Conversion Development of Engine Management & Fuel System from Diesel to LPG on used small truck and bus(2.6L) to meet 2002 Korean emission regulation and 80,000km durability requirement.

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Abstract : This Study is to retrofit the using from diesel vehicle to LPG and develop the engine management system. The major activities are as follows; the development of engine management system, engine hardware conversion technology, the optimization of vehicle performance, low emission technology. With this process, we passed the government emission certification test. In addition to this, the mass production for retrofit is also studied.

Results of emission and durability test for certification are as follows; Durability : there was no problem during 30,000km vehicle durability test. Emission : there was good emission levels satisfying the regulation. It is necessary to secure the infra and reduce the retrofit cost for the application.

Introduction

As the air condition of Seoul city becomes worse, The EM regulation has been tightened in this area gradually. To solve this air pollution problem of Seoul city, the Ministry of Environment of Korea government enacted the "Special law for air conservation of Central city area "from 2006. It enforces the old diesel vehicle which

over the certification period of emission by OEM car maker to change into low emission vehicle as installation of Diesel Oxidation Catalyst or Diesel Particulate Filter or engine conversion to LPG or CNG under subsidies of the equipment cost by Korean central and local government. In this paper, we describe the used vehicle conversion development of LPG from diesel which vehicle was over 100,000Km driving mileage, about 3.0ton GVW. The diesel engines we studies for this paper are Hyundai Motors' D4BB/D4BA engine model(2,607/2,476cc swept volume) and Kia Motors' JT engine model(2,957cc swept volume), in-direct injection type diesel combustion chamber and NA intake system.

Low-emission engine retrofit system

Low-emission engine retrofit system is the innovative equipment by changing to LPLi electronic control system engine and installing three-way catalyst. Also, O2 sensor and ECU are installed to optimize Three-way catalyst efficiency. And air-fuel ratio of mixture into engine is controled to stoichiometric air-fuel ratio by O2 sensor feedback.

LPLi(Liquid Phase LPG injection) system

LPLi system doesn't turn to tank pressure as mechanical LPG fuel line. it has fuel pump in tank and the pump sends out high pressure LPG as far as injector. Finally, Liquefied LPG is sprayed to operate engine by injector.

Unit	Function
Pump Module	Pump module consists of multi-valve and pump and it sends out LPG in the fuel tank in the form of liquid by pump
Regulator unit	Regulator unit keep up the differential pressure and various kinds sensor is installed.
Intake manifold unit	Intake manifold unit is a module organizing injector and fuel line.
Pump driver	Pump driver has a function to control motor in fuel tank as five steps.

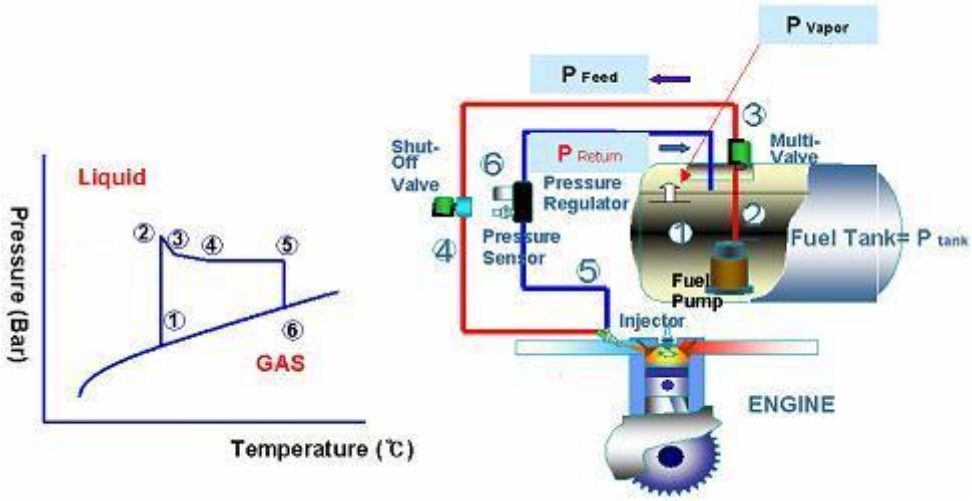

Fig. 1 Flow of LPLi fuel

LPLi system is similar to gasoline engine. Injection method is sprayed by injector from compressed liquefied LPG in the tank. Basic pressure in the tank is keep up +5bar from fuel pump. Generally fuel line pressure is 5~15bar(depend on fuel tank pressure). Output of pressure · temperature sensor in pressure regulator sends out to ECU and it is analyzed by P-T(pressure-temperature) characteristic graph. ECU instructs injector to keep injecting from feedback.

