COMBUSTION OF LPG-AIR LEAN MIXTURE: A SOLUTION FOR POLLUTION REDUCTION OF MOTORCYCLES IN VIETNAM

Bui Van Ga, Tran Van Nam

Environment Protection Research Center

The University of Danang

41 Le Duan, Danang, Vietnam

Email: buivanga@ud.edu.vn

Abstract

Motorcycle is the main source of air pollution in urban region of Vietnam. There are more than 13 millions motorcycles now in the country. The long term aim of our research on "clean vehicle" is reducing pollution emission of in-used motorcycles in Vietnam to meet the EURO III standard. The project is carried out by two stages:

1. Utilization of LPG on motorcycles
2. Application of catalyst converter for post treatment on LPG motorcycles

The present paper focuses on the first stage of the project. For this purpose, an experimental study of combustion LPG-air mixture has been carried out on experimental engines. The result shows that this mixture can be burnt with very low equivalent ratio. The specific fuel consumption is reduced considerably at this limit. This is an important advantage of gas fuel for vehicles running in urban conditions.

For applying the result, a new bi-fuel system (LPG/Gasoline) namely GA-5 has been studied and manufactured for adapting LPG on original gasoline motorcycles. In the system, the LPG in gaseous state at 30mbar is used, no evaporator is needed and the mixture fraction at any regime of engine is controlled by combining of three valves: idling valve, power valve and accelerating valve. The installation of new fuel system doesn't cause any change of the structure and outside view of the original motorcycle.

In case of necessity, the LPG/Gasoline motorcycle can be easily changed to run on gasoline by turning the fuel valve to gasoline position. Thus, this is comfortable for the users in the first step while the LPG supplying network is not largely installed.

The motorcycle running on LPG with GA-5 conversion kit has an emission reduction of about 80% of CO, NO_x concentrations and about 60% of HC concentration in comparison with original gasoline running. The durability of LPG motorcycles is better than that of gasoline ones since the gas doesn't wash away the lubrication film. The fuel consumption is tested with 50cc, 100cc and 110cc motorcycles. With 1kg LPG they can run from 90 to 120km depending on road conditions.

Application of LPG on motorcycles is thus an appropriate way to reduce pollution emission and fuel consumption for transport in Vietnam.

Key Words: bi-fuel carburettor, LPG, motorcycle, pollution

1. Introduction

In Vietnam motorcycles are main individual vehicles with more than 13 millions units actually. According to the forecast, the automobile market in the country will not have an extraordinary develop in next decade. So the motorcycles will be continued in use for a long future. As the urban infrastructure in the country hasn't been well-developed, the motorcycles run usually at low load regime: high fuel consumption and serious pollution emission are thus as result. We can find out the correlation between motocycles number and CO emission in a case study at Nga-Ba-Hue of Danang City (fig. 1 and fig. 2). This correlation points out that the motorcycle is essential responsible of air pollution in urban region.

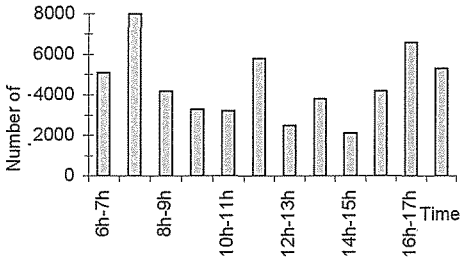


Fig. 1: Circulation density at Nga Ba Hue, Danang City

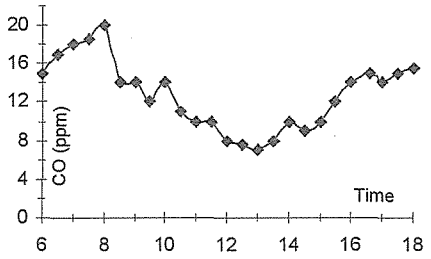


Fig. 2: CO concentration in air at Nga Ba Hue, Danang City

In recent year, many solutions have been applied for automobile for this purpose [1], while there are not many modifications relating to the motorcycle engines. In fact, because of small and compact engines, the advanced technologies applied successfully on automobile engines have difficulty in applying on motorcycles [5]. The motorcycle is essentially used in countries on way of development where the emission regulations are not too rigorous. With these regulations, there is no need of application of advanced technologies on motorcycles. So motorcycle manufactures don't carry out the researches of technologies to reduce pollution emission for this kind of vehicle. Somme new generation motorcycles have been developed (fuel injection, hybrid motorcycles...) in recent years. They are environment friendly but they are not commercialized yet because of high price. The carburetor system is thus still applied on most kinds of small cylinder motorcycle. Fig. 3 represents the result of emission control of a number of motorcycles in Danang. CO emission according to Vietnam regulation is 4.5% in idling regime, so about 60% of motorcycles satisfy the regulation.

