

EXPERIMENTAL INVESTIGATION OF THE SYSTEM DESIGNED FOR HELPING COLD START UP OF THE LPG ENGINES

Ozgur SOLMAZ

Selcuk University, Department of Mechanical Education, Konya, Turkey

Recai KUS

Selcuk University, Department of Mechanical Education, Konya, Turkey

Hakan ISIK

Selcuk University, Department of Electronic and Computer Education, Konya, Turkey

Abstract

In this study, a system was designed and produced to assist cold start of the first generation spark ignited LPG engine and regulate LPG fuel temperature. The produced peltier effect heating system was mounted on the gasoline engine line that was modified to run with LPG. The experiments were performed whether the mounted heating system is on or off as the environment temperature was changed from -10°C to 10°C . According to the obtained results, when the designed system is off, the engine does not start up with LPG when environment temperature below 5°C , and on the other hand the obtained best result among experimental results of this study was obtained as the engine starts up in 8 sec. when the designed system is adjusted to 50°C at the exit of the heating system and environment temperature is -10°C .

Keywords: Alternative Fuel, Cold Start, Gasoline Engine, LPG, Peltier heating

INTRODUCTION

Air pollution and climatic changes are rapidly increasing at all around the world. These negative effects occur mostly from internal combustion engines. Air pollution is increasing in developed cities of Turkey and nearly 55% of the air pollution in summer, originates from vehicles. As a result of increasing air pollution and gasoline price in many countries, LPG (Liquid Petroleum Gas) is the most preferred alternative fuel especially for city travels because of being lower emission and its cost [1,2].

According to data of Turkey Statistical Institutions, total vehicle count in Turkey is 14.316.700 and 2.592.695 of them use LPG fuel system [3]. With a different aspect, these numbers show that 18 % of vehicles in Turkey have LPG fuel system. LPG systems in vehicles are classified into three generations. Common usage type of Petroleum Gas systems are LPG spraying with third generation systems. On the other hand, the first generation LPG systems are applied to vehicles with carburetors. An important problem in the first generation LPG systems is initiation problem of engine in cold weather

condition. If an estimation is made as vast part of vehicles before 1990 using the carburetor and the first generation LPG system, it means that 210.000 vehicles have encountered to the start up problem. The second and third generation LPG systems do not face this problem because these systems start up the engine with gasoline.

There are a lot of studies on performance and combustion efficiency of LPG systems in vehicles. However, there is not enough study about cold startup problem in the first generation LPG systems. One of these studies is the study of Liu et. al. [4] that investigated cold operation characteristics about first firing cycle of LPG engine. They investigated changes of hydrocarbon emissions and in cylinder pressures at different ignition timing degrees and temperatures between -9°C and $+40^{\circ}\text{C}$. Consequently, optimum ignition advance degree was determined. Vasiliev et al. [5] studied on improvement of a heat storage device for heating fuel of an internal combustion engine. In their study, thermal accumulator working as result of absorption and casting of the heat energy in case of solid-liquid phase exchange of heat storage

substance was examined. Yamin and Badran [6] performed studies about decreasing heat loss of engine especially during operation. They used LPG among many fuels which can be alternative for gasoline, in gasoline engines. They investigated effects of mixture ratio, compression ratio, place of spark-plug and burning time in different speeds on heat loss. Chen et al. [7] studied homogeneous pre-mixing of LPG as fuel in a diesel engine. They mixed a little amount of dimethyl ester into LPG to control combustion and flame temperature. Experiments for exhaust characteristics and motor performance were performed and analytical studies were carried out about burning. Usage opportunities and problems of LPG usage in diesel engines were investigated in their experiments. As a result, it is shown that the engine can work efficiently in a wide load interval and NO_x emissions can be decreased. Price et al. [8] calculated thermodynamic performance of a LPG evaporator (regulator) in various engine working intervals in Ford Focus. The tests were performed in two different working temperatures. In addition to this, they investigated passing temperatures from gasoline to gas. At the same time, they studied the effect of various LPG compounds on engine performance and they found that fuel compounds which have similar calorific values. They have also discussed the temperature of engine cooling water in the inlet and outlet of evaporator and they stated that temperature difference between the cooling water inlet and outlet are needed to calculate heat transfer rate to the LPG in evaporator. They determined that temperature difference used in energy balance at the maximum power was 6 K.

