METHANOL SUPPLEMENTATION IN A NATURALLY ASPIRATED COMPRESSION-IGNITION ENGINE— PERFORMANCE, FUEL ECONOMY AND EXHAUST EMISSION CHARACTERISTICS

by

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CERTIFICATE

I, the undersigned, certify that the thesis entitled 'Methanol Supplementation in a Naturally Aspirated Compression-Ignition Engine-Performance, Fuel Economy and Exhaust Emission Characteristics' which is being submitted by Mr. B.P. Reddy for the award of the degree of Doctor of Philosophy in Faculty of Engineering of the Indian Institute of Technology, New Delhi is a record of the candidate's own bonafide research work carried out under my guidance. The matter embodied in this thesis has not been submitted in part or full, elsewhere for the award of any degree.

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ABSTRACT

Compression-ignition engines are being widely used for surface transport, power generation, operation of farm machinery and various other miscellaneous applications. In developing countries like India, the public transport or mass transport system is more economical than individually owned vehicle system. Mass transport system is not only cheaper but also more fuel efficient. Buses, trucks and other heavy vehicles which form the core of public transport system are all powered by compression-ignition engines unlike individual transport automobiles which are operated by the spark-ignition engines.

In the agricultural sector C.I. engines are widely employed in tractors and pump sets. In India there are around 2.7 million diesel operated pump sets and a very large number of diesel powered tractors. In addition to tractors and pump sets diesel engines are also being used to operate a wide variety of farm machinery.

Apart from their use in surface transport and agricultural sector, C.I. engines are also widely employed as prime movers in small power plants and in stand-by generating sets used in hospitals, cinema theatres and large commercial organisations. Thus, it can be seen that C.I. engines have varied and many applications and their number is growing

rapidly. This growing use of oil engines has increased the consumption of fuel oil.

Today there is a growing scarcity of fuel oil which is a nonrenewable 'stored' fuel. Many countries are dependent entirely on imports to meet their oil requirements while many more are going to be added to this list as their indigenous reserves get exhausted. In India the problem is very acute as two thirds of the country's oil requirements are being met through imports. The oil import bill has been steadily raising. It has increased from Rs. 2,000 crores in 1975-76 to around Rs. 6,000 crores in 1979-80. Today more than sixty per cent of the total foreign exchange earnings of the country are being spent in importing oil.

This increasing scarcity of fuel oil and the uncertainty of obtaining it from foreign sources, has prompted an intensive search for alternate fuels obtainable from sources other than petroleum and suitable for use in C.I. engines. Methanol is one such fuel. It can be produced from a variety of organic materials including lignite, wood, coal, oil shale, natural gas, as also from municipal and farm wastes. For a country like India having vast reserves of coal and lignite, coal based methanol can provide an indigenous substitute for oil.

Methanol has a high octane rating and a poor cetane value. It's high autoignition temperature and large ignition delay makes it unsuitable as a complete fuel for existing C.I. engines. Methanol is difficult to blend with diesel oil as it does not form stable blends and tends to separate out, particularly at low ambient temperatures. Hence, it can be best used in C.I. engines as an auxiliary fuel using bifuel approach. In the bifuel operation methanol fuel can be admitted in the induction manifold through a variable jet carburettor specifically incorporated for this system, while the required quantity of diesel oil is injected in the conventional manner.

In the work reported here methanol supplementation as indicated above has been employed. In order to assess the extent to which methanol can be supplemented and the effect of the supplementation on the engine performance and exhaust emission characteristics, experiments have been carried out using Ricardo variable compression Engine fitted with Comet MK.V Compression Swirl Combustion chamber.

In the experiments an attempt has been made to determine the limits of operation with bifuel approach. In order to avoid throttling losses, the throttle has been kept wide open while the quantity of methanol is regulated by the variable main jet. The load and speed regulation has been obtained, as in the case of conventional diesel engine by moving the rack of the fuel pump and thereby varying the quantity of diesel oil injected.

Tests have been conducted first with diesel oil alone as fuel covering the entire load and speed range. The influence of static injection timing on knocking and smoke-limited power output has been evaluated in the entire speed range of 1500 to 2200 rpm. Having established the smoke-limited power outputs for optimised injection timing (static) and knowing the corresponding diesel flow rates, the energy inputs have been evaluated. Later the flow rates of methanol have been adjusted through variable jet carburettor to have 10 per cent and 20 per cent energy contribution by methanol at maximum load condition. Load variation has been obtained by reducing the diesel consumption with 10 per cent and 20 per cent energy contribution by methanol settings mentioned above.

The smoke levels at every load has been compared with and without methanol. An attempt to contribute above 20 per cent energy by methanol has been found to result in quenching of combustion at full load with consequent loss of power. It has also been found that with methanol substitution the optimised static injection timing used with diesel alone requires to be changed because of severe engine knocking. Hence tests have been conducted with retarded static injection timing when methanol supplementation is made.

From the test results various graphs have been plotted to evaluate the relative engine performance with and without methanol supplementation. These graphs show the effect of methanol supplementation on various parameters such as specific-energy consumption, smoke level, smoke-limited power output and brake mean effective pressure.

In the current investigations it has been found that the performance with methanol supplementation is comparable with that obtained on diesel alone. Smoke-limited power output has increased in certain cases when methanol is supplementing the energy probably because of better air utilisation. The smoke level has been found to be slightly more throughout the load range with methanol except near full load. With methanol admission through the induction system, starting of the engine becomes difficult. Starting in all cases has been made with diesel alone and methanol is admitted through carburettor only after the engine has warmed up sufficiently.

The contribution of energy by methanol has been found to increase proportionately at part loads because of the method adopted for load control. This has made the engine to run up to no load with no difficulty even at lower speeds. Part load performance with methanol supplementation is slightly inferior to running on diesel alone.

A series of experiments have been conducted to assess the effect of methanol supplementation on exhaust emissions.

The products of combustion that are important as pollutants are unburned hydrocarbons, oxides of nitrogen, carbon monoxide and partial oxidation products such as aldehydes. The above pollutants have been accurately measured under different operating conditions of the engine. Carbon monoxide and unburned hydrocarbons have been measured with the help of HORIBA Instruments Incorporated MEXA-300A Infrared Exhaust Analyser. Exhaust NO and NO_x concentrations have been measured with Thermo Electron's model 10-A, Chemi-luminescent NO-NO_x gas analyser.

Chemical technique has been used to find the relative aldehyde concentrations. At no load and part loads with methanol supplementation the aldehyde concentrations have been found to be more. This may probably be due to greater energy contributed by methanol under these operating conditions. Methanol operated engines have high exhaust aldehyde emission rates. Near full load condition also the aldehyde concentrations have been found to be more with methanol supplementation.

Apart from these experimental investigations of engine performance and exhaust emission characteristics with and without methanol supplementation, certain computerised studies have also been carried out. Equilibrium composition of various combustion species with diesel and diesel-methanol combinations have been computed. The trends of NO variation in exhaust have been correlated using the 'frozen' expansion concept.

These experimental and analytical investigations have clearly established that methanol can be substituted for diesel to provide upto about 20 per cent energy contribution at full load and greater replacement at part loads.

The overall engine performance with methanol supplementation is comparable with that obtained with diesel alone. Methanol substitution can be introduced in existing C.I. engines with some modifications involving incorporation of a carburettor in the induction system. The engine needs starting on diesel and after warming up can be switched over to bifuel operation.

Methanol carburation can be profitably employed to save the scarce diesel oil. It also reduces exhaust NO concentrations and diesel smoke although aldehyde concentrations in the exhaust effluent increase with methanol carburation.

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