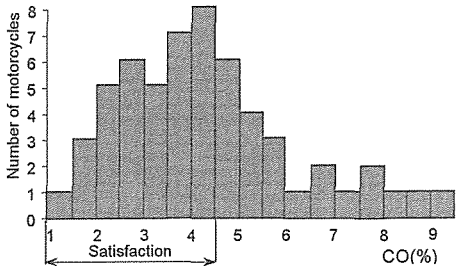


Fig. 3: Pollution emission of motorcycle in Danang City

Thus the research of technologies for emission reduction of motorcycles is essential work of air protection in urban region of Vietnam. Application of catalyst converter on this kind of vehicle is not efficient because it uses carburetor with variable equivalent ratio. The practical way is utilization of « clean fuel » on motorcycles. Utilization of hydrogen or natural gas NGV with high pressure gas cylinder is not convenient for small size motorcycles. Thus the most suitable solution is utilization of Liquefied Petroleum Gas LPG with catalyst converter for cleaner motorcycles [7], [8], [12].

In fact, utilization of LPG for vehicles is now considered as an effective solution for urban air pollution in many countries. The transformation of gasoline car to LPG one is carried out easily thanks to the existent accessory kits (NECAM, LOVATO... accessories for example) [2]. There is no available similar kit for small cylinder motorcycles actually.

Since 2000, the Environment Protection Research Center has carried out a research project on "clean motorcycle". The long term aim of the project is reducing pollution emission of in-used motorcycles to limits between EURO III and EURO IV standards. The research is carried out by two stages:

1. Utilization of LPG on motorcycles
2. Application of catalyst converter for post treatment on LPG motorcycles

In the present work, we will focus on experimental study of lean combustion of LPG-air mixture and LPG kit to transform traditional motorcycles into LPG or LPG/gasoline ones [6]. The kit is simple, local manufactured, low cost, conserves the structure and outside of motorcycle. The new LPG system allows the motorcycles to run in appropriate regime for economizing fuel and reducing pollution emission [10], [11].

The essential problem needed to be solved for gaseous fuel application on motorcycles is supplying the mixture with suitable fraction at any operating regimes. For small power engine of motorcycles, the fuel consumption is not quite important so that we can use the gas directly at gaseous state [6]. The gas supplied to the Venturie is adjusted by the three-valve system [13].

2. Experimental study

Study of combustion of LPG-air mixture is carried out on an experimental engine which has rectangular combustion chamber 68x34x47 mm^3. The engine has two transparency windows for light access. The experimental apparatus was presented in our previous works [4].

Fuel supply is done by injection LPG in gaseous state into admission manifold or injection of LPG liquid state directly into the combustion chamber. The figure 1 shows evolutions of flame front and pressure in combustion chamber of the engine of lean mixture combustion. The recognized pressure is shown on the figure 2. The maximal pressure attaints 46 bars when equivalent ratio is 1.05 and it is reduced to 20 bars at lean combustion with □=0.6. Thanks to gaseous state, the mixture is more homogeny that allows the LPG engine to run with very lean mixture.

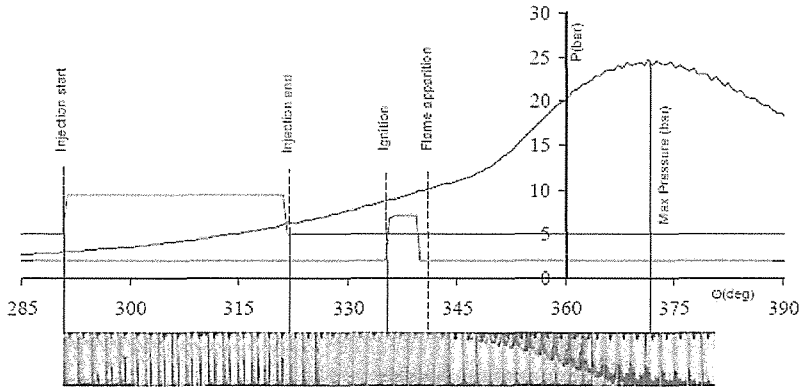


Fig. 4: Evolution of flame front and pressure in combustion chamber of LPG experimental engine

Effect of equivalent ratio on specific fuel consumption is presented on the figure 3. The result shows that the fuel consumption is double when equivalent ratio changes from 0.6 to 1.4. This observation is very interesting in practice. In fact, the motorcycles in urban condition run most of the time at low load regime. With original gasoline carburettor, at this regime the mixture is very rich so that the fuel consumption and pollution emission are too high. In our research we try to solve this problem with our new LPG kit.