In this study, initiation difficulty of internal combustion engines that are using the first generation LPG systems at cold weather conditions was aimed to be eliminated. For this purpose, a heating system was developed. Then experiments were performed in case of the mounted heating system was on or off, while the environment temperature is changing from -10°C to 10°C . During the experiments, environment temperature control was achieved in an air-conditioning room. Beside temperature values, initiation time periods of

the engine were measured while heating system was on and off.

EXPERIMENTAL STUDY

In the experiments, the first generation LPG system was mounted to Murat 124 marked 4 strokes, 4-cylinder engine that have carburetor in fuel system. A heating setup was also installed to LPG system. Experiments were carried out in an air-conditioned room at Selcuk University, Technical Vocational High School, Air-Conditioned and Refrigeration Laboratory. Engine and experiment system were placed in this room. Specifications of the engine that are used in experiments are given in Table 1.

Table 1. Technical specifications of test engine

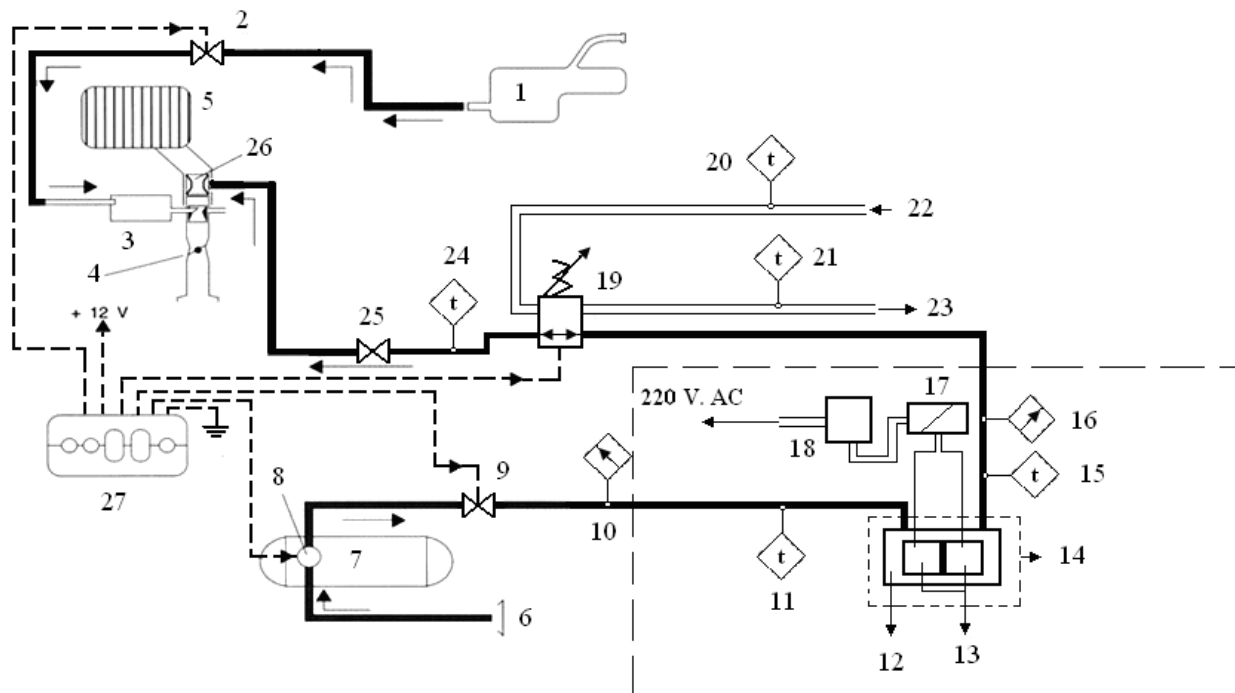
Brand	: FIAT Murat 124
Engine Type	: Line type
Working Principle	: 4 Stroke
Number of Cylinders	: 4
Cylinder Diameter	: 73 mm.
Stroke	: 71.50 mm.
Total cylinder volume	: 1197 cm^3
Compression Ratio	: 8.8/1
Maximum Power	: 60 HP (5600 rpm.)
Ignition order	: 1 – 3 – 4 – 2
Cooling System	: Water cooling

