COAL BASED BENZOLE AS GASOLINE EXTENDER AND SPARK-IGNITION ENGINE FUEL-PERFORMANCE, FUEL ECONOMY AND EXHAUST EMISSION CHARACTERISTICS

By

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CERTIFICATE

I, the undersigned, certify that the thesis entitled ''Coal Based Benzole as Gasoline Extender and Spark-Ignition Engine Fuel-Performance, Fuel Economy and Exhaust Emission Characteristics'' which is being submitted by Mr. M.R. Madan 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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(M.R. MADAN)

ABSTRACT

The growth in economic and industrial activities is dependent upon transport both public as well personal. Inspite of a very efficient public transit system there is always a great desire and demand for personal vehicle. Japan has one of the best and most advanced mass-transit system in the world and yet the streets and high ways are jammed with motor vehicles. In 1973, the figure of 'persons per vehicle' (car) for India was 738 against a world's average of 15. This shows that the demand for automobiles and other light vehicles will grow rapidly in this country.

Although 'alternative engines' have been in use since the introduction of motor vehicle, there are a few exception to the spark-ignition (S.I.) engines that power passenger cars, scooters and other light vehicles. There is no other power-plant in sight for light vehicles which can compete with it in cost, flexibility, size and owner satisfaction. It would appear probable that for the next a few decades at least the S.I. engine will have no serious challenger in the field of light vehicles. This is a limited role for S.I. engine but none the less a vast field.

The S.I. engine uses gasoline as a fuel which was

both plentiful and reasonably inexpensive in the world market upto the end of 1973. This nation's transport planning was also dominated by abundant supply of cheap petroleum fuels from abroad. The present consumption of crude oil in India is about 22 million tonne. About sixty five per cent of the total consumption is imported from abroad. The sudden spurt in the price of crude oil in the international market has put an unbearable strain on the economy of India, and other developing countries. That apart, world's resources of oil are rapidly depleting, making the adequacy of gasoline supplies in future a matter of serious concern greatly increasing our vulnerability to insecure imports.

As part of the current effort to reduce petroluem imports, alternative or supplementry automotive fuels, derived from domestic feed stock, are under active investigation. It is a complex problem which has not tailor made solution. The long term strategy may be to develop synthetic fuels from unconventional energy sources, but the technology for using solar and other unconventional energies on a large scale is not yet available. Warnings of impending fuel oil shortages are being heard across the nation today, therefore some short term strategy will have to be evolved to supplement the waneing petroleum based fuels. In the near future the choice will be restricted to fuels that can be handled in the existing

handling and storage equipment and require minor changes in the design of carburetion system of the S.I. Engines. The primary goal of future energy policies will have to be to utilize the nation's sizeable indigenous resources. India is fortunate to have vast reserves of coal which can be exploited for this purpose.

Recently another dimensions has been added to the suitability of fuels, for vehicle engines and that is the question of its environmental impact. Gasoline powered vehicles constitute the principal and preponderant contributors to atmospheric pollution in big cities. Pollution is a direct hazard of plants, animals and man, and causes the structural and functional changes of the biosphere posing a threat to the maintenance of an environment suitable for life. Any substitute or supplementry fuel should have acceptable emission levels with or without the existing systems of control. Thus there is an urgent and pressing need to develop and utilise for S.I. engines liquid fuels that are obtainable from indigeneous resources like coal and that are relatively more 'clean' burning in nature.

Benzole is one such fuel which is obtained as a by-product from coal carbonized for gasification or preparation of metallurgical coke. Small quantities of benzole are recoverable from the light oil of coal tar but almost all

benzole recovered commercially is from oil obtained by scrubbing coke oven gases. The commercial benzole is a mixture of three aromatic hydrocarbons, benzene, toluene and xylene in the proportion of approximately seventy five, fifteen and ten per cent respectively.

Benzole's most desirable feature as a motor fuel is its high octane rating. Benzole is not only excellent motor fuel, when used by itself, chiefly on account of its anti knock property, but is able to a confer this property on other fuels with which it is mixed. The most economical way to maintain gasoline anti-knock quality, as the use of lead alkyl anti-knock is reduced, is to increase the percentage of aromatic hydrocarbons like benzole. The removal of lead from gasoline would assist in reducing the objectionable pollutants from automobile. Lead additives are toxic to catalytic materials and reduce catalytic activity which results in increasing emission level with milage accummulation. Compression ratio can also be increased to take advantage of benzole's good anti-knock properties to achieve higher out-put and efficiency.

More recently alcohols, especially methanol, have attracted attention because of its potential to relieve fuel shortage in the country. Alcohol requires a livening agent, and while alcohol and gasoline will not mix freely, alcohal and benzole are miscible without much of the problem of phase

separation. This is another useful property which can be exploited for its use as motor fuel.

In order to assess the potential of benzole and its blends with gasoline as a S.I. engines fuel, experimental investigations have been carried out on a single cylinder Ricardo variable compression engine as well as on multi-cylinder BMC engine. Ricardo variable compression engine is ideally suitable for comparative evaluation of different fuels, while BMC engine is representative of automotive engines used on the road.