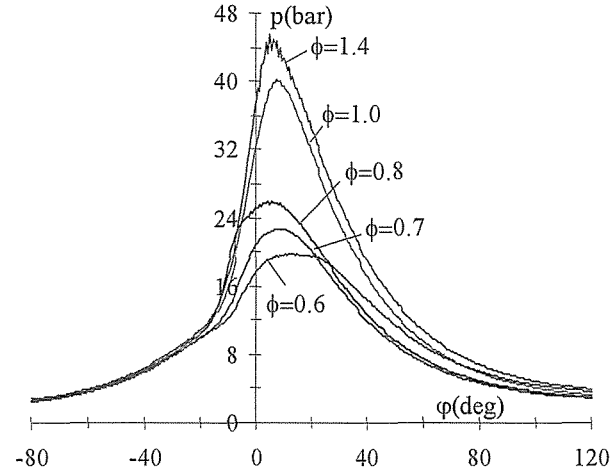


Fig. 5: Effect of equivalent ratio on pressure evolution (n=1000rpm)

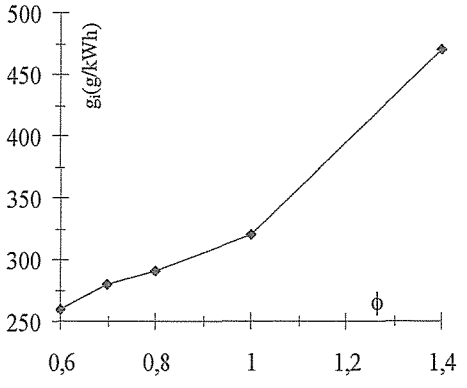


Fig. 6: Effect of equivalent ration on fuel consumption

3. Practical realization

As we have mentioned, for reducing fuel consumption and pollution emission of motorcycles, the essential problem needed to be solved is supplying the mixture with suitable fraction at any operating regimes. In the LPG system of automobile, the fuel exits the reservoir in liquid state and then vaporizes in vaporizer/pressure reducer system. The gas pressure decreases to a value lightly inferior to atmospheric one. The LPG gas is then aspirated to the Venturie throat by depression as the gasoline carburettor. With this principle, the characteristic curves of LPG carburettor are similar to the gasoline one.

For small power engines of motorcycles, the fuel consumption is not quite important so that liquid exiting LPG vessel may be the cause of an excessive fuel. Otherwise, the liquid LPG needs the vaporizer/pressure reducer, the cumbersome apparatus which will not be suitable for limited space of the vehicle. Thus the most suitable for motorcycles is supplying of LPG in gas state with pressure slightly higher than that of atmosphere [5], [8], and [9]. The gas supplied to the Venturie is adjusted by the three-valve system: idling valve, power valve and acceleration valve [13]. The function of the system can be explained as following:

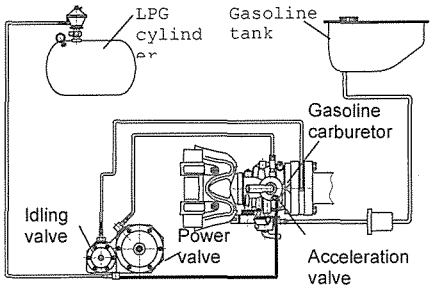


Fig. 7: LPG/gasoline bifuel system for motorcycle

- As idling regime, the vacuum in downstream of the Venturie is high, the idling valve is opened allowing just a small quantity of LPG to supply into the manifold: the engine runs at idle regime with minimum speed.
- When the engine runs up to about 60% maximal power, the power valve related to Venturie is opened, the gas flow supplying into Venturie is controlled to obtain lightly lean mixture. Thus in most of operation time, the motorcycle runs with economic equivalent ratio.
- When full power is needed, acceleration valve is acted: a supplementary quantity of gas is added into the manifold, the mixture becomes richer and the engine supplies higher power.

Basing on the principle, we manufactured a LPG/gasoline conversion kit for motorcycle. Fig. 7 represents schema of LPG/gasoline conversion system for motorcycle. The original gasoline system of the motorcycle is preserved so that the vehicle can run on gasoline as before modification in case necessary.