The heating system called as heating device, heats up and transmits LPG coming from storage tank and was located between regulator and gas solenoid valve. It is powered by chargeable batteries. Heater peltier plates in the heating system that are controlled by control device and relay were manufactured from copper material by using peltier effect rule. The produced heating system and experimental setup are shown in Fig. 1. LPG coming from the tank passes through heating system before entering LPG regulator and thus starting procedure of the engine becomes easier due to the occurrence of the heating.

The experiments were performed in starter period ($\sim 300 \text{ rpm}$) of the engine. Engine setup operation before starting the test experiment is that change engine oil and cooling water. Ambient air temperature was controlled by an air conditioner during the experiments. Measurements were performed when environment temperature was in the range of -10°C to 10°C , and heating device outlet

temperature was arranged as 20 °C, 30 °C, 40°C, 50°C and off condition. During the experimental process, the engine was waited to

cool down to ambient condition after completing each experiment.



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|-----------------------|-----------------------------------|----------------------------|
| 1. Fuel tank | 10. Manometer for inlet pressure | 19. Regulator-evaporator |
| 2. Fuel electro valve | 11. Thermocouple (T_1) | 20. Thermocouple (T_3) |
| 3. Float | 12. Heater plate | 21. Thermocouple (T_4) |
| 4. Throttle valve | 13. Peltier plate | 22. Cooling water inlet |
| 5. Air filter | 14. Heating system | 23. Cooling water outlet |
| 6. LPG charging hole | 15. Thermocouple (T_2) | 24. Thermocouple (T_5) |
| 7. LPG tank | 16. Manometer for outlet pressure | 25. LPG adjusting screw |
| 8. Multivalve | 17. Relay | 26. Mixer |
| 9. LPG Electro valve | 18. Temperature control device | 27. Commutator |

Figure 1. Experimental rig and its components

Each experiment was started after the engine and ambient air temperature are the same. Two temperature values were read from thermocouples as one for the beginning of 1 min. period and one for the end. Measured five temperature value results of the experiments and environment temperature were compared in table form. Because inlet temperature of LPG heating system is equal to the environment temperature at the beginning of the experiment. The temperature symbols in Figure 1 are as follows;

T_1 : Gas temperature before heating system

T_2 : Gas temperature after heating system

T_3 : Regulator inlet temperature of engine cooling water

T_4 : Regulator exit temperature of engine cooling water

T_5 : Carburetor inlet temperature of gas

At the beginning of each experiment, starting time of the engine was recorded to evaluate the performance of the designed heating system. When the engine didn't start up at the end of 30 sec. it was stated that "engine could not been worked", for the other condition starting up time was recorded. In the experiments when heating system was on, starter was pressed after the heating system was executed for 30 sec. Starter time began after 30 sec. heating time. Power source of the heating system was a battery. Thus, the batteries used for the experiments were charged.

RESULTS AND DISCUSSION

Former experiments were performed between 0°C and +10°C environment temperature and when the heating system is

off. Results of these experiments are presented in Table 2. Start up time of the engine was obtained as 30 sec., under condition of the +10°C environment temperature.