Fig. 1 shows the function and each unit of LPLi injection process. This low emission engine is the same grade power and low emission performance as gasoline engine from LPLi(Liquefied LPG sprayed to intake port). Weak points of existing mechanical mixer have a limit about low power, bad fuel efficiency, tar, back fire and strengthened EM regulation. Whereupon LPLi system has advantages as follows.

LPLi control system

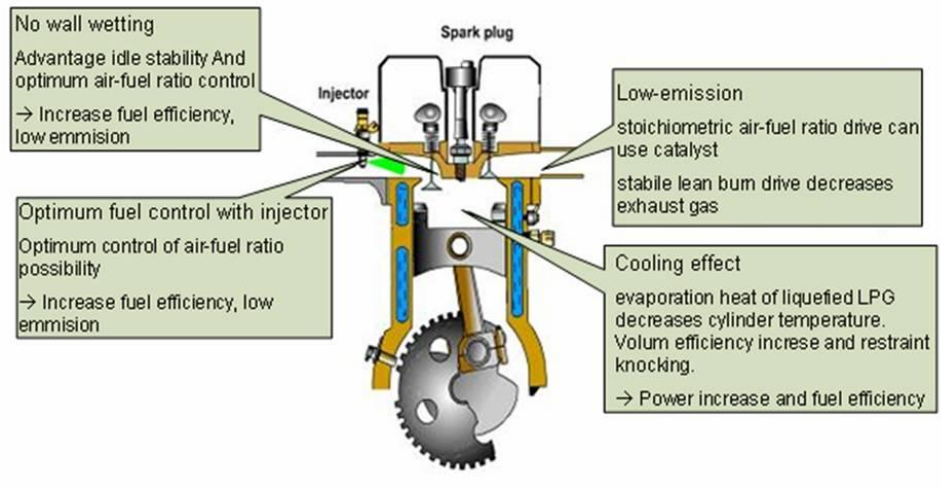

Fig. 2 Advantage of LPLi system

◎ **General**

LPLi system consists of sensor for engine state, ECU for system controls from sensor output signal and actuator. ECU controls injection, idle speed, ignition and so on. It has various diagnosis test mode, so if engine has a trouble, it can check the trouble easily.

◎ **Injection control**

SOI(Start Of Injection) and injection duration are under the control of ECU. It realizes optimum stoichiometric air-fuel ratio during the continuous engine operation. Each injector is placed on intake manifold which is linked cylinder-head intake port.

Fuel pump performs the supplier from fuel tank to injector on regular pressure. And, fuel pressure regulator adjusts this pressure.

If the engine state is cold or heavy load, ECU performs open loop for keeping up engine performance. So ECU supplies rich mixture to engine. And If the engine state is hot or steady, ECU performs closed loop. At this time ECU catches the signal from O_2 sensor and controls SOI or duration to realize stoichiometric air-fuel ratio high efficiency of three-way catalyst.

◎ **ISA(idle speed actuator) control**

During idling time follow engine load to keep up optimum idle speed, by-pass air mass is controlled through the throttle by ISC(Idle Speed Controller)

ECU drives ISC to keep idle speed about engine load in idling. When engine is idle speed, owing to air-conditioner switch(ON/OFF) idle speed can change, this time ISC motor maintains idle speed

◎ **Ignition control**

Ignition power transistor is located in ignition circuit built in ECU. Transistor is being controlled to ON/OFF primary current. this control provides optimum ignition about engine working state. Ignition has been decided by engine speed, mass air flow, coolant temperature and atmospheric pressure by ECU.

◎ **The others control function**

- Fuel pump control : When Engine is cranking or working, supply an electric current to fuel pump, turn on the fuel pump relay.

Construction detail explanation.

