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EXPERIMENTAL INVESTIGATIONS ON THE USE OF BITTER APPLE OIL IN A LOW HEAT REJECTION SUPERCHARGED CI ENGINE

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ABSTRACT: The modified vegetable oil fuels also have shown poor performance and heavy smoke in conventional diesel engines. The use of vegetable oils in low-heat rejection engines is the only solution to overcome the problems of these oils. The high in-cylinder temperature of these engines reduces the ignition delay and aids combustion. In testing insulated engines, experimental findings have been mixed and at best below the level of the benefits anticipated. Some studies show an improvement in fuel economy, most of which predicted worse fuel consumption using insulation. Therefore, little progress has been made in explaining the conflicting results and in determining the physical explanation behind the experimented data. Initially, modifications are carried out by employing the engine's PSZ-coated cylinder head and liner. Bitter apple vegetable oil fuel is used in all these LHR configurations to determine performance, emissions and combustion characteristics. Volumetric efficiency drops due to the high-temperature environment and the lubricating oil failure are the main problems associated with LHR engines. Therefore, experiments are conducted with supercharging to compensate for the volumetric efficiency drop.

INTRODUCTION:

The concept of a low heat rejection (LHR) engine or semi-adiabatic engine is nothing but employing insulation on the combustion chamber walls of the engine. There is a definite improvement in thermal performance with increased insulation and numerical studies support it almost unanimously, but experimental investigations have raised doubts on the validity of the prediction and some even proved it wrong. The volumetric efficiency is going to be affected in LHR engines. The higher operating temperatures of these engines cause a decrease in density of the air thereby reducing the mass of air charged in the cylinder volume during suction stroke. Because of this engine power output reduces. By employing supercharging, and turbocharging, the volumetric efficiency loss can be compensated and power output may be recovered. But this is only at the expense of increased exhaust back pressure. A single-cylinder, vertical, direct-injection diesel engine is used to carry out experiments and the details of the experimentation work are discussed. The volumetric efficiency due to high temperatures inside the engine cylinder is investigated. Detailed experiments are conducted with supercharging on the LHR engine and the details are given.

VEGETABLE OILS AS AN ALTERNATE TO DIESEL:

Several researchers [4, 5, 9, 24, 25] have carried out experimental investigations to improve the performance of engines fuelled by vegetable oils in conventional diesel engines. Goering et al [3] studied the characteristic properties of eleven vegetable oils to determine which oils would be best suited for use as an alternative fuel source. Of the eleven oils tested, corn, rapeseed, sesame, cottonseed, and soya bean oils had the most favorable fuel properties. Tahir et al [2] tested sunflower oil as a replacement for diesel fuel in agricultural tractors. Sunflower oil viscosity was 14% higher than diesel fuel at 37°C. Engine performance using the sunflower oil was similar to that of diesel fuel but with a slight decrease in fuel economy. Oxidation of the sunflower oil left heavy gum and wax deposits on test equipment, which could lead to engine failure. There is an improvement in engine performance when these modified vegetable oils are used instead of base vegetable oils [13, 14, 15, 22, 23, 24, 25]. This performance improvement can be attributed to good atomization of these modified fuels in the injector nozzle and a significant reduction in the viscosity. The performance and smoke emissions with vegetable oil esters in CI engines are similar to diesel fuel. The low volatility, slightly higher viscosity and high density of vegetable oil esters are the causes for slightly inferior performance [12, 17]. However, the performance can be further improved by using low volatile, high viscous vegetable oil and low volatile vegetable oil esters in Low Heat Rejection engines [20, 21]. The in-cylinder convective heat transfer of the ceramic-insulated LHRE did decrease in some cases [7, 16]. Yet, the fuel consumption rate of some LHREs rose. Many researchers [10, 11] attribute this to the deteriorated fuel combustion. To improve the performance of LHREs, two effective methods can be adopted. One is to prolong ignition delay and other is to increase fuel injection rate. Therefore, fuels which have low cetane number should be selected to prolong the ignition delay of LHREs. There are not many experimental investigations perhaps because of the difficulties encountered and the considerable amount of time, money and effort involved in setting up the apparatus. The investigation of Woschni et al [8] also indicates that a LHR engine performs poorly, even though the trend is not clear as in the case of brake specific fuel consumption. They attribute the poor performance to enhanced heat transfer in the cylinder which is caused by a drastically increased convective heat transfer coefficient which in turn is resulted from high cylinder surface temperatures. The maximum power a given engine can deliver is limited by the amount of fuel that can be burned efficiently inside the engine cylinder. This is limited by the amount of air that is introduced into the cylinder in each cycle. If the inducted air is compressed to a higher density than ambient, prior to entry in to the cylinder, the maximum power an engine of fixed dimensions can deliver will be increased. This is the primary purpose of super charging. Three basic methods are used to accomplish this. The first is mechanical super charging where a separate pump or blower or compressor, usually driven by power taken from the engine, provides the compressed air. Considering the above, the present work is planned carefully. Vijaya Kumar Reddy, K., [19] tested various vegetable oils such as simaroube oil, Cotton seed oil, Rapeseed oil, Karanj oil, Palm oil, Bitter apple oil, in a single cylinder diesel engine. It is reported that Bitter apple oil performs better compared to other vegetable oils. (Hence this oil is chosen for the present investigations exclusively in LHR engine). The concept of use of vegetable oils in LHR engines is yet to be investigated thoroughly to develop a feasible vegetable oil based engine.

