
Pundlik Nivrutti Patil #1 Dr. Dheeraj Sheshrao Deshmukh #2 Jitendra Gulabrao Patil #3

#1 Ph.D Research Scholar, Mech. Engg. Dept. SGDCOE, Jalgaon ( M.S.)India
#2 Professor & Head, Mech. Engg. Dept. SSBT’s, COET, Bambhori, Jalgaon. ( M.S.) India
#3 Associate Professor, Mech. Engg. Dept. SGDCOE, Jalgaon ( M.S. ) India

ABSTRACT

Liquid Petroleum Gas (LPG) as an alternative fuel has some excellent physical, chemical and combustion characteristics like aspects that makes it to be preferred fuel for Spark Ignition (SI) engine. It is observed that for slow speed engine, the indicated power could be directly calculated from the indicator diagram, but in modern high-speed engine it is difficult to obtain accurate indicator diagram due to effects of inertia forces. In such cases Morse Test could be used to measure indicated power, frictional power and mechanical efficiency of multi-cylinder engine. Friction of the piston ring assembly is a major contributor in total frictional losses in SI engine and piston ring assembly is dominant source of engine rubbing forces. This paper presents review on comparisons of frictional power losses, brake power and other performance parameters for spark ignition engine fueled by petrol and LPG under various engine operating conditions.

KEYWORDS: Performance Characteristics, Frictional Power Loss, Morse Test, Engine Efficiency.

I. INTRODUCTION

Today, use of petroleum products has increased tremendously and the increased use of automobile, rapid rate of industrial and technological development throughout the world. Gasoline is the fuel of the majority of spark ignition engine with the transport sector and the problem of fuel scarcity has become very grave. From the past few decades alternative fuel has continued to be studied due to possibility of lower emissions and lower cost & for better performance.

The major alternative fuel under considerations are Liquefied Petroleum Gas (LPG) which is obtained from the hydrocarbon produced during the refining of crude oil and from heavier component of natural gas. The acceptance of alternative fuel by the public depends on the fuel cost and perception of performance of the vehicle, safety and environmental impact. LPG is a petroleum derived coloured gas and consist of propane or butane or mixture of both, LPG has high octane rating of nearly 110 RON which enables higher compression ratio to be employed and hence give higher thermal efficiency.

LPG has the following characteristics:

1. By volume, realtive fuel consumption of LPG is about ninety percent of that of gasoline.
2. The LPG has higher octane number of about 110, which enables higher compression ratio to be employed and gives more thermal efficiency.
3. Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved.
4. The Engine life is increased for LPG engine as cylinder bore wear is reduced & combustion chamber and spark plug deposits are reduced.
5. Due to higher ignition energy requirement, Starting load on the battery for an LPG engine is higher than gasoline engine.
6. LPG system requires more safety. In case of leakage LPG has tendency to accumulate near ground as it is heavier than air. This is hazardous as it may catch fire.
7. The Volume of LPG required is more by 15 to 20% as compared to gasoline.
8. LPG operation increases durability of engine and life of exhaust system is increased.
9. There is reduction in power output for LPG operation than gasoline operation.
10. LPG has lower carbon content than gasoline or diesel and produces less CO₂ which plays a major role in global warming during combustion.
11. The LPG powered vehicles have lower ozone forming potential and air toxic concentrations.

The objective of the study is to compare the operational performance of engine under the variable operating conditions and for the performance, the Morse test to be used in which one by one cylinder is cut off and the frictional power was measured for constant speed under variable load. For the heat balance sheet, calorimeter is used to find BSFC.

To carry out the performance test using gaseous fuels there is need for modification in conventional petrol engine which is depend on the type of fuel used for the performance.
II. ENGINE MODIFICATION SYSTEM FOR LPG OPERATION:

Fig 1 Vacuum Mixing system [6]

In this system, a constant air-fuel mixture is supplied to the engine (through gas-air mixer) while in the second system the fuel is injected at right time with right quantity according to engine operating conditions.