◎ **LPLi fuel tank**

LPLi fuel tank is different from the existing mixer type fuel tank. Fuel pump exclusive uses LPG to keep up liquid phase for all fuel line installed in the tank. At this point in time used pump is the same as HMC and KMC but the tank and position of bracket is altered set to test vehicle. LPLI tank replaces the existing diesel tank.

◎ **Fuel pressure regulator module**

Fuel pump in tank sends out high pressure fuel to fuel pressure regulator module. Pressure in line is always kept up +5bar by use balance between diaphragm and spring.

◎ **IFB(InterFace Box)**

IFB decides the amount of injection and supply to injector from revolution per minute of pump. IFB is received engine rpm, TPS(Throttle Position Sensor) and fuel rail pressure etc. from ECU and control injector, pump driver GTS(Gas Temperature Sensor) and GPS(Gas Pressure Sensor). also, If pump has a problem, it sends a beep to driver itself.

◎ **ECU(Engine Control Unit)**

ECU is developed by Engine Tech. Exclusive use of LPLi ECU verifies a fuel characteristic and then controls the engine at the same condition all the time. Also, It judges a abnormality by sensor, If sensor fails, ECU sends out basic signal to stabile drive.

◎ **Ignition Coil**

Ignition coil is located on the cylinder head cover, and High-voltage current is supplied Ignition plug at cylinder head to use a hi-tension cord

◎ **Cylinder head**

Cylinder head is processing good that is tested airtight test after precision manufacture about ignition plug tap, valve and valve-seat lapping and grinding process under the cylinder head and so on to Injection nozzle location of diesel engine cylinder head

◎ **Injector**

In order to spray liquefied LPG Injector is installed icing-tip to prevent moisture freezing phenomenon due to vaporization latent heat after injection. When needle valve of injector is open, high pressure fuel through pressure regulator is jetted to cylinder. At this time injection volume is regulated by only injection duration because injector has uniform hole size. Injection duration is controlled by IFB(Inter Face Box).

◎ **Three-way catalyst**

Three-way catalyst function is purification that is made by process of combustion, through the oxidation and reduction. TWC shows best efficiency at stoichiometric air-fuel ratio.

◎ **Throttle body**

Driver can control engine power through air mass flow into engine throttle body of intake manifold. ECU receives feedback from TPS(Throttle Position Sensor) and engine is operated by order of driver. ISC(Idle Speed Controller) makes constant rpm on idle, and operates to warm-up a vehicle.

