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APPLICATION OF ALTERNATIVE FUELS FOR INTERNAL COMBUSTION ENGINES, IIP, DEHRA DUN

DP/IND/82/001/11-03

INDIA

Technical report: Development of 2-stroke methanol engines*

Prepared for the Government of India by
the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Mr S. Radzimirski

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ABSTRACT

The title of the post was Expert in Combustion Studies in SI Engines" in the project IND/82/001 "Application of Alternative Fuels for Internal Combustion Engines". The duration of the present mission was 5 weeks beginning from 26 May 1987, assisted organization - Indian Institute of Petroleum, Dehra Dun, India. The mission was a continuation of writer's three previous missions held under the port 11-03 in 1985-1987. During the present mission a prototype of the control system for the engine with dual intake system was designed, fabricated and tested. On the basis of this experience its final improved version for the Vijay scooter was designed and is being fabricated at IIP. Tests of the methanol Vijay engine with selective exhaust gas recirculation were conducted and advantages of the system confirmed. The problem of abnormal combustion in two-stroke methanol engines was fully explained. The activity of the poject work in the area of methanol two stroke engines was summed up. The objectives of the project in the area are considered to be fully met. Recommendations concerning further possible studies which might be taken by IIP were given.

I. INTRODUCTION

The title of the post was "Expert in Combustion Studies in SI Engines" (Job Description DP/IND/82/001/11-03B/31.9B revised 27.09.1985) in the frame-work of the project IND/82-/001 "Application of Alternative Fuels for Internal Combustion Engines", duration of the mission - 5 weeks beginning from 26th May 1987, duty station-Dehra Dun, India, assisted

organization - Indian Institute of Petroleum.

The present mission was a continuation of three previous missions held by the winter under the post 11-03:

- First mission: from 8 January to 7 July 1985,
- Second mission: from 3 December 1985 to 2 March 1986,
- Third mission: from 3 November 1986 to 3 February 1987.

The duties of the expert under post 11-03 outlined in the above mentioned "Job Description" were as follows:

"The expert will be required to assist the Indian Institute of Petroleum in the following specific jobs:

i) Planning of the research activities related to experiment and analytical studies on two-stroke SI engines. This would include design and development of suitable systems for fuel introduction, modification of other engine systems and guidance with regard to combustion and emission studies on two-stroke engines from the point of view of alcohol fuel utilization. Also to assist in development of techniques/methods to evaluate carburation requirements, delivery ratio, trapping efficiency etc.

ii) Training IIP engineers on the above subject through lectures and group discussions.

The expert will also be expected to prepare a final report, setting out findings of the mission and recommendations to the government on further action which might be taken."

The main objective of the present mission was to continue works started earlier on the development of suitable technologies for the application of methanol in two-stroke SI engines for two-and-three wheelers, to fill gaps in experimental and analytical data with regard to particular processes, to bring conducted works to a conclusive end and to sum up the findings of the project activity in the field of methanol two stroke engines.

The following works were envisaged during the present mission (see writer's letter of 8 June 1987 to UNDP Office, New Delhi):

1. to develop a control system for the dual intake system,

2. to start works with selective exhaust gas recirculation and/or dual intake system on methanol fuelled two-stroke engines,

3. to give further recommendations on the work carried out so far concerning abnormal combustion and on further experimentation related to it.

4. to give views on the findings of the activity concerning development of methanol operated two-stroke engines and to recommend possible further studies which may be considered by IIP.

II. DUAL INTAKE SYSTEM

During writer's first and second missions to IIP a new concept of scavening in two-stroke engines, termed, "dual intake system", was devised, functional model of the Vijai engine

with this system fabricated and comprehensive tests on the engine bench conducted. The invented system prooved very efficient. It reduced fuel losses due to scavenging through of the fresh charge by 35%-45% depending on operating conditions which, in turn, resulted in the significant reduction of HC emissions and fuel consumption. Consequently, it was decided to confirm those findings on a vehicle during tests on chassis dynamometer and in the field. For this purpose, a dual intake system which would be accommodated in the limited space in the Vijai scooter and could automatically control engine power output was required. The first stage of works on the development of such a system was conducted and completed during the present mission.

