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APPLICATION OF ALTERNATIVE FUELS FOR INTERNAL COMBUSTION ENGINES, I.I.P., DEHRA DUN

DP/IND/82/001

INDIA

FINAL REPORT *

Prepared for the Government of India
by the United Nations Industrial Development Organization
acting as Executing Agency for the United Nations Development Programme

226

Based on the work of Mr. Edmond Vieilledent,
Expert in Lubrication Requirements of Two-stroke Engines,
under the post 11-07

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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1. Explanatory Notes

Currency rate during the period of mission is 11,85 Rs. for 1 US $.

Definitions and abreviations

In this report the following abbreviations and special terminologies are used:

Petroil	Mixture on defined percentage of gasoline and oil
VI	Viscosity Index
S.A.E.	Society of Automotive Engines
A.S.T.M.	American Society of Testing Material
S.C.R.T.	Silicon Control Rectifier Thyristor
E.F.I.	Electronic Fuel Injection
N.S.	Neutral Solvent
B.S.	Bright Stock
T.D.C.	Top Dead Centre
B.D.C.	Bottom Dead Centre
E.I.	Electronic Ignition
K.L.	Kiloliter
M 10	Gasoline methanol blend at 10% methanol
M 100	Neat methanol
I.I.P.	Indian Institute of Petroleum
I.F.P.	French Petroleum Institute

2. Abstract

Application of alternative fuels for internal combustion engines,
DP/IND/82/001

The duties of the expert outlined in the job description are as follows:

- Planning of research activity to study lubrication requirements of small two-stroke engines with alcohols and alcohols blended fuels. Both separate lubrication as well as "Petroil" lubrication systems should be studied.

- Establishment of necessary additional techniques for study of engine and lubricant performance.

- Guidance on basic and applied research.

- Training of engineers on the aspects of lubrication and wear of two-stroke S.I. engines.

The objectives of the first part of my mission (two months duration) are as follows.

I. Determination of the planning of research concerning:

a) Definition and development of a suitable oil for M 10 two-stroke engines.
b) Definition and development of a suitable oil for M 100 two-stroke engines.
c) Optimization of a separate lubrication system on the reference engine 150 cc.
d) Study the fuel economy on two-stroke engines.
e) Study a direct injection system on the two-stroke engine aiming at fuel economy and emissions decrease.

II. Adaptation of the C.E.C.-ASTM method for the evaluation of two-stroke engines lubricant.

a) CEC L 21.T.77-method applied on the 150 cc Bajaj engine modification of the different parameter according to the new type Indian reference engine.

b) CEC L 19.T.77 and
CEC L 20.A.79 method applied on the 50 cc Hero-engine (aluminium chromium plated cylinder) as reference 50 cc Indian engine.

III. Instructions given for the adaptation of the test benches and equipment required.

IV. Supplying two-stroke synthetic oil suitable for neat methanol.

V. Supplying of a pump for separate oiling studies.

VI. Supplying of a special equipment for electronic and mechanical direct injection.

VII. Training of IIP engineers.

3. Introduction

For some years now, serious effort seems to have been made to improve the quality of two-stroke oil lubrication to meet the requirements of the two-stroke engine existing on the market. However, the production of two-stroke S.I. engines in India follows a nearly exponential curve giving a projection for the end of this century of 21 million vehicles equiped with two-stroke engines, against only a small growth of cars equiped with four-stroke engines (see annex III).

According to this trend the consumption of two-stroke oil will reach 70 or 80% of the total consumption of oil for all engines. That is the reason why the performances of two-stroke oil must be increased in order to reduce the oil consumption and smoke emissions. On the other hand, the consumption of fuel for two and three wheeelers is in constant growth and it is necessary to study the possibility of using an alternative fuel. This is claimed to be a valuable goal for the Indian economy balance (see annex III).

In the future, we will have to reduce oil and fuel consumption and emissions on the two-stroke engine.

The author's different tasks are detailed in this report.