EMS diagram

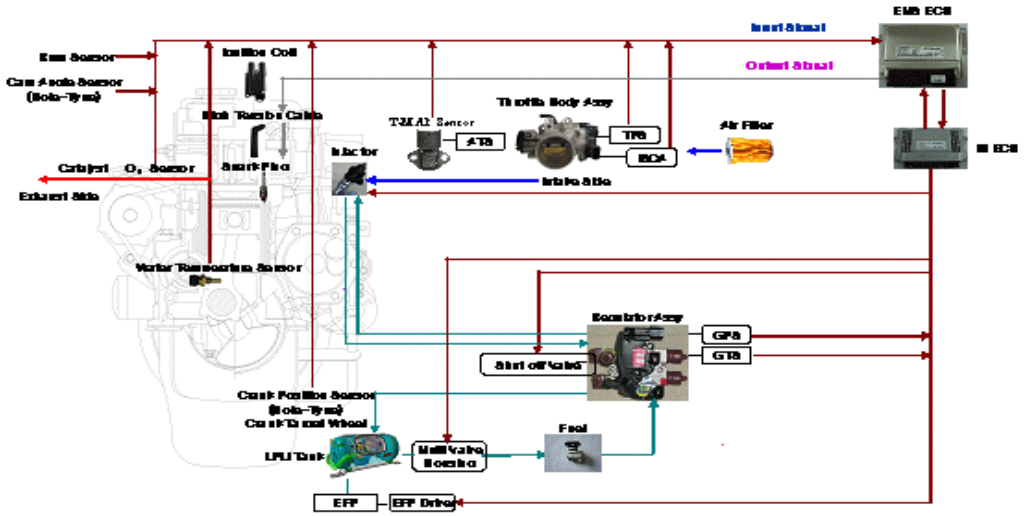

Fig.3 Schematic of engine management system

Experimental method and set up

Engine dynamometer test

◎ **Test purpose** : ECU development and performance test of HMC D4BB-L engine

◎ **Test condition** : KSR0071 regulation A condition

◎ **Test method**

Table. 1 Engine dynamometer test

		Contents		Remark
		#1 vehicle	#2 vehicle	
Test place		Engine Tech #3 cell		
Dyno.	Maker	Meidensha Electronic Mfg. Co., Ltd.		
	Type	Meiden Eddy Current Dynamometer		
	Absorbing Power	31.4/110kw		
	rpm	900/3,150 ~ 8,000 rpm		
Engine specification	Engine name	D4BB-L	JT-L	
	Displacement	2,607	2,957	
	Compression ratio	9.5	10.46	
	Aspiration	NA		
	Fuel	LPG		
Test details		Full Load & Partial Load Performance		
		Exhaust gas temperature and other temperature ・ pressure condition		
		Optimum air-fuel ratio, ignition, injection duration mapping		

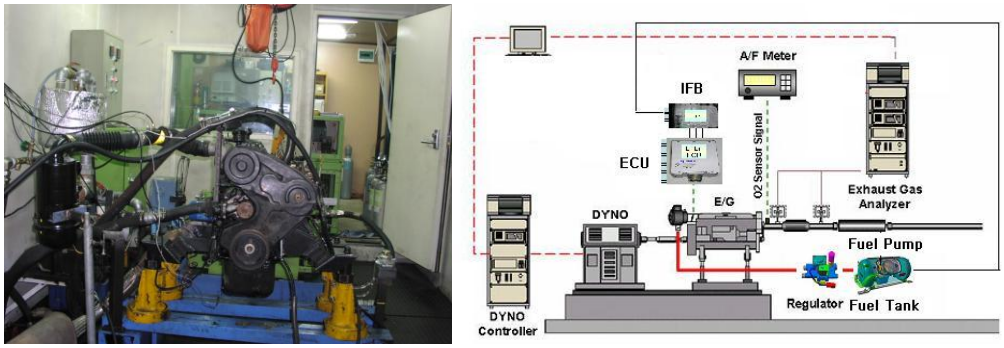

Fig. 4 Engine dynamometer(#3 Cell) and schematic of engine dyno. system

◎ Organization of engine test system and specification

Table. 2 Engine test system and specification

	Model / Maker	Specifications
Engine dynamometer	Meidensha Electronic Mfg. Co., Ltd.	.Water-cooled eddy current type .Max. absorption power : 110KW .Max. speed : 8,000 rpm .Max. toque : 31.4 kg-m/ 3,000 rpm
Exhaust gas analyzer	EXL-2300/Firm Tech	.THC analyzer : FFI-102(FID) .NO/NOx analyzer : FCL-103(CCD) .CO(H/L) analyzer : FIR-700(NDIR) .Flow controller, Sampling line, etc.
Air flow meter	Laminar type air flow meter	
A/F meter		.ETAS: Lamda meter V4.0

Vehicle driving performance test

◎Test outline

Test purpose : Driving performance of HMC D4BB-L, KMC JT-L engine transfer to estimate LPLi engine.

Test method

Table. 3 Vehicle test items

	#1, #2 vehicle
Place	Song-do new town
Contents	Vehicle driving performance
	Exhaust gas temperature and various pressure·temperature data acquisition
	ECU Mapping Data
Equipment	D4BB-L DAQ System

Exhaust gas performance test

◎Test outline

Test purpose : In order to estimate emission of test vehicle.

◎Test method

	#1 vehicle	#2 vehicle
Place	Agency for Technology and Standards	
Contents	Exhaust gas performance test	
Equipment	D4BB-L DAQ System	

◎Chassis dynamometer specification

	Model / Maker	Specifications
Chassis Dynamometer	Crayton	Model : EC-50 Spec : Type : Hydrauric Max. speed : 140KPH
Motor Exhaust gas analyzer	MEXA-8420/Horiba	AC100V, 60Hz RECO-1V
λ meter	ETAS	Model : Lambda meter V4.0

Results

Engine dynamometer test result

		Torque (kg-m/rpm)	Power (Ps/rpm)	Exhaust gas temp.(℃)	Remark
#1 vehicle	Diesel	18.0/2200	82/4200	740	Standard of a new car
	LPLi	18.7/2000	86/4200	755	
#2 vehicle	Diesel	19.5/2000	90.0/4000	750	Standard of a new car
	LPLi	20.5/2000	94.3/4000	758	