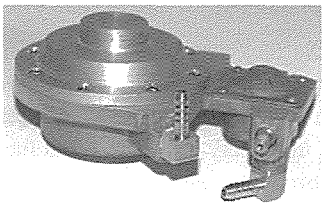


Fig 8: Group of Idling valve and power valve

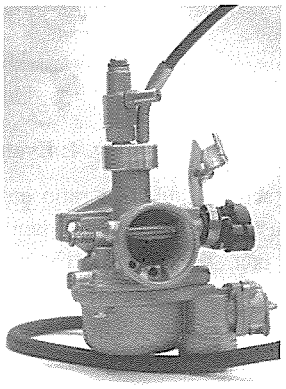
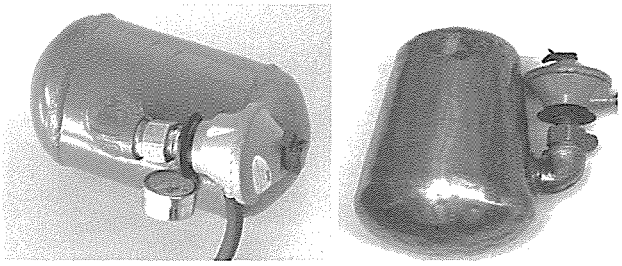


Fig. 9: Adapting of acceleration valve on carburetor

Figure 8 shows group of idling valve and power valve with the adjusting crew for idling regime control. The acceleration valve is mounted on the carburettor as shown in fig. 9.

As original motorcycles are designed for using gasoline fuel only, we have some difficultiesto install a new LPG system on original chassis. To preserve original structure of the vehicle, we should manufacture the LPG cylinder with special forms for adapting to various kinds of motorcycles. The small gasoline tanks taking also special form are manufactured so that they can be put at free place under driver site of the motorcycle. Fig.10 a, b show two different forms of LPG cylinder. Fig. 11 shows a special gasoline tank for 100cc Honda Dream II LPG/gasoline bifuel motorcycle. Fig. 12 shows



a . b.

Fig. 10: Different forms of LPG cylinders for adapting to different ki of motorcycles

an example of adapting LPG cylinder and gasoline tank on a Honda Dream II motorcycle. The LPG cylinder is tested according to the safety standard of pressure vessel. An electro valve (fig. 13) is mounted at exit of LPG cylinder and a pressure security valve is mounted on the cylinder for safety use.

The structure and the style of the original motorbikes are preserved after the new fuel system has been installed. Fig. 14 shows the view of different motorcycles after installation of LPG/gasoline conversion kit.

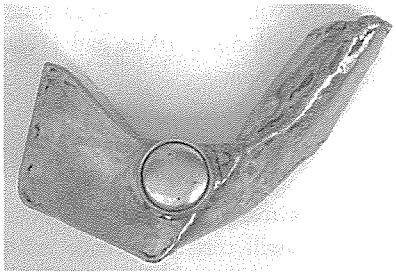


Fig. 11: Special form of gasoline tank for Honda Dream II LPG/gasoline bifuel motorcycle

Fig. 12: Installation of LPG cylinder and gasoline tank on Honda Dream II LPG/ gasoline bifuel motorcycle

4. Performance of lpg motorcycles

The LPG motorcycle is tested on testing bench and on road with different operating conditions. The results are as following:

- *Pollutant emission:* Pollution analysis in different operation conditions shows that the CO, HC concentrations of LPG case are inferior to that of gasoline case. Pollution reduction rate may reach to 80%. Reduction rate is much more when engine load increased. The figure 15 presents the result of CO measure in exhaust gas of LPG motorcycle in comparison with gasoline case. When the engine speed increases, CO concentration in exhaust gas of LPG motorcycle decreases rapidly while it increases in gasoline case. At engine speed of 60km/h, the concentration of CO in exhaust gas of LPG driven case reaches only 25% of this value in gasoline driven case.

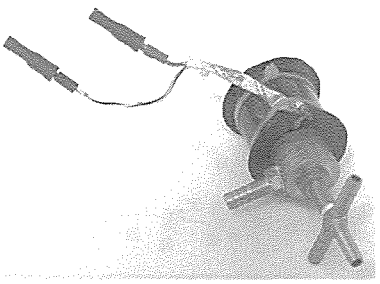
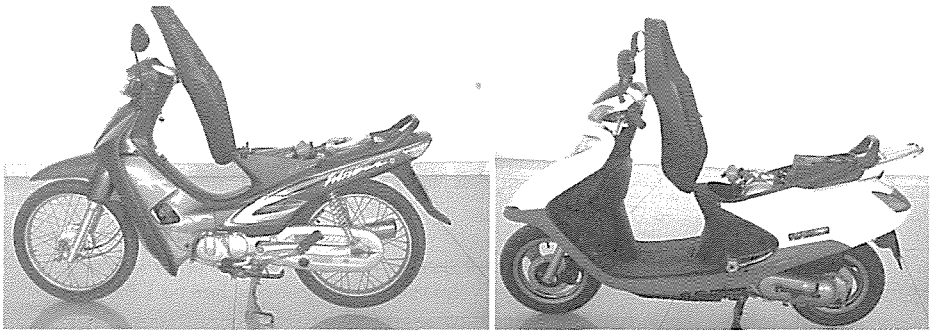