Experimental Work:

The information regarding various components of the engine, modifications carried on them, the instrumentation used for experimentation isdiscussed in this work. The experimental set-up is designed to suit the requirements of the present investigations. Transducers like needle lift pick up, optical pick up and necessary electronic devices are also used during the course of experimental work. For studying the processes inside the cylinder data acquisition system is used [6]. This is used for analyzing the measured cylinder pressure data and to quantify the combustion parameters. The components of the system are the pressure pick up, charge amplifier, TDC position sensor, A/D card and a personal computer. Various parameters such as peak cylinder pressure, occurrence of peak pressure, start of combustion and ignition delay are analyzed with the system [25].

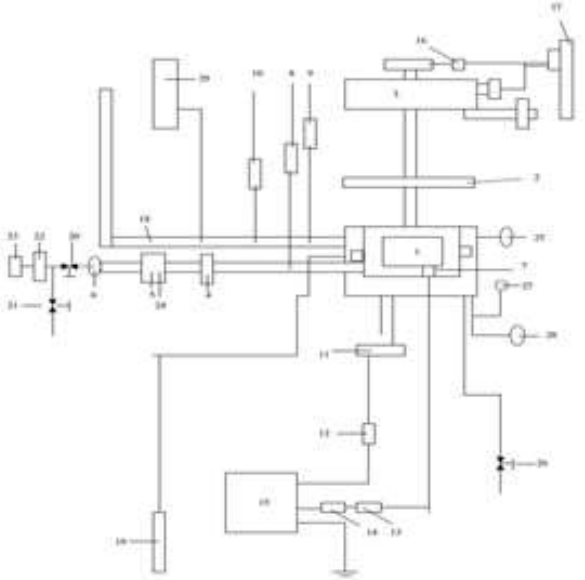

Fig. 1 Lay-out of Experimental Set-up

1. Engine 2. Flywheel 3. Electric dynamometer 4. air damper 5. Digital air flow meter 6. Air Filter 7. Pressure transducer 8. Manifold vacuum gauge 9. Exhaust temperature measuring unit 10. Exhaust gas analyzer 11. Cam shaft 12. TDC pick up 13. Charge amplifier 14. A to D converter 15. Personal Computer 16. RPM pickup 17. Dynamometer control unit 18.Exhaust pipe 19. Fuel flow measurement 20. Throttle valve 21. By-pass valve 22. Receiver tank 23. Super charger 24. Inlet pressure manometer 25.Lub oil temperature meter 26.Cooling water inlet 27. Cooling water temp. measuring unit 28. Cooling water flow meter 29. Turbocharger

Due to the high cylinder wall temperatures of LHR engines, the incoming charge suffers loss of density and hence volumetric efficiency. This volumetric efficiency drop reduces ignition delay but greatly increases combustion duration (less premixed combustion). Greater combustion duration means reduced heat release during the main stage of combustion and, a low rate of cylinder pressure rise, in complete combustion. To improve the thermal efficiency of the LHR test engine, the volumetric efficiency drop is to be compensated. Hence the present work is planned accordingly. To supercharge the engine, a blower which is driven by a motor is used.

RESULTS AND DISCUSSIONS:

The volumetric efficiency is drastically affected by high in-cylinder temperatures in LHR engines. The effect of the LHR test engine (i.e. cast iron piston with heat dam, the crown coated with PSZ and the heat dam surfaces coated with PSZ) on the volumetric efficiency is studied. The variation of volumetric efficiency drop of the LHR engine compared with the base engine is shown in fig.2. The volumetric efficiency drop varies from 1.8% at 0.20 kW to 11.8% at 3.7 kW rated load. The drop in volumetric efficiency increases with the engine output as is evident from the same figure.