4. Generality

The properties of methanol as an alternative fuel for the engine have been described in several reports and it therefore would appear superfluous to give any supplementary information on that type of fuel.

The use of methanol in two-stroke engines gives rise to the main following problems:

- Lubrication
- Engine efficiency
- Consumption, emissions
- Startability
- Driveability.

Several road tests have already been made by IIP with a fleet of two wheelers fed with a gasoline methanol blend M 10 (10% of methanol). The results are encouraging and a series of tests is being planned now on the test benches.

5. The work programme

It is defined and summarized as follows:

1) Advise on parameters of an evaluation procedure for selection and development of suitable formulation for both petroil and separate lubrication system on two-stroke engines, including oil dosage for:

   a) Normal gasoline operation
   b) Methanol gasoline blend (M 10)
   c) Neat methanol operation.

2) Advise on selection and optimization of hardware for separate lubrication system on an existing 150 cc engine.

3) Advise on achieving state of the art fuel economy for existing design. This would also include fuel injection systems.

4) Training of IIP engineers on lubrication and performance evaluation aspect.

A - Lubrication studies

As far as the test procedure is concerned, many methods (C.E.C.-ASTM) have been adapted and eventually modified in order to meet requirements on the Indian engines.

(i) Mixibility test : modified BIA method

(ii) Stability test : a special method has to be defined

(iii) Compatibility with the engine
We adopt the C.E.C.-ASTM method adapted to the Indian engines.

. Engines below 50 cc capacity
. Tightening test - CEC L 19 T 77
. General fouling test - CEC L 20 A 79

Laboratory engine "Hero-Majectic"
. Engines over 50 cc capacity
. CEC L 21 T 77
Sequence I - Tightening test
Sequence II - Power loss
Sequence III - Pre-ignition test
adapted for Indian Laboratory
Engine : 150 cc "Bajaj".

(iv) Behaviour of the elastomeres/polymeres and plastic materials.
Laboratory test.

(v) Rust sensitive engine parts
Modified ASTM method.

. All these procedures require special equipment on the test benches which has to be installed during the first part of the mission.

In order to study lubrication in two-stroke engines feeding on methanol, differents types of synthetic oils and additives are also required from around the world from specialized chemical industries. Also IIP can provide some synthetic oils for these tests.

As far as the separate lubrication system is concerned, we also tried to procure from Mikoni, Japan, a special oil pump that could be adapted for the 150 cc Bajaj engine.

B - Others studies

Direct injection system (both low and medium pressure) for two-stroke engines. Different companies have been contacted to provide special mechanic or electronic equipment required for this study.

C - Training of IIP engineers

According to point N. 4 of the author's job description, I have been lecturing on the following topics:

(i) Lubrication problems in the field of two-stroke engines

(ii) Performance evaluation of lubricants for two-stroke engines

(iii) General performances of two-stroke engines (scavenging-carburation-injection-emissions)

The participants have shown a real interest in these lectures, however, two remarks should be made:

. The participants being made up of people of differents technological levels and training degrees, it was rather difficult to adapt the teaching to all of them.

. Due to time constraints, the lectures were necessarily limited in range. In my opinion, a more general course on the subjects would be much more adequate . As an example, I would like to mention the French Petroleum Institute, where a post-graduate school exists offering specialized training in the field of engines and industrial petroleum applications.

The courses provided in that school are both directed at basic comprehension and practical applications. The school is separate from the Institute and the teaching staff belongs only partly to it. It probably would not be possible to create such a school in Dehra Dun in the next future. But the idea of having a structured, basic and applied continuous training at IIP would be highly recommendable. To insure the continuity of this training, it would be good to utilize also teaching personnel from outside the IIP to avoid overburdening the current research staff of IIP.

