by about 26%. This indicates that CPO has a less intense premixed combustion phase.

Effects on Engine Parts

Visual inspection of the dismantled engine after 500 hours of cumulative operation discovered heavy carbon deposits in the combustion chamber, particularly around the fuel injector, around the valve seats and in the piston bowl. After cleaning, traces of wear were found at various parts at the upper land of the piston, while the cylinder liner was slightly scuffed. The piston rings were found to have larger end gaps, increased to 1.40 mm from the original 0.35 mm. Meanwhile, inspection into the disassembled injection pump found traces of wear at the plunger and the delivery valve. A spray test carried out on the fuel injector at room conditions discovered reduced quality of spray, with reduced mist and less even spray.

The various defects detected could possibly have caused degraded engine performance. Heavy carbon deposits can lead to problems like valve sticking, which can cause leaking during the compression stroke and loss of engine power. Serious wear of the piston, piston rings and cylinder liner can definitely cause power loss and reduced engine efficiency. Meanwhile, an affected fuel injection pump can lead to reduced injection pressure. A faulty injector can lead to poor quality injection, which results in reduced atomisation and mixing, which ultimately affects the overall fuel combustion process.

However, despite all the defects detected, the part that was the main cause of performance degradation of the test engine was not known. In order to determine the significance of the affected parts to overall engine performance, the parts interchange test was carried out.

Parts Interchange Test Engine

Fig 4 compares the performance of the old engine to the standard new engine. The old engine clearly had degraded performance, in terms of both efficiency and power.

Injection pump

Fig 5 shows the effect of the old injection pump. Although wear was detected visually from the previous observation of the physical condition of the pump, the performance of the new engine with the old fuel pump was only marginally lower. For a wide operating range, the bsfc was comparable with that of the standard new engine. This result shows that the wear at both the plunger and delivery valve are actually minor and both the components were still in working condition.

Injector

Fig 6 shows the effect of the old injector in new engine. Again, despite the previous observation that detected decreased spray quality, the engine performance was unexpectedly good, with comparable bsfc to the new standard engine. The comparable bsfc shows that the spray quality of the old injector did not have any adverse effect on the overall efficiency of combustion.

The nozzle was therefore found to be still in working condition.

Engine head

Fig 7 shows the performance of the old engine head fitted in the new engine. This test actually evaluates the condition of the valve seats. It is obvious that the power and efficiency losses were significant with the old head. The leak at the valve seats reduced the effectiveness of the compression and power strokes. The leak at the seats was probably caused by *valve sticking* — the inability of a valve to return to its position properly due to deposits on the stem, which resist the smooth movement in the valve guide.

Cylinder

Fig 8 evaluates the performance of the old cylinder. Except for the piston rings, which are actually a new set, all the other components, i.e. the piston, crankshaft, camshaft, etc, are originally from the old engine. In this test, a new engine head, injector and fuel pump was installed on the old engine. The result shows that the old engine achieved almost the same performance as a new one throughout the load range, only marginally worse at very high load. The cylinder liner is therefore confirmed to be in working condition, being able to achieve performance as good as that of the new engine, which otherwise will leak even with new rings. The other remark is that the wear at piston land has negligible effect on engine performance.

"Decarbonising", in the sense associated with petrol engines, is seldom required on a diesel engine [Abbey, 1968]. Apart from a superficial coating, carbon does not accumulate in the combustion chamber as it is automatically removed under normal working conditions. The engine should therefore run for a considerable period before it is necessary to remove the cylinder head to do cleaning. Since the design of individual makes and running conditions influence the rate of carbon formed, it is difficult to quote a definite period. Most manufacturers agree, however, that top overhaul should be carried out after 750-1000 running hours or after 24000-32000 km with a road vehicle engine. The emphasis of top overhaul is to ensure good compression in order to restore the engine power and efficiency.

In the case of running the engine with vegetable oil, the carbon deposition is greater, subsequently causing valve sticking and power loss after only 500 operating hours for this particular engine. Therefore, in order to restore the engine performance, the engine will require top overhaul earlier than when running with diesel, particularly to get rid of valve sticking. However, further research is required to examine the equivalent operating hours of vegetable oil to suggest an appropriate period for top overhaul. This is most essential to maintain the performance and efficiency of the engine.

