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EFFECTS OF VOLUMETRIC EFFICIENCY ON SPARK IGNITION ENGINE FUELLED BY LIQUEFIED PETROLEUM GAS (LPG): A REVIEW

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ABSTRACT

This present study discussed the usage of LPG in spark ignition engine. A brief review on the LPG conversion technology and the fuel system has been studied. The main concerned in using LPG as fuel is lower volumetric efficiency compared to gasoline that gives lower power output also been discussed.

Keywords: liquefied petroleum gas, volumetric efficiency, spark ignition engine.

INTRODUCTION

Stringent emission regulation and striking fuel priced has provoked attention in the development of alternative fuels technologies. This situation becomes worse as depletion world crude oil reserved that created an unbalanced ratio between supply and demand. Liquefied petroleum gas (LPG) has been recognized as one of the promising alternative fuels for internal combustion engines. It's known as one of the cheapest and readily available for transportation system that will remain for the foreseeable future [1].

LPG is a clean fuel and also known as "Autogas". LPG consists of mixture of propane (C_3H_8) and butane (C_4H_{10}). Presently, LPG is one of the alternative fuels that received much attention as a replacement of traditional fuels, gasoline and diesel. The usage of LPG especially in spark ignition engine has broadly used in few countries such as Korea, Turkey, Russia and Italy [2].

Among the advantages in using LPG as an alternative fuel are LPG has higher octane number compared to traditional fuels, low carbon to hydrogen ratio, does not contain aromatic hydrocarbons, lower cost for development of LPG infrastructure, abundantly available, good knocking resistance, better fuel consumption, better cold start performance, prolong engine life and lower toxic emissions production [3-11]. However, power output of LPG in gasoline engine is reduced by about 10 percent compared to gasoline fuel [8-10, 12-18]. The loss of power when using LPG has stimulated the research and development of LPG conversion technology parallel to the growing in engine technology. The conversion of gasoline vehicles to employ LPG has been around for many years and had been evolved through five generations as per shown in Table-1.

LPG FUEL SYSTEM

Current LPG fuel system has employed liquid injection instead of gas injection. The liquid LPG injection system generally is identical to the fourth generation of LPG conversion technology. In view of operation, the basic LPG fuel delivery control system and how it operates is as per Figure-1 and according to the following methodology [7]:

- All information submitted to the LPG control unit are transferred to the external programming device, while the engine runs on gasoline
- The submitted data is processed and sent to the LPG control unit
- All the operating parameters of an engine fuelled on LPG are continuously checked during engine running

The injection timing of liquid LPG injection system is computed based on the basis of petrol injection times. Liquid LPG is injected in the intake manifold of the engine near to the inlet valve separately for each cylinder. The distance of the injector is vary depends on the design of an engine, thus gives different mixing formation between air and fuel and power produce. Even though LPG conversion technology have evolved five generation, there is no standard installation methods and adjustment where the tuning process is totally based on the human factor especially experience and qualification.

Table-1. LPG generation [7,19].

Generation	Description
First	Mechanically controlled LPG carburetion system, open loop LPG system, suitable for carburetor engine. Also known as the Induction system. Simplest type of LPG kit. Introduces gas into the engine in a vapor form through the inlet manifold.
Second	Electronically controlled, close loop, single point injection LPG system, suitable for early Electronic Fuel Injection (EFI) gasoline engine.
Third	Multipoint injection LPG system.
Fourth	Multipoint sequential injection also known as the Sequential Gas Injection System (SGIS). Injects LPG as a vapor for each cylinder very close to the inlet valves.
Fifth	Multipoint sequential liquid LPG injection, Unlike first to fourth generation, LPG is fed into the engine in its liquid form and without vaporizing.

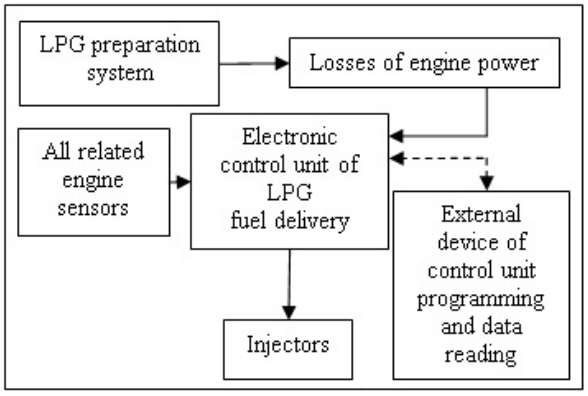

Figure-1. LPG fuel delivery control system [7].