6. Activities

A) Two-stroke lubrication and improvement of oil economy:

a) Study of the actual IIP knowledge level concerning two-stroke engines lubrication:

(i) Results of tests carried out with normal gasoline
(ii) Results of tests carried out with gasoline methanol blend
(iii) Results of tests carried out with pure methanol.

b) Study of the IIP method used until now and examination of the results.

c) Proposal to use CEC-ASTM method with European reference oils.

d) Adaptation of these methods on the Indian engine:
for CEC L 21 - up-to-date Bajaj 150 cc engine,
for CEC L 20 and L 19 - 50 cc Hero-Majestic engine.
These engines could be transformed to use pure methanol (carburator, compression ratio, etc).

e) Supply of two-stroke synthetic oils suitable for methanol through some companies in the world:

. Castrol, England
. Unichema, Netherland
. Esso, France
. Exxon, USA
. Nyco, France
. Orogil, France.

f) Planning of research:

Lubrication test programme for petroil engine. These tests are conducted with:

(i) 3 typesof fuel:
. Normal gasoline (definition-composition)
. M 10 - Normal gasoline blend with 10% of methanol
. M 100 - Pure methanol.

(ii) 9 types of reference oil:

RL55 - RL56 - RL81 - RL05 - RL07

Used for L 21 method with 3 sequencies on the 150 cc Bajaj engine.

RL09 - RL10

Used for L 20 method on the 50 cc Hero-Majestic engine.

RL79 - RL86

Used for L 19 method on the 50 cc Hero-Majestic engine.

(iii) 6 test oils:

With 3 variable fuel oil ratio 3% - 2% - 1%

- 2 T Indian oil
- IIP formulation (1)
  . 250 NS + 10% PS + package

or, 60% /200NS + 30% / 350 NS + 10% BS + package

- IIP formulation (2)
  . 250 NS + 5% synthetic oil + package

or, 60% / 200 NS + 35% / 350NS + 5% synthetic oil + package

- Pure synthetic oil IIP + package
- Pure synthetic Castrol
- Pure synthetic Unichema + package.

(iv) On 2 laboratory engines:

- New type 150cc Bajaj engine
  transformed for M 100 (spare part and carburator)
- Hero-Majestic 50 cc engine
  transformed for M 100.

Separate oiling system.

Supply of a special oil pump from Mikuni, Japan
Measurement of delivery curve (function of Revs and throttle)
Oil pump coupling on the 150 cc Bajaj engine
Series of test, with CEC L21 - Sequence I method to determine the minimum flow rate required by the engine.

B - Improvement of the fuel economy:

a) Lectures to the IIP engineers concerning the scavenging on two-stroke engines and the different ways to reduce the losses through the exhaust system.

- Up-to-date technology concerning transfer channel and ports - double stream scavenging.
- Direct electronic fuel injection in the cylinder (low pressure injection).
- Direct mechanical fuel injection on the cylinder head (medium pressure injection).

b) The laboratory test of the electronic fuel injection in two-stroke engines requires a special electronic equipment.

Look for a supplier in France to study and make this type of equipment.

c) Same applies for the medium pressure injection (40 bars).

It is not possible to find injectors and pumps in France because for a 150 cc engine the quantity injected by stroke is too limited.

It is may be possible to find this type of equipment in Italy (E. Spica, Livorno).

C - Training of IIP engineers:

- Lectures on:
  a) Lubrication of two-stroke engines
  b) Effects of lubricants on the engines
     Description of tests with CEC-ASTM method
     - tightening test
     - general fouling test
     - pre-ignition test.
  c) Formulation on the two-stroke lubricants
     - with normal gasoline
     - with oxygenated fuel.

7. Recommendations

It was recommended to IIP staff:

a) To get in touch with Bajaj Auto Ltd to determine the possibility of choosing an up-to-date 150 cc laboratory engine with the necessity to supply the same spare parts during a minimum of ten years.

b) To do the same with the Hero-Majestic Company for 50 cc laboratory engine.

c) Facilities required to carry out these tests.

(i) To equip properly two dynamometers test benches, one for the 150 cc engine with the possibility to record the engine torque, with variable programmation; another for the 50 cc engine with the same requirements.