Usually a mixer system is shown in fig. 1 in which mixer is installed to the airflow just before the intake control valve, and it is essentially a tube which the air flows through. It has a carefully designed internal profile though, such that the air initially flows through a medium diameter hole, which then expands to the maximum internal diameter of the tube as the airflow continues. Since air has momentum, this creates a partial vacuum at the expansion point. This vacuum is proportional to the airflow rate and the LPG systems are used to meter the amount of gas joining the airflow. Just at this expansion point, there are some small holes inside the mixer. These pick up the partial vacuum and send this back along a pipe to a vaporizer. The vaporizer has a large diaphragm which responds to the amount of vacuum in the mixer. As this vacuum (i.e. airflow rate) increases, the diaphragm is pulled on (since the other side of it is referenced to normal atmospheric pressure) and this opens a progressive valve, which controls how much LPG is allowed in. So more LPG is expanded to gas. This gas goes back down to the same tube into the mixer, joins the airflow and goes off into the engine to be burnt in the same way as petrol. Open loop LPG system operates in the way described. A restrictor valve is added to the pipe between the mixer and the vaporizer, which the installer will use to tune the system. By adjusting this valve, the installer can tune how much of the vacuum the vaporizer experiences, so can control how much gas can join the airflow and so keep the engine in tune. However, vaporizer diaphragms bed in over time, so gradually the tuning drifts out. Also the response of the diaphragm to the vacuum is fairly course, and it's not always feasible to tune the system such that the correct mixture is presented to the engine under all loads and conditions. These systems do work, but for better performance regular re-tuning is required. [6].

III. PERFORMANCE MEASUREMENT:

The friction horsepower can be measured by the following techniques.

a) Measurement of FMEP from IMEP.

b) Break down motoring test.

c) Williams line method

d) Morse test.

The difference between indicated power and the brake power output of an engine is the friction power.[1] [2]

• The frictional losses are ultimately dissipated to the cooling system (and exhaust) as they appear in the form of frictional heat and thus influences the cooling capacity required. Moreover, lower friction means availability of more brake power; hence brake specific fuel consumption is lower.

• The bsfc rises with an increase in speed. The level of friction decides the maximum output of the engine which can be obtained economically. In the design and testing of an engine; measurement of friction power is important for getting an insight into the methods by which the output of an engine can be increased. In the evaluation of ip and mechanical efficiency measured friction power is also used.

If the mean effective pressure is based on BP it is called the brake mean effective pressure (and if based on IHP it is called indicated mean effective pressure (IMEP)).

Similarly, the friction mean effective pressure (FMEP) can be defined as,

\[
\text{FMEP} = \text{IMEP} - \text{BMEP}
\]

The torque is related to mean effective pressure by the relation,

\[
\text{BP} = \frac{2\pi NT}{60}
\]

\[
\text{IP} = \frac{\text{PimLANk}}{60}
\]

IV. DETERMINATION OF FRICTION POWER BY MORSE TEST:

This method is suitable and used to determine the power lost in overcoming the friction and the power developed by the engine is greater than what is available at the output shaft, as some part of the total power developed by engine is lost due to the friction.

Morse Test is carried out as follows.

The engine is run at maximum load at certain speed. The B.P is then measured when all cylinders are working. Then one cylinder is made inoperative by cutting off the ignition to that cylinder. As a result of this the speed of the engine will decrease. Therefore, the load on the engine is reduced so that the engine speed is restored to its initial value. The assumption made on the test is that frictional power is depends on the speed and not upon the load on the engine.
**Formulae used:**

1. **Brake power,** \( BP = \frac{2\pi NT}{60000} \)
   
   Where,
   - \( T \) = Torque = RS N-m
   - \( R \) = Torque arm length
   - \( S \) = spring balance reading (kg)

2. **Total Fuel consumption**
   \( TFC = \frac{q \times 1000 \times \rho \times t}{3600} \) (Kg/hr)
   
   Where,
   - \( q \) = Fuel consumption (10cc)
   - \( t \) = Time taken for 10cc of fuel consumption (sec)
   - \( \rho \) = Density of diesel (kg/m³)

3. **Specific Fuel consumption (SFC)**
   \( SFC = \frac{TFC}{BP} \) (Kg/Kwhr)

4. **Heat input,**
   \( HI = TFC \times CV \) / 3600 (Kw)
   
   Where
   - \( CV = 43000 \) Kj/Kg

5. **Indicated power**
   \( Ip = ip1 + ip2 + ip3 + ip4 \) (kw)
   
   Where,
   - \( Ip1 = bp – bp1 \)
   - \( Ip2 = bp – bp2 \)
   - \( Ip3 = bp – bp3 \)
   - \( Ip4 = bp – bp4 \)

6. **Brake thermal efficiency,**
   \( \eta_{bth} = \frac{BP}{HI} \) (%)

7. **Indicated thermal efficiency,**
   \( \eta_{ith} = \frac{IP}{HI} \) (%)

8. **Mechanical efficiency,**
   \( \eta_{m} = \frac{BP}{IP} \) (%)

9. **Frictional Power**
   \( FP = BP – IP \) (Kw)

**(V) LITERATURE REVIEW**

1. **C. S. Mistry [4]** are experimentally find out the results for the Morse test, with gasoline operation the liquid fuel must be provided with necessary heat for its vapourization and mixed with the correct amount of air while the gaseous fuels the carburetor need only to mix the proper amount of air so as to produce homogenous mixture with the right equivalent ratio to be fed to the engine. It is to be expected that the performance of the multi-cylinder engine on gaseous fuels will be superior to gasoline in terms of fuel mixture, distribution among the various cylinders.