VOLUMETRIC EFFICIENCY OF LPG IN SPARK IGNITION ENGINE

Volumetric efficiency is defined as the mass of air fuel mixture flowing through a cylinder in a complete engine cycle which could fill in the swept volume by the same cylinder [6]. The process starts as the inlet valve opens and finishes as the inlet valve closes. At this time, the cylinder contains mixture of air and fuel (fresh charge) together with the remaining from the previous cycle. Figure-2 shows the model of this process and volumetric efficiency may also be defined by Equation 1.

Currently, fuel supply system of LPG vehicles on spark ignition engine may be classified into two types; liquid phase LPG injection (LPLI) and liquid petroleum gas injection (LPGI). These fuel supply have improved the engine performance compared to the old method that is mixer type. However, the LPLI and LPGI still produced lower engine power compared to gasoline [21]. The power lost in using LPG also in agreement to the other researchs [22-27]. Major reason to justify lower power output is volumetric efficiency. Volumetric efficiency of gasoline is higher compared to LPG because gasoline is injected in a liquid form and as it vaporizes, it cools the air thus produce improved volumetric efficiency [6,18,28]. The vaporized or liquid LPG fuel injection leads to discharging intake air because gaseous nature will occupied the space and reduce the amount of air entering in the engine cylinder [10,21,29]. Most of the LPG conversion inject the fuel at intake system or intake manifold and the vaporization of fuel depends on few factor such as pipes thermal insulation, ambient air and liquid fuel temperatures, shape and dimensions of the intake system, heat of vaporization of the fuel, load and rotational speed of the engine [29]. Pumping loss associated with conversion system hardware also is the reason in loss volumetric efficiency [10]. Watson and Phoung had perform an experimental study to compare liquid and gas gaseous LPG port injection on a one-cylinder CFR engine and found 4 to 6 percent different in volumetric efficiency between liquid and gaseous fuel depending on engine load and mixture strength [20].

$$\eta_v = \frac{m_a + m_f}{V_d \cdot \rho_i} = \frac{m_a(1+\frac{F}{A})}{V_d \cdot \rho_i} \quad (1)$$

where; m_a and m_f – mass of air and fuel inlet per cycle, V_d – swept volume, ρ_i – induced mixture density, F/A – fuel air ratio by mass [20]

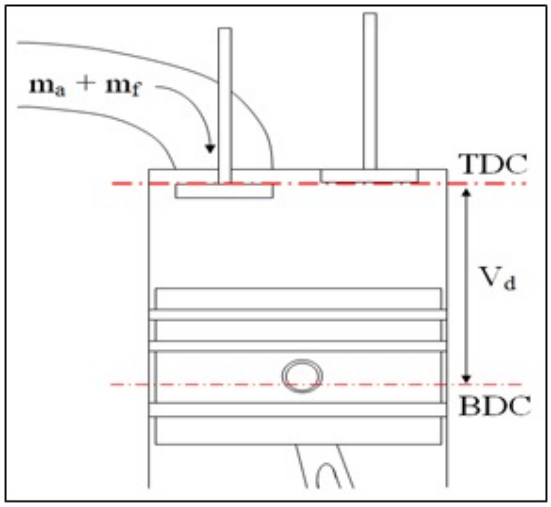

Figure-2. Model of fresh charge induced into combustion chamber.

On the other hand, researcher claimed that by injecting LPG into the engine in a liquid form rather than vapor had improved the volumetric efficiency, producing more power with less fuel consumption [30-33]. Sometime, power produced is higher compared to gasoline.

Even though the power output of LPG fuel is lower than gasoline fuel due to its volumetric efficiency, the usage of LPG as a fuel for spark ignition engine still increasing in many countries. Despite this, lots of question remains open especially on the volumetric efficiency that affected the power produce by engine.

VOLUMETRIC EFFICIENCY ENHANCEMENT METHODS

There are few studies conducted to improve volumetric efficiency of LPG fuel. One of the study suggested to offsetting the heat in the manifold of the engine [11,34]. Wallace [34] found that volumetric efficiency increase up to 8% with respect to gasoline when offsetting the heat in the manifold. By cooling and densified the intake air also resulting in an increase of volumetric efficiency [34]. Moreover, increase the compression ratio due to higher octane number of LPG effectively improve the volumetric efficiency of the engine in using LPG as fuel [11,23,35-38].

CONCLUSIONS

A brief review for LPG as fuel system for spark ignition engines has been discussed in this paper.

Volumetric efficiency sees as the major problem associated with LPG fuel, this issued also been addressed in this study together with its enhancement method that found in the literatures. Further study is needed in order to overcome this issue for better combustion and friendly environment technologies.

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