The first prototype of the required system was designed and fabricated. The carburettor size in the primary circuit was selected and its setting optimized. Tests showed that the system was working properly, over the wide range of loads and speeds. At very low speeds and high loads fuel spilling from the carburettor was observed which, however, is characteristic of this engine type with standard intake system as well. The proportion of flow through primary and secondary circuits could be adjusted in the wide range. Only at WOT the flow through the secondary system was smaller than required (not more than 40% of the total flow) which was attributed to the high flow restrictions resulting from too small inner diameter of fittings and pipes. On the basis of accummulated experience with the first prototype, necessary alterations were introduced in the design of the system.

Its final version more compact and with improved flow control is being fabricated at IIP and after initial tests on the engine bench will be evaluated on the Vijai scooter.

III. SELECTIVE EXHAUST GAS RECIRCULTION AND DUAL INTAKE SYSTEM ON METHANOL FUELLED TWO-STROKE ENGINES.

The second method of the reduction of fuel losses in two-stroke engines developed during the writer's previous missions to IIP was "Selective Exhaust Gas Recirculation" (SEGR) It consists in the introduction of air fuel mixture through an ordinary intake system and recirculated exhaust gas extracted from the selected point of the exhaust system into the transfer ports. So far this method has been examined on a petrol Vijai engine. With SEGR fuel losses due to scavenging through are reduced by 40-50% which results in improvement in fuel consumption and reduction of HC mass emissions. The advantage of this method is that it effectively suppresses knocking combustion and decreases the temperature of combustion chamber and exhaust gas (See: writer's report of January 1987). Given very good efficiency of the invented system with petrol, it was decided to evaluate its potential in methanol engines, in particular, with a view to suppress their knocking combustion and consequently to increase the compression ratio in order to improve the engine efficiency.

A Vijai engine tested on the bench was converted for methanol. Engine components from the Vijai scooter earlier converted and tested with methanol (carburettor) were used for

this purpose, which made it possible to start tests during the writer's stay at IIP. The work confirmed known advantages of SEGR.

As power output of the methanol engine is higher than that of petrol one it is possible to use SEGR upto a recirculation ratio of 15-20% at WOT without sacrificing engine and, consequently, vehicle performances. The detailed programme of further works to be carried out at IIP was laid down and discussed with Mr.Mukesh Saxena, IIP scientist in charge of the work. The procedure is similar to that used during the previous tests with petrol (see writer's report of January 1987). It is recommended to gradually increase the engine compression ratio from standard value of 7.5 to at least 9.5 by steps of 1 by facing the cylinder head and profiling its squish area.

Initial tests with dual intake system conducted on the same converted Vijai engine showed that it worked very well with methanol as well and similar reductions in fuel consumption and HC emissions were achieved as with petrol. Therefore, it is immaterial whether further development works are carried with methanol or petrol.

IV ABRNOMAL COMBUSTION IN TWO-STROKE ENGINES.

During the present mission, the work on abnormal combustion observed in methanol two-stroke engines was continued and brought to a conclusive end. Main conclusions which can be drawn from the work are summarised below.

In the report from the previous mission (see writer's report of January 1987) it was suggested that there were two kinds of abnormal combustion, termed "pinking" and "thudding". The "pinking" was indentified as knocking combustion. The nature of "thudding" which occured at retarded ignition timings was, however, not clear. The latest tests with the help of AVL Digital Analyzer showed that "thudding" is a knocking combustion as well. Its c :ency is about 6000-7000 Hz and identical to that of "pinking".

It was found that at higher loads (from WOT down to 40-50%) the effect of ignition timing is similar as in four-stroke engines i.e. the knock intensity increases with timing advance. However, at lower loads the trend is reverse. The knock intensity increases with retarding timing and is maximum at very retarded timings of 4-8° bTDC which is unusual. The examination of pressure traces in the cylinder made it possible to explain this phenomenon. At lower loads and advanced timings (24-28° bTDC) the from cycle to cycle variation is relatively small. In all the cycles the maximum pressure occurs close to TDC and is definitely higher than compression pressure. The rate of pressure rise is moderate, in general between 1.0-1.5 kg/cm^2 deg. The knock of trace to light intensity occurs in most cycles. With retarding timing the from cycle to cycle variation gradually increases. The percentage of cycles with very retarded combustion rises as well. The cycles with retarded combustion are usually followed by cycles with very fast combustion which, is turn, results in high pressure and rate of pressure rise. This

is attributed to high percentage of unburnt or partially burnt fresh change in the residual gas and high temperature of this gas. The knock occurs only in cycles with high pressure rise. At retarded timings (4-8° bTDC) the heavy knock occurs in every second or every third cycle. Therefore, the abnormal combustion observed in the methanol two-stroke Bajaj engine was identified as typical knock under all tested conditions, however, the mechanism of its formation depends very much on operating conditions.