   The results found from the Morse test indicate the frictional power increases with increase of the speed of an engine and it is also found that the frictional power to be higher for petrol compared to LPG which is because of short warm-up period to generate enough heat for gaseous fuel vapourization and to warm-up the lubricating oil.

2. **Zuhadi Salhab, Md. H. Qawasmi et. al. [6]**
   They performed the test on four stroke four cylinder Mazda 3i engine by varying the torque and the engine speed and measuring the engine performance. The test were repeated for gasoline and LPG as well but no modification of air-fuel ratio was made and experimentally they conclude that the use of LPG instead of conventional gasoline will mean reduction in low engine brake power, brake specific fuel consumption with a loss of approximately 7%.
Figure 5 shows full capacity of operation with LPG and gasoline with a small decrease of power with LPG, probably due to the loss of volumetric efficiency when using a gaseous fuel due to the intake air displacement (lower density for gas). Although the maximum power developed by the injected LPG is almost the same as in gasoline, its performance over the whole speed range is about 7% lower (compared with other results in [13], test results show 6% less power with LPG than with gasoline).

3. Hakan Bayraktar & Durgun Orhan [9]

They compared the result obtained from the experimental studies between LPG and Gasoline fuel as

- In the case of using LPG in SI engines, the burning rate of fuel is increased, and thus, the combustion duration is decreased. As a consequence of this, the cylinder pressures and temperatures predicted for LPG are higher than those obtained for gasoline.
- The maximum cylinder pressures and temperatures predicted for LPG are higher. This may cause some damages on engine structural elements.
- LPG reduces the engine volumetric efficiency and, thus, engine effective power. Furthermore, the decrease in volumetric efficiency also reduces the engine effective efficiency and consequently increases specific fuel consumption.
- LPG decreases the mole fractions of CO and NO included in the exhaust gases.


predicted the friction mean effective pressure (FMEP) for S.I. engine & include prediction of rubbing losses from the crank shaft, reciprocating & valve train component.

5. Dhiraj karla, Dr. Viresh Babu A. Vijay Kumar [10] reviewed the previous studies on LPG fuel S.I. engines power output volumetric efficiency from LPG found to be decreasing but advancing the ignition timing & increasing the compression ration has on adverse effect on NOx & brake thermal efficiency was found to be increased with LPG fueled S.I. engine also emission characteristics are also improved as HC, CO & CO2 showed reduction in concentration with LPG.

6. Mistry, C and Gandhi, A [7] experimentally they found that for both fuel, it was observed that brake thermal efficiency and indicated thermal efficiency increases with increase in speed and it will be higher for petrol than LPG. This is because of higher fuel consumption in case of LPG as compared to petrol. It is also found that brake power developed is higher in case of LPG whereas heat carried by jacket water is covered by exhaust gases and unaccountable losses are higher in case of petrol engine.

7. M.K. Dubey & R. Randa [3] are experimentally found out brake specific fuel consumption (B.S.F.C.) is comparatively lower for LPG & also brake thermal efficiency for LPG are more than petrol fuel for the same load.

8. Hamatake et. al.[11] studied the frictional behaviour of piston ring assembly by varying no. of piston rings and concluded that to reduce the friction losses, decrease the number of rings.

9. Ali M. Pourkhesalian, Amir H. Shamekhi and Farhad Salimi [12] investigated the performance of a four stroke, four cylinder SI engine fueled with different alternative fuels. It was evaluated that the engine fueled with gaseous fuels resulted decrease in volumetric efficiency and power output, emission characteristics are also improved as HC, CO & CO2 showed reduction in concentration with LPG.

VI. CONCLUSION

It can be concluded from this review that the power output and volumetric efficiency are decreased but the break thermal efficiency is found to be increased using LPG as performance variables of S.I. engine. It is to be expected that the performance of multi-cylinder engine of gaseous fuel
with Morse test would be superior with respect to gasoline in terms of fuel mixture at variable load and speed conditions, brake thermal efficiency and indicated thermal efficiency are found to be higher for different speed because of lean burning nature of the gaseous fuel with reduction in dissociation frictional losses and low burned gas temperature. It is observed that there is lot of scope for further research through experimentation for increasing efficiency by reduction in frictional losses and performance enhancement.

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