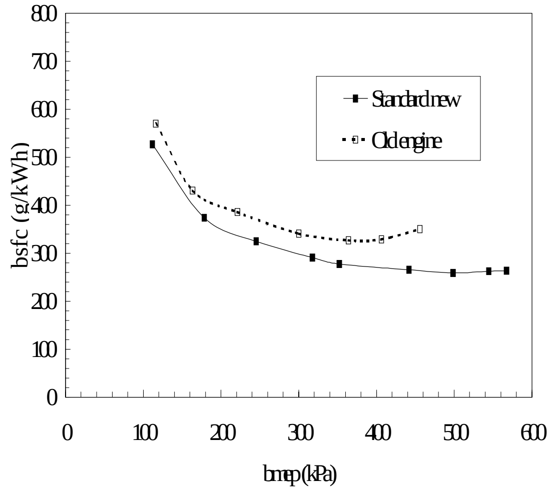

Fig. 4 Performance of old engine compared to standard new engine

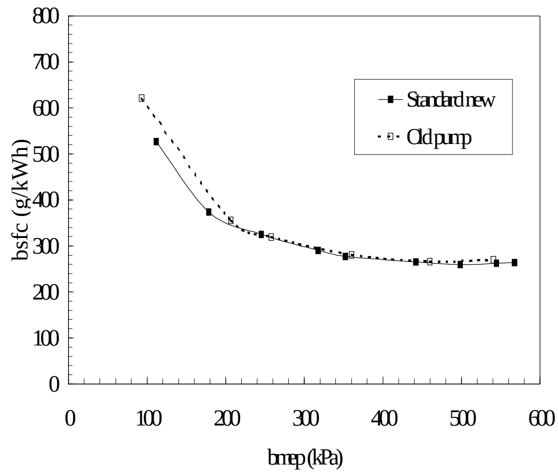

Fig. 5 Performance with old injection pump compared with standard new engine

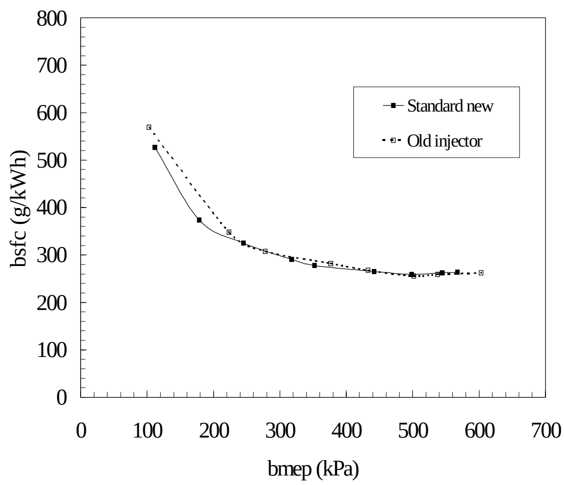

Fig. 6 Performance with old injector compared with standard new engine

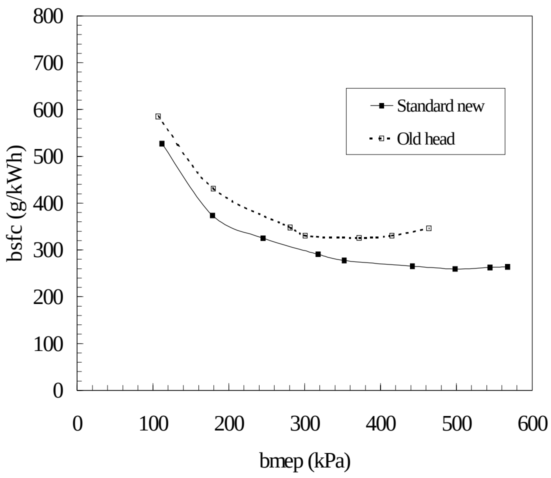

Fig. 7 Performance with old head compared with standard new engine

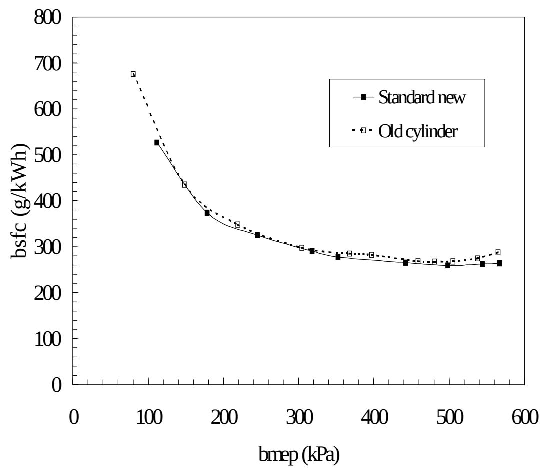

Fig. 8 Performance with old cylinder compared to standard new engine

CONCLUSIONS

1. While running vegetable oil such as CPO in diesel engine, the performance is comparable with those of diesel. However, prolonged used of CPO causes degradation of power and efficiency.
2. Visual inspection onto engine parts after 500 cumulative hours running with CPO found heavy carbon deposits in the combustion chamber, wear at the injection pump plunger and delivery valve, wear at the upper piston land, wear of the piston rings and less misty spray from the nozzle. Some scuffing of cylinder liner was also noticed. However, other parts look normal.
3. Parts interchanged into the new engine revealed that the engine performance degradation was caused mostly by the problem of "valve sticking". Due to the deposits at the valve stems, the inability of the valves to return properly to the seats had caused leaking during the compression and power strokes.
4. The wear detected was actually normal even when running with diesel but using CPO might have speeded up the wear rate. However, despite the visually detected defects of the parts mentioned, the performance tests found that the parts are actually in working condition and did not really cause engine degradation.
5. In order to maintain the power and efficiency of an engine when running with CPO, more frequent top overhaul is most essential. However, further work is needed to find the equivalent working hours of CPO relative to diesel, in order to recommend a suitable maintenance period.

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