In this case the Vibrometre Type, but before my departure I recorded the failure of the electronic measurement. I had to take with me all the broken down electronic module and transport them to Vibrometre Europe for quick repair.

During my last information visit to Vibrometre in Paris and Switzerland, I learned that this material would be sent to India before the end of January.

(ii) To provide two 50 cc engine endurance test benches for CEC L 20 test with 5 phases of programmation (for that I got in touch with some companies in Europe).

(iii) To supply a special coupling (between engine and brake) on the case of Vibrometre dynamometre and also a starter.

(iv) Special oiling pump mounting in laboratory for measurements of main characteristics.

d) Correct writing of the transposition of the CEC - ASTM method for 150 cc and 50 cc engine to IIP method.

e) Purchase the CEC reference oil in Europe, type RL05 - RL07 - RL81 - RL78.

f) To carry out all the tests included on the lubrication test programme.

g) For studies of the direct injection system, the E.H.L. company (located in Paris suburb) has been contacted to supply a special laboratory equipment. A quotation for this material will be sent to UNDP Delhi and I recommend that it be purchased as soon as possible.

Nota: Before I left IIP Dehra Dun, I gave all these recommendations to the different responsible engineers of the project and asked for a fortnightly progress report.

8. Advancement of the test studies

Preparation of the different part of the procedure has been started and is progressing according to the local work possibilities.

Transformation and adaptation of the test benches will take a rather long time which cannot be specified at the moment. It becomes clear that at the date this report was written, no relevant practical results could be obtained because the test facilities were still to be established.

9. Conclusion

At the end of this first part of my work, it is too early to draw conclusions since at this time definite results are still inexistent. But now, I am sufficiently informed of the important problem created in India for the coming years by the huge growth of the number of two-stroke engines and by the possibility to use alternative fuels in two-stroke engines.

The three main points are:

a) Two-stroke oil economy by improvement of the quality of oil and reduction of the fuel/oil ratio.

b) Fuel economy by improvement of the engine efficiency.

c) Reduction of emissions resulting from the two precedent improvements.

A strict application of the CEC-ASTM test method on the Indian engine should make possible to solve the Indian problem with the two-stroke engine. On the other hand, our knowledge on the efficiency and fuel economy of the two-stroke engine should be continuously updated by a co-operation with the local manufacturers to allow co-operative development and modifications of the engine in order to meet the established target.

The three points above should meet the different goals indicated in my work programme. It is my opinion, that the work can be brought to a good end, if the appropriate equipment (reference oils, special synthetic oils, oil-pump electronic equipment and other which is not available at the moment but will be through arrangements concluded in different countries - France, Japan, England, the Netherlands) can be procured on time.

Health and safety aspects of use of neat methanol in the laboratory

Methanol is highly toxic to humans and appropriate health precautions must be taken.

It should not be ingested (due to confusion with ethanol).

Neat methanol does not have a suitable warning odour (addition of a stench agent).

Direct ingestion is the most serious, leading to permanent blindness and possible fatalities.

Exposure through skin contact or inhalation can also be serious, particularly over prolonged periods as methanol can be accumulated in the body.

Exposure of skin to methanol can cause deffating and under extreme conditions, may be fatal.

As far as safety is concerned, flammability is the most important issue. Neat methanol fires require the use of special foams (polymeric polar solvant) applied on the burning liquid surface.

Neat methanol used as an alternative fuel in two-stroke engines

The research activity on neat methanol (M 100) as a future motor fuel is well known in different countries of the world and particularly in Europe and USA.

The advantages and disadvantages of neat methanol as a motor fuel in two-stroke engines are:

a) A special design of the engine is needed (materials, compression ratio, carburator, etc);

b) The thermal efficiency has to be increased by about 20% because of its high octane number; anti-knock lead additive is needed in the fuel;

c) Low flamme temperature reduces the general temperature of the engine and decreases the deposits in all parts of the engine. The engine lubrications should be improved.

d) Low volumetric heating value:
This disadvantage is worst for methanol. Theoretically the methanol tank volume should be twice as big. But because of the better efficiency it is normally necessary to increase the tank volume only by approximately 60%.

e) Broad flammability limits:
This allows smoother operation with leaner mixtures and in fact reduces carbon monoxyde emissions. But the aldehydes emissions are important and it is necessary to reduce the volume of unburnt methanol rejected into the atmosphere (see annex III).

