

EXHAUST EMISSIONS AND PERFORMANCE EVALUATION OF A SPARK IGNITION ENGINE BURNING METHANOL & METHANOL - GASOLINE MIXTURES

By

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A Thesis

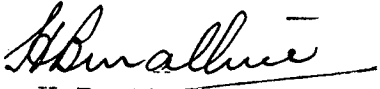
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CERTIFICATE

I, the undersigned, certify that the thesis entitled "Exhaust Emissions and Performance Evaluation of a Spark Ignition Engine Burning Methanol and Methanol-Gasoline Mixtures" which is being submitted by Mr. R.K. Bakshi, in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in the 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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(R.K. BAKSHI)

ABSTRACT

(i)

During the recent years the problem of fuel for internal combustion engines has become very important. The most commonly used S.I. engine fuel, gasoline, is prepared out of petroleum of which there are limited reserves. With the growing rate of consumption it is feared that they are not going to last long. Many countries today are solely dependent on imports to meet their fuel oil requirements. The situation is very grave in developing countries like India which imports two-thirds of her fuel oil requirements. Recent hike in oil prices has created great scarcities and the situation is likely to be aggravated further in future.

Even for countries having vast resources of petroleum, complete dependence on these fossil fuels is fraught with dangers as these fuels are irreplaceable and are likely to be exhausted sooner or later.

Apart from their irreplaceable nature, another very important aspect of petroleum fuels is the extent and nature of environmental pollution caused by their combustion in the engines. Gasoline powered vehicles discharge through their tail pipes significant amounts of pollutants like carbonmonoxide, hydrocarbons, lead compounds and oxides of nitrogen. The disastrous effects of these pollutants on human health, plant

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life and property are well known.

In view of these problems of fast dwindling reserves of petroleum fuels and the hazard of environmental pollution caused by their combustion, attempts must be made to develop the technology of clean burning synthetic fuels. These fuels in order to be useful should be such that they have attributes of perennial renewal, they perform well in the engine and their potential for environmental pollution is quite low.

In the work reported here, methanol and its blends with gasoline have been used as S.I. engine fuels. Methanol can be manufactured from a host of organic materials including lignite, wood, coal, oil shale, natural gas and indirectly from municipal and farm wastes. For countries having vast reserves of coal but little or no oil deposits of their own, Methanol from coal can provide an indigenous substitute to oil. Conversion of coal to methanol is simpler and cheaper as compared to its liquifaction to gasoline.

✓ Methanol burns cleaner than gasoline and engine emissions, in general, would be reduced and fewer emission control devices would be required to meet the present day stringent emission standards. ✓

✓ Methanol's most desirable feature as a motor fuel

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is its high octane rating. Even more impressive is its ability to boost gasoline's octane quality when used as a blend. Compression ratios can therefore be increased to take advantage of methanol's higher flame speed and good antiknock properties to achieve higher outputs and efficiencies. ✓

In order to assess the potential of methanol as a complete fuel and also of its blends with gasoline, experimental investigations have been carried out on a single cylinder Ricardo variable compression engine. This engine is ideally suited for comparative evaluation of different fuels.

To determine the optimum compression ratio of each blend at which it gives best performance, tests have been carried out with gasoline, ten percent, twenty percent, thirty percent, forty percent and sixty percent methanol-gasoline blends and also pure methanol. With each fuel and fuel blend, mixture strengths have been varied over a wide range and spark timings adjusted to give maximum power at each engine setting. Each blend has been tested at various compression ratios for assessing its ability of higher compression operation without knock and determination of optimum compression ratios.

From the test results, various graphs have been plotted to evaluate the relative engine performance with each fuel and fuel blend. The comparison of performance has been made on the basis of relative power output, specific fuel consumption and specific energy consumption - a measure of energy cost for producing a unit of automotive power.

✓ During the present investigations it has been found that a ten percent blend gives minimum specific fuel consumption and minimum specific energy consumption. The minimum specific fuel consumption for the thirty percent blend becomes more than that of gasoline and for the higher blends there is a rapid increase in specific fuel consumption.