For determination of optimum compression ratio of each blend at which it gives best performance, tests have been conducted with gasoline, ten per cent, twenty per cent thirty per cent, forty per cent, fifty per cent benzole-gasoline blends and also benzole neat. With each fuel and fuel blend, mixture strength have been varied over a wide range and spark timings adjusted to give maximum power at each engine settings. 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 of each fuel and its 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 investigation it has been found that there is an allround increase in engine power output with the increase of benzole percentage in the blend. This gain in power is maximum with the thirty per cent blend and starts decreasing thereafter although the power output continues to be greater than that obtained with gasoline. Thus at a compression ratio of 7 commonly used in Indian vehicular engines the 30 per cent blend shows an improvement of about 6 per cent in maximum power output over that obtained with gasoline while benzole neat gives about 4.5 per cent more peak power. This shows that for the present day S.I. engine employing compression ratio around 7, thirty per cent benzole gasoline blend is the most suitable blend from the point of power output alone.

Since benzole and its blends have a higher octane rating than gasoline higher compression ratios can be employed without knock. To investigate this aspect tests have been conducted at different compression ratios with various benzole gasoline blends and benzole neat with a view to find the optimum compression ratio for each blend and to compare the engine performance with each blend when operated at its opti-

mum compression ratio. Whereas for commercial gasoline the optimum compression ratio has been found to be around 7.5, that for the thirty per cent blends it is around 8.5 while that for benzole neat it is even higher than 11. The thirty per cent blend gives about eight per cent more power than that obtained with gasoline when the engine is operated at their respective optimum compression ratios.

The investigations with regard to fuel consumption show that ten per cent blend gives the best fuel economy on mass as well as on an equivalent energy basis. On volume basis all blends and benzole neat give better economy in specific fuel consumption. At a compression ratio of 7.5 the ten per cent blend shows a maximum saving in specific energy consumption of about 8 per cent as compared to that obtained with gasoline. Comparison of fuel economy obtained with various blends when used at their optimum compression ratios has indicated a continuous improvement with all benzole-gasoline blends and benzole neat.

For the analysis of exhaust gases, a series of experiments have been carried-out with various fuels in order to test their potential for environmental pollution. The fuel tested are gasoline, ten per cent twenty per cent, thirty per cent, forty per cent, fifty per cent benzole-gasoline blends and benzole neat. The combustion products that are

most important as air pollutants are carbon monoxide, oxides of nitrogen, hydrocarbon and partial oxidation products such as aldehydes. The concentration of carbon-monoxide, unburned hydrocarbons and oxides of nitrogen have been measured accurately under various operating conditions of the engine. Carbon-monoxide, carbon dioxide and oxides of nitrogen have been measured with the help of Grubb Parsons Infra-Red Gas Analyser Model SB 2 (NDIR). The total hydrocarbons concentrations have been determined with AIMIL-NCL dual column gas chromatograph equiped with flame ionization detector.

Carbon monoxide is present in the exhaust gases from the combustion of any carbon containing fuel under fuel rich conditions. It is highly toxic and is harmful even when present in small concentrations. One of the major aim of the present day exhaust emission controls is to minimize the concentration of carbonmonoxide. In the present investigation the carbon-monoxide has been found to decrease continuously at all air fuel ratios with the use of blends containing higher and higher percentage of benzole including benzole neat. From theoretical and experimental analysis it has been found that the carbon monoxide concentration in exhaust more nearly reflect the frozen composition than the equilibrium expansion, particularly so in the lean range.

Unburned hydrocarbons along with oxides of nitrogen

in presence of ultra-violet radiation are mainly responsible for smog formation. It has been found that decreasing concentration of hydrocarbons invariably lead to smog reduction. The concentrations of hydrocarbons have been experimentally determined by means of a gas chromatograph fitted with flame ionization detector. It has been found that adding benzole to gasoline reduces the mole concentration of unburned hydrocarbons over a wide range of air fuel ratio. Benzole neat also gives less hydrocarbons. Generally the total hydrocarbon content of the exhaust from aromatic fuel is lower than from the paraffins, on molar basis.

The second contributor to the formation of smog is oxides of nitrogen. The concentrations of oxides of nitrogen (NO_x) have been measured with the help of NDIR and the results have been confirmed by the 'wet chemical technique' also. These experiments have shown that there is slight increase in the concentration of oxide of nitrogen with benzole and its blends. The increase for blends is marginal.

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 find relative aldehyde concentrations in the exhaust with gasoline, benzole and two blends. These experiments have shown that total aldehydes for benzole and its blend are lower than that for gasoline.

Apart from experimentally investigating the engine performance and exhaust emission with benzole and its blends with gasoline, as mentioned above, certain analytical studies have also been carried out using computer programmes specially developed for this purpose. Equilibrium compositions of important species in exhaust for various fuels and fuel blends considered here, have been calculated with the help of these programmes. Concentrations of certain pollutants like carbon-monoxide and nitric oxide have also been predicted for various fuels and fuel blends.

These studies and investigations have clearly established the utility of benzole-gasoline blends for use in present day S.I. engines. They can be profitably utilized in modern high compression spark-ignition engines to stretch the current supplies of gasoline. Their use can be an immediate short term measure to meet the present day fuel-oil scarcity. Use of blends containing modest amount of benzole can improve the economy and performance of S.I. Engines. The level of the major objectionable exhaust pollutants are reduced and can be further controlled with the existing methods of controls.

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