Table 2. The results of performed experiments for different environment temperatures when the heating system is off

Environment Temperature (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	Case
10	10,5	11	10.5	11.2	10.2	Engine started up in 30 sec.
	10.8	11.4	27.5	24	13.2	
5	5.1	5.3	5.6	5.5	5.5	Engine could not been worked.
	5.1	5.4	15.5	13.1	5.8	
0	0.1	0.2	0.9	0.3	0.4	Engine could not been worked.
	0.3	0.1	12.4	9	2.4	

The results of these experiments, it can be seen that the engine could not start up with LPG in and under 5 °C environment temperatures. After this observation, the experiments were repeated when the heating system was on and these experiments

constitute the second part of this study. Firstly, temperature control of the heating system was set to 20 °C. The obtained results can be seen in Table 3 when the heating system was set to 20 °C.

Table 3. The results of performed experiments for different environment temperatures when control temperature of the heating system was set to 20 °C

Environment Temperature (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	Case
10	10	10.8	10.9	10.6	11.4	Engine started up in 10 sec.
	10	15.3	27.3	23.4	13.1	
5	5	5	1.3	1.8	2	Engine started up in 20 sec.
	5	10.2	13.5	11.3	2.7	
0	0	0.4	0,8	0.6	0.8	Engine started up in 40 sec.
	0	8.6	17.8	13.8	1.7	

It can be seen from Table 3 that when the heating system is set to 20 °C, readings of the engine startup time were recorded as 10, 20 and 40 sec for the environment temperature values of 10°C, 5°C and 0°C, respectively. The measurements were planned to have in 60 sec. between the first temperature measurement and the last measurement. When entry temperature of LPG to regulator (T₂) and entry temperature of LPG to carburetor (T₅) were investigated, it can be seen that T₅ decreased somehow.

The reason of this decrease can be interpreted by means of regulator and its component heating with engine cooling water because the regulator is being heated as the engine warm cooling water passes through it. Startup time of the engine was measured as 40 sec. when the

environment temperature is 0°C. The reason of this too long time for starting can be explained that the engine could not started up with LPG. If Table 2 and Table 3 are compared for the cases in which environment temperatures are the same, start up time of the engine is 20 sec. earlier when the environment temperature is 10 °C and the engine could be started up when the system is on at 5°C and 0°C environment temperature values.

In the last stage of the experiments, a shorter start up time in lower environment temperatures was aimed with increasing temperature settings of the heating device. With this purpose, heating device was set to 30°C, 40°C, and 50°C, respectively. Results of these experiments can be seen in Table 4.

Table 4. The experiments results under conditions that the control temperature of the heating system is set to 30 °C, 40 °C and 50 °C

Setting of temperature control device (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	Case
30	-10.8	-10.8	-14.1	-12	-10	Engine started up in 12 sec.
	-10.2	-5.6	-5.4	-3.3	-9.2	
40	-6	-5.6	-7.7	-6.8	-5.4	Engine started up in 10 sec.
	-5.4	0.3	-5.6	-3.5	-4	
50	-10.8	-10.6	-12.7	-11.4	-10.1	Engine started up in 8 sec.
	-9.3	4.4	-5.8	-6.8	-8.5	

As seen in Table 4, as the control temperature of the heating system increase from 30 °C to 50 °C, the engine startup time decrease from 12 sec. to 8 sec. It was demonstrated that the engine started up in shorter time by increasing temperature of the heating system. In addition, the gas temperature in exit of the regulator is low when it is high in entry of the heating system and regulator.

CONCLUSION

In this study, performance improvement opportunities and decrease the startup time of the LPG consuming car for the first generation were examined. It was seen from the results of the performed experiments that internal combustion engines with the first generation LPG systems having troubles when initiating under ambient air temperatures lower than 5 °C or they may not start entirely. Therefore, a heating device was developed and tested. The best experimental result with the designed and tested heating system is starting up in 8 sec. under -10 °C ambient air temperature. It is recorded that the designed system eliminates initiation problem of internal combustion engines with the first generation LPG system in cold weather conditions.

As a conclusion of the performed experiments, it was seen that working period of heating device was shortened after the temperature control of the heating system was inserted and set to higher values such as 50°C. From this observation, it is determined that temperature value of electronic control unit which will be adjusted to temperature of the heating device should be determined according to ambient air temperature and LPG entrance temperature to the engine.

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