The minimum specific energy consumption for all the blends as well as pure methanol has been found to be less than that of gasoline. Comparison of performance at optimum compression ratios has indicated a continuous improvement of power output with methanol-gasoline blends and pure methanol.

A series of experiments have also been performed with various fuels for the analysis of exhaust gases in order to test their potential for environmental pollution. The fuels tested are gasoline, ten percent, twenty percent and thirty percent methanol-gasoline blends and pure methanol. Blends containing more than thirty percent methanol have not been

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considered for exhaust analysis, as the earlier mentioned performance tests have shown that specific fuel consumption rises steeply with blends having methanol concentrations beyond thirty percent. These higher blends do not offer any advantage with respect to performance, without making major modifications in the present day spark ignition engines.

In these tests the concentrations of major exhaust pollutants like carbonmonoxide, unburned hydrocarbons and oxides of nitrogen have been measured accurately under various operating conditions of the engine. In addition, the concentration of aldehydes which are principally responsible for imparting odor to the exhaust affluent, has also been determined with various fuels and fuel blends.

Carbonmonoxide is highly toxic and is harmful even when present in small concentrations. Minimising of carbonmonoxide concentration is one of the major aims of S.I. engine exhaust emission controls. It has been found in the above mentioned tests that this can be achieved through the use of methanol-gasoline blends in place of gasoline. Carbon monoxide has been found to decrease continuously at all air fuel ratios with the use of blends containing higher and higher percentages of methanol.

The concentrations of unburned hydrocarbons, which along with oxides of nitrogen are responsible for the formation of photochemical smog, have been experimentally determined by means of a gas chromatograph fitted with a flame ionization detector. It has been found that adding methanol to gasoline reduces the concentration of unburned hydrocarbons over a wide range of air fuel ratios. For pure methanol the unburned hydrocarbon concentrations have been found to be very small as compared to gasoline.

In absence of costly and sophisticated instruments, the need of a suitable indigenous instrument for accurate measurement of oxides of nitrogen concentrations in the engine exhaust was felt. Such an equipment based on "wet chemical technique" has been specially designed and fabricated for this work.

This equipment has then been used in conjunction with spectrophotometer for determining oxides of nitrogen concentrations in the exhaust with gasoline, methanol and various methanol-gasoline blends. These experiments have shown that the concentration of oxides of nitrogen in the exhaust effluent decreases continuously as blends containing higher and higher methanol concentration are used. Pure

methanol has been found to give much lower concentrations of oxides of nitrogen as compared to those obtained with gasoline and the three methanol-gasoline blends under investigation.

Extensive tests were carried out to evolve a suitable technique for accurate measurement of aldehyde concentrations in the engine exhaust. This chemical technique was then used to experimentally evaluate relative aldehyde concentrations in the engine exhaust with gasoline, methanol and the three methanol-gasoline blends under investigation. These experiments have shown that addition of methanol to gasoline increases the concentration of aldehydes in the exhaust effluent. Pure methanol has been found to give larger concentrations of aldehydes as compared to gasoline and the three methanol-gasoline blends tried.

Apart from experimentally evaluating the engine performance and exhaust emissions with methanol and various methanol-gasoline blends, as outlined above, certain analytical studies have also been carried out using suitable computer programmes specially developed for this purpose. Combustion calculations for determining equilibrium compositions, for various fuels and fuel blends considered here, have been made

with the help of these programmes. Concentrations of certain pollutants like carbonmonoxide and nitric oxide have also been predicted for various fuels and fuel blends.

The above studies have clearly established the utility of methanol-gasoline blends for use in present day S.I. engines. They can be profitably utilized in modern high compression S.I. engines to stretch the current fuel supplies and utilize the non-polluting potential of these blends. Use of blends containing modest amount of methanol can improve the economy and performance of S.I. engines while decreasing engine exhaust emissions. Their use can be an immediate short term measure to meet the present day fuel scarcity.

Future S.I. engines can be designed to accomodate pure methanol which can be produced from a variety of sources including coal. It's superior lean combustion characteristics and high compression operation without knock can be profitably employed to achieve higher efficiencies from such engines. It's use would result in much lower pollutant emission levels and offers a possibility of eliminating the need for exhaust gas treatment.

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