Comprehensive tests were carried out with a view to comparing anti-knock properties of methanol and petrol in the Bajaj engine. They showed that the above described findings were true for petrol as well. Whether methanol properties are inferior or superior to those of petrol depends upon operating conditions. In general methanol is superior with regard to its anti-knock properties at lower speeds and retarded timings but is inferior at advanced timings and/or higher speeds. Test with primary reference fuels (blends of isooctane and normal heptane) showed that at trace knock the actual octane number of methanol is about 73 units and that of petrol 70 units. However, under conditions of heavy knock (advanced timing) this number drops very much for methanol down to below 60 units but for petrol is less affected. In writer's view unusally inferior methanol anti-knock properties in the tested Bajaj engines result from its very high sensitivity (difference between Research and Motor Octane numbers) on the one hand and high severity of working processes in two-stroke engines which can be attributed to high

residual gas content and its temperature on the other hand. The conducted work showed limitations of methanol in respect of its anti-knock properties under conditions of high severity of working process. At the end of writer's stay at IIP, a presentation was delivered and a group discussion held on the subject of abnormal combustion, octane requirements, methods of knock suppression etc.

V. REVIEW OF THE ACTIVITY CONCERNING THE DEVELOPMENT OF METHNOL OPERATED TWO-STROKE ENGINES

In the course of the project "Application of alternative fuels for internal combustion engines" 6 two-stroke engines were converted at IIP for methanol operation:

- 3 Bajaj scooter engines
- 1 TVS moped engine,
- 2 Vijai scooter engines

Out of the 6, 2 engines: a Bajaj and a Vijai were subsequently mounted in the scooters and subjected to comprehensive field tests. The methanol Bajaj scooter has been run for 12000 km and the Vijai one for 6000km.

The conducted works, given their complexity and extent, made it possible for IIP in particular and India in general to acquire valuable experience in the area. It is to note that very little information was available on the application of neat methanol in two-stroke engines at the beginning of the works. Therefore, in contrast with other areas of methanol application e.g. four-stroke car engines, Diesel

engines where it is possible to benefit from studies done all over the world, IIP had to conduct pioneering works with regard to two-stroke engines e.g. on problems of lubrication, abnormal combustion, optimisation etc.

The work showed that the conversion of petrol two stroke engines into methanol operated ones is feasible providing that necessary modifications are introduced. In India two wheelers equipped with two-stroke engines are one of the main means of individual transport and therefore, the cost and simplicity are predominant factors. Consequently, the two-stroke methanol engine should be, at least at this level of development, a simple carburetted engine, preferably with fuel-oil lubrication. For this reason, the writer does not anticipate any possibility of using such measures as fuel injection, catylytic converters etc. in India mopeds, scooters and small motor-cycles in the nearest and even more remote future. If such measures were required to reduce unburned fuel emissions, it would be rather advisable to give up the idea of using to-stroke engines and go in for four-stroke concept. With this in view and taking into account unwillingness of many manufacturers to introduce major modifications into their products and often insufficent R&D facilities for this prupose the work was carried out with an objective to keep modifications down to a minimum required for the proper and reliable engine and vehicle operation, good performances such as fuel economy, driveability and good engine durability comparable with that for

petrol. As far as unburnt fuel emissions are concerned, the objective was to keep them at the level not exceeding that with petrol.

All these objectives were fully met. The introduced changes were as follows:

- replacement of materials sensitive to methanol with materials resistant to methanol in the fuel system; it comprised needle valves, floats, fuel filters and tubes,

- modifications of the carburettors with a view to increasing the fuel flow to the rate required for proper mixture strength (size of the off-idle port, idle, main and starting fuel jets, passages) and passages in the fuel three-way valves.

- spark plugs with higher thermal value,

- retarding of the ignition timing as compared with standard one for petrol,

- slight increase in compression ratio (high increase not allowed due to abnormal combustion),

- new oil with special formulation.

The formulation of the fuel was also optimised. It was found that requirements with regard to its properties were met under Indian conditions with a blend of 90% vol. methanol and 10% ordinary petrol.