With the help of a supercharger the inlet boost pressure can be increased and hence drop in volumetric efficiency can be compensated. The variation of volumetric efficiency with power output for LHR test engine at different inlet pressures is shown in fig.3. From the figure it is observed that the volumetric efficiency decreases with power output. However, the volumetric efficiency of the LHR test engine increases as the intake boost pressure increases. The volumetric efficiency for the LHR test engine is higher than the base engine at a pressure of more than 780mm of mercury.

The compressor work is deducted from the engine output for the calculation of brake thermal efficiency, since a blower driven by a separate motor is used for supercharging in the present experimentation. Fig.4. shows the variation of brake thermal efficiency with load at pressures from 765 mm of mercury to 810 mm of mercury. The increase in brake thermal efficiency is marginal at lower loads. The reason for this may be that even in naturally aspirated LHR engine sufficient air is available at lower loads. Therefore sending some more air does not improve the combustion efficiency. Thermal efficiency gains are maximum at full load with the increase of boost pressure.

The peak pressure depends on the amount of fuel taking part in the uncontrolled combustion phase which is governed by the delay period and spray envelope of the injected fuel. Fig.5. shows the effect of supercharging on the peak pressures at various loads. As the load on the engine increases, peak pressure also increases. At the rated load (3.7 KW), the peak pressure maximum is 95 bar at an inlet boost pressure of 790mm of mercury. Whereas it is only 64 bar for the naturally aspirated LHR engine. Peak pressures are lower for naturally aspirated Bitter apple-fuelled engines compared with the base engine.

Ignition delay variation with power output for supercharging conditions is shown in fig.6. It is observed from the figure that the ignition delay decreases with increase in inlet boost pressure in the low load range. Whereas at full load ignition delay increases with supercharging pressures because of the reduction in the combustion chamber temperature. Lowest ignition delay is for the LHR engine with a supercharging pressure of 780mm of mercury.

It is believed that a good amount of reduction in smoke emissions is possible in supercharged LHR engines. The reason may be that of better combustion in a hotter environment. A comparison of smoke number with power output for two supercharged conditions is shown in fig.7. The reduction in the smoke level is found to be 3.0 BOSCH units at inlet boost pressures of 765-810mm of mercury compared with the Bitter apple fuelled base engine at the rated load. It will be better to redesign the engine to withstand higher pressures for reduced smoke emissions. With the increase in boost pressure, the exhaust temperature increases by 20^0C to 60^0C compared to the naturally aspirated LHR engine as indicated in fig.8. Exhaust temperatures are higher with larger supercharging pressures.

CONCLUSIONS:

1. An increase in the intake boost pressure improves the brake thermal efficiency of the engine.
2. 6% boost pressure by supercharging is required to compensate for the volumetric efficiency drop in the naturally aspirated LHR engine.
3. Brake thermal efficiency improves by 3% with supercharging when compared with a naturally aspirated LHR engine.
4. Volumetric efficiency compensation with supercharging reduces smoke emission by 30 to 40% compared to naturally aspirated LHR engines.
5. Peak pressure for the supercharging condition is 95 bar.

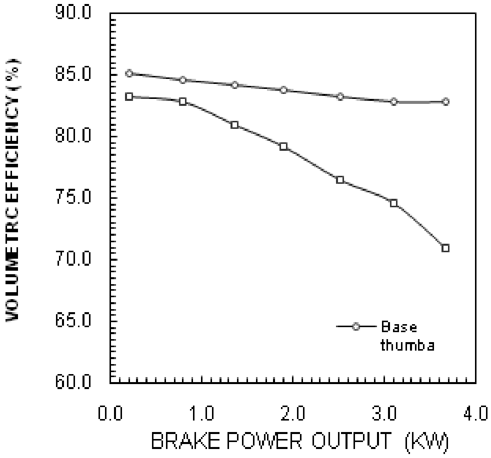

Fig.2 Comparison of Volumetric efficiency with power output for standard and LHR engines

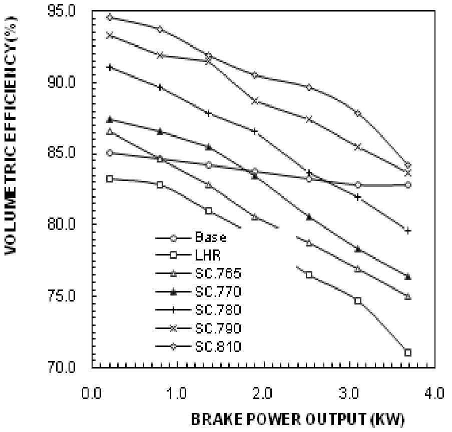

Fig.3 Comparison of Volumetric efficiency with power output for different supercharging pressureeressures