Fig. 13: Electro valve



a. *b.*

Fig. 14: Overview of Wave model (a) and Spacy model (b) LPG/gasoline motorcycles

- *Engine power and longevity:* The maximal power of LPG engines can be controlled by adjusting gas pressure. The figure 17 a and b represent power and torque of a 100cc motorcycle engine running on gasoline and LPG

with 30mbar gas pressure. In this case, the maximal power is reduced about 20% when running on LPG in comparison with gasoline case. Experimental results show that this power is suitable for motorcycle running in urban conditions of Vietnam. We can obtain higher engine power by adjusting gas pressure.

The durability of LPG motorcycles is better than that of gasoline ones since the gas doesn't wash away the lubrication film on the surface of cylinder.

- *Economy:* The fuel efficiency of LPG engine is presented on the figure 17c. The specific fuel consumption (g/kWh) of LPG running case is reduced about 50% in comparison with gasoline case in zone of frequently used of engine speed. The real fuel consumption is tested on road with 50cc, 100cc and 110cc motorcycles. With 1kg LPG they can run from 90 to 120km depending on road conditions.

5. Conclusions

The LPG motorcycle using the fuel system presented in the paper has many advantages in both environment protection and economic aspect. The application of this kind of vehicle will certainly reduce urban pollution in countries where motorcycle parks are important such as in Vietnam.

The application of this solution requires the establishment of LPG supplying network and it can be developed quickly if the Government applies a special tax policy to reduce the LPG price for transportation purposes.

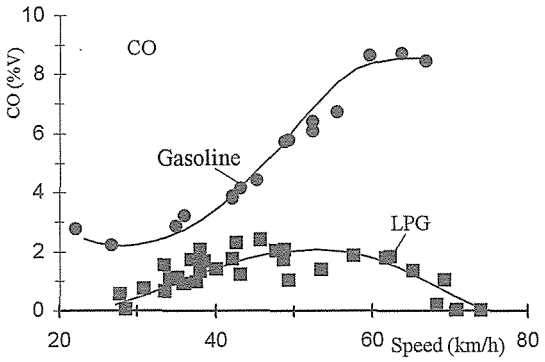


Fig. 15: Comparison of CO emission in exhaust gas of gasoline and LPG motorcycles

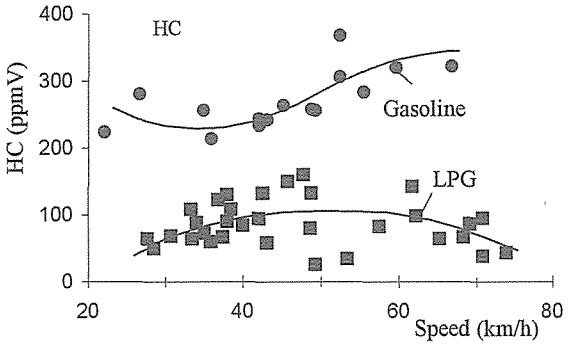


Fig. 16: Comparison of HC emission in exhaust gas of gasoline and LPG motorcycles

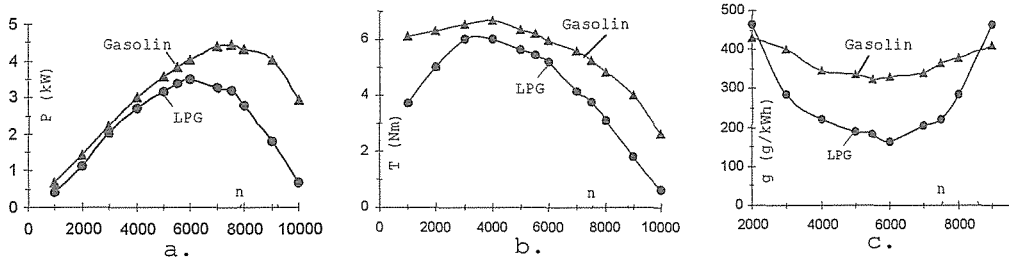


Fig. 17: Comparison of power (a), torque (b) and specific fuel consumption (c) of 100cc HC09E-6345499 engine (Honda Wave motorcycle) running on gasoline and on LPG (gas pressure 28 mbar)

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