High latent heat of vaporisation

This can be both an advantage and a disadvantage. The increased cooling effect of the evaporation gives an increase in volumetric efficiency.

The higher compression ratio of the methanol engine contributes to the same effects.

On the other hand the cooling effect is disadvantageous for the drive-ability during the warm-up.

Low vapour pressure at cool start

It is difficult to start a cold engine using neat methanol below 7º C without special devices. Different systems are possible with two-stroke engine application.

Corrosive effect

It is necessary to use more corrosion-resistant materials in the fuel system. Special corrosion protection of all parts which come in contact with the methanol is necessary. A high quantity of anti-rust doper should be used as an additive to the oil.

Indian gasoline consumption by type of vehicle

Type of vehicle	Consumption (Million Tonnes) 1980	1985	1990	1995	2000
Car Four-stroke Engines	0,84	1,26	2.5	2,8	3,1
Motorcycles Scooters Autoriksha Moped Two-stroke Engines	0,50	0,900	1,600	2,500	3,446

Estimates on road population of vehicles

Type P. Vehicle	Number of vehicles (Million) 1980	1985	1990	1995	2000
Car	0,6	0,90	1,8	2	2,23
Motorcycle Scooters Autoriksha Moped	2,000	4,000	8,500	14,5	21,1

Estimated Indian two-stroke oil consumption

Type of Vehicle	oil requirement - 3% fuel/oil ratio on KL 1980	1985	1990	1995	2000
	10,000	30,000	50,000	80,000	115,000

ANNEX IV

Remarks on the IX National Conference

I have participated with a great interest in the IX National Conference on I.C. Engines and Combustion, particularly as chairman of the Session FII. (fuel quality, economy, engine performance, experimental techniques and instrumentation) and also on the panel of group discussion on:

- Improved engine design for two wheelers and vehicles emissions regulation for India.

The discussions were particularly interesting in order to know the point of view of some of the manufacturers.

Concerning the improvement of the two-stroke engine design, the conclusions are:

- Adoption of four-stroke engines in two-wheelers seems to be difficult in India because of the maintenance problems and the higher cost of these engines. The two-stroke engine is a better machine but it needs improvements of various aspects.

- Development to improve the scavenging efficiency.

- Fuel economy-lower emissions. A low or medium pressure direct injection system is needed.

- Development of the two-stroke oil formulation in order to increase the quality of oil and decrease the fuel/oil ratio to obtain a better lubrication and lower smoke emissions.

- To this end, the separate oiling system seems to be preferable.

- Generally, the user and the mechanic must be trained for maintenance and tuning of the two-stroke engine vehicles because new technologies are coming to India with foreign collaboration.

Concerning the vehicles emissions regulation in India, the conclusions are:

. First CO from petrol vehicles and smoke from diesel vehicles are to be controlled. Next, HC emissions from two-stroke engines are of major concern.

. Improvement in engine efficiency and reduction in emissions will take place progressively.

. The development of simple and inexpensive diagnostic and emission measurement equipment is of great importance for making the regulations effective and ensure the proper maintenance of vehicles.

ANNEX V

Persons met in connection with the mission

UNDP	Mr. Kamal Hussein SIDFA, UNIDO
	Mr. P.N. Pathak Programme Officer
IIP	Dr. Gulati Director
	Mr. S. Singhal Head, Petroleum Products Application Division
	Dr. B.P. Pundir Project Co-ordinator Engines Laboratory
	Mr. R.L. Mendhiratta Engineer
	Mr. Mathew Abraham Engineer
	Mr. Janardan Sharma Engineer
	Mr. K.K. Gandhi Engineer
	Mr. B.K. Puri Secretary