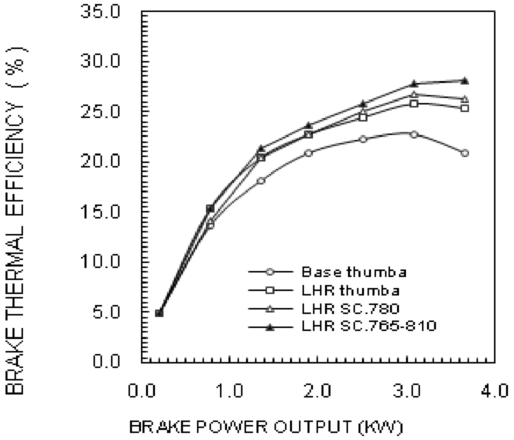

Fig.4 Comparison of Brake thermal efficiency with power output for vol. eff. Compensating intake boost pressure

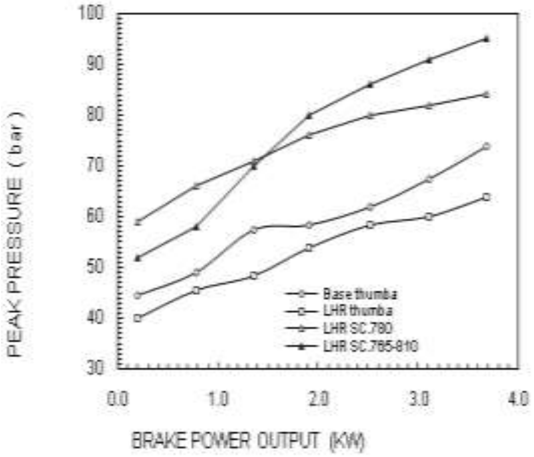

Fig.5 Comparison of Peak pressure with power output for vol. eff. Compensating intake boost pressure

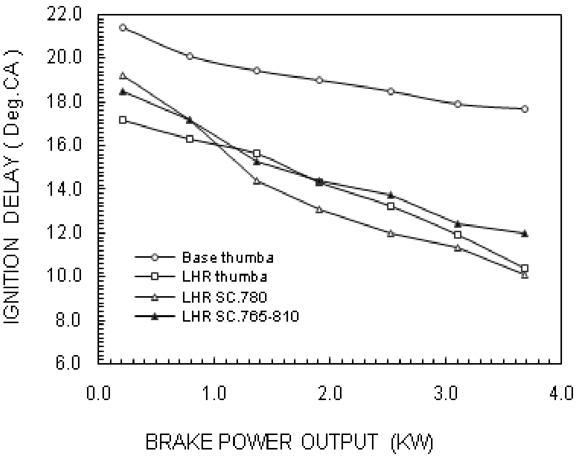

Fig.6 Comparison of Ignition delay with power output for two supercharging conditions

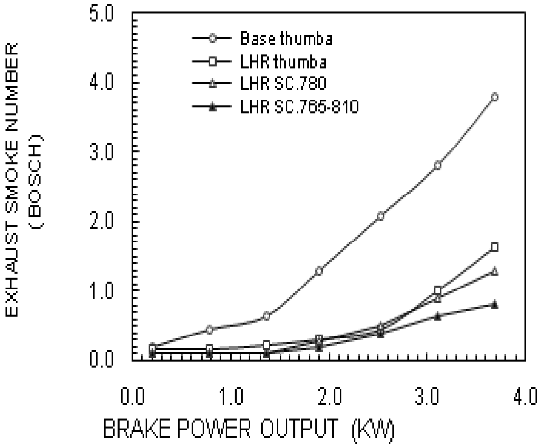

Fig.7 Comparison of Exhaust smoke number witi with power output for two supercharging conditions

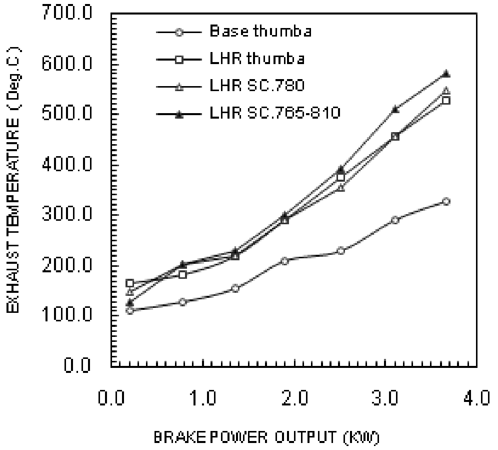

Fig.8. Comparison of Exhausttemperature with power output for two supercharging conditions

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