All these changes are considered minor, not disturbing the main advantage of two-stroke engines i.e. simplicity of

design, manufacturing and maintenance. After the initial problems resulting from impurities in methanol had been overcome (see writer's report of January 1987), the two scooters worked reliably for the last 6000 km without any breakdowns which could be attributable to methanol. The methanol scooters, in particular the Bajaj, are characterised by excellent energy economy. The energy consumption is by 30% lower than that of the average petrol vehicles with comparable, very good driveability. With oil of new, improved formulation developed at IIP the initial problems of component, in particular, top ring wear and engine cleanliness (see writer's report of June 1985) seem to have been overcome too. The metrology of scooter engine components showed that their wear was reduced to an acceptable level. As the statistical sample of methanol engines is very small, these results have to be confirmed in further tests.

The experimental works carried out on converted engines were supported and complemented by analytical studies e.g thermo-fluid modelling and mathematical simulation of two-stroke spark ignited engines conducted under the guidance of UNIDO experts Dr.R.Pefley and Dr.L.Browning (see their final report of December 1986). Moreover, fundamental studies of combustion process in the constant volume bomb under conditions simulating the process in two-stroke engines were conducted under the guidance of another UNIDO expert Dr.G.de Soete. Thus in writer's view the objectives of the project in the area of methanol two-stroke engines were met. A group discussion attended by IIP staff members invol-

ved in the work was held to sum up the experience and identify fields for further studies which might be taken by IIP.

Detailed technical reports covering all the mentioned subjects are being prepared by IIP.

VI. RECOMMENDATIONS

By saying that the objectives of the project in the area of two-stroke engines were fulfilled and the work was brought to a conclusive end, the writer does not mean to recommend to discontinue further works the moment the UNIDO project is over. Just the contrary it is recommended to carry out further development on the basis of valuable experience accumulated in the course of the project, set-up facilities and developed techniques. As final decisions concerning the tomorow's energy policy in India, methanol and other alternative fuels included, have not been taken yet, further works should be concentrated on systems/methods that could be of use in both petrol and alcohol operated two-and three-wheelers.

To begin with, IIP own experience has been mostly limited to old designs manufactured by Bajaj and SIL which are the most wide spread in India. However, many modern engines with improved scavenging and better carburation have entered the market lately e.g. manufactured by Lodhia, Kinetic Honda etc. These designs as well as small four-stroke engines

should be included in IIP studies.

The first area of development where it is recommended to concentrate IIP work is scavenging process. This should include the improvement of standard scavenging in some engines as well as further work on two systems being developed at IIP: dual intake system and selective exhaust gas recirculation. Both are relatively uncomplicated, suitable for Indian engines and efficient. The selective exhaust gas recirculation combined with advanced ignition timing and increased compression ratio is considered to be especially promising with regard to fuel economy and emissions. It should be well publicized, further developed and adapted to given engine models in cooperation with interested vehicle manufacturers.

The next area to work on is a lean burn technique in two-stroke engines. the first step in this direction has been already made in the course of methanol engine development. This method only marginally, if at all, reduces the inherent draw back of two-stroke engines i.e. low trapping efficiency, however, it efficiently improves fuel economy and emissions. Both the techniques: improved scavenging and lean burn are efficient in petrol, as well as in alchol engines. They should be developed keeping in view special requirements arrising from specific Indian operating conditions and maintenance.

The last but not the least area of interest is the adjustment of fuel properties to two-stroke engine requirements and

vice versa. In India two-stroke engines account for more than 50% of petrol consumption and this share is going to increase. Therefore, specific requirements of these main "consumers" as to fuel volatility, anti-abnormal combustion properties etc. have to be taken account of. The specifications for required fuel properties should be laid down by IIP.

Detailed recommendations as to studies to be carried out in respect of the three mentioned areas were given to IIP scientists in charge of the work. Writer's views and recommendations with regard to methanol introduction in India were given in the report of June 1985, in chapter III. They hold good and therefore, the writer does not consider it necessary to repeat them in this report.

Finally the writer wishes to thank Dr.R.Krishna - Project Director and Mr.S.Singhal - Project Coordinator for the valuable assistance received from Indian Institute of Petroleum in the course of his four missions. Very good cooperation of staff members of Engine Laboratory, in particual Dr.B.P.Pundir, Mr.M.Saxena, Mr.M.Abraham, S.Maji, S.K.Jain and B.K.Puri is also acknowledged. The writer also wishes to acknowledge good cooperation of other UNIDO experts involved in the work on two-stroke engines: Mr.H.C.Wolff, Dr.-E.Vieilledent, G.de Soete and L.M.Browning.