Vehicle driving performance valuation item and result

		Diesel	#1 vehicle	#2 vehicle	Remark
Acceleration	0→200m	15.7 sec	14.1 sec	14.2 sec	3rd, 4th, 5th
	3rd gear(20→80km/h)	12.5 sec	10.6 sec	10.7 sec	
	4th gear(20→90km/h)	14.8 sec	13.1 sec	14 sec	
	5th gear(20→120km/h)	35.4 sec	33.5sec	32.5 sec	
Max. speed	Rated Rpm	126 km/h	143 km/h	147 km/h	5th
발진가속	0→100km/h	20.8	19.3 sec	16.2 sec	3rd, 4th, 5th
Outsail acceleration	4th(60→100km/h)	12.3	11.5 sec	9.5 sec	4th

※3 times Average

Emission test

		CO[g/km]	HC[g/km]	NOx[g/km]	Test mode
EM. regulation	Before 2002. 06.	3.11	0.29	0.43	CVS-75
	After 2002. 07.	2.73	0.10	0.43	
#1 vehicle		1.11	0.06	0.18	
#2 vehicle		0.7	0.05	0.13	

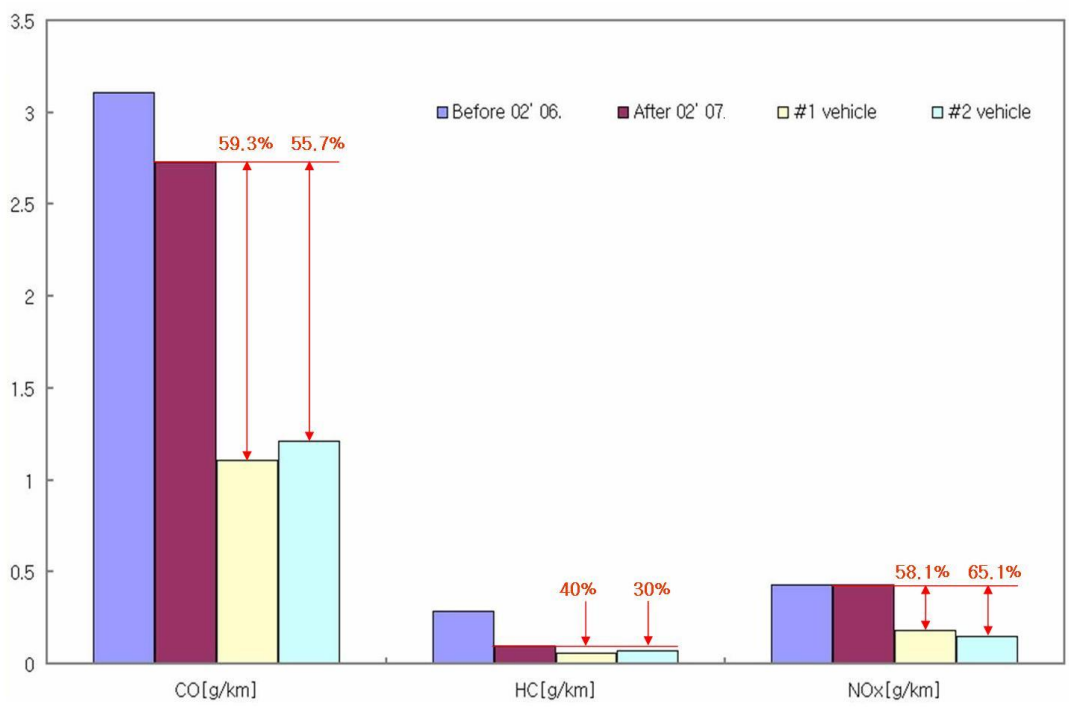

Fig. 5 Emission test graph

Conclusion

When diesel engine is changed to low emission engine, We confirmed enough retrofit possibility and chose parts from experiment.

1. Engine dynamometer test result, low emission engine has better performance than diesel engine of standard of a new car. Exhaust gas temperature also shows similar level, so we confirmed durability.

2. Vehicle driving performance test result, low emission vehicle has improved data. It shows that low emission vehicle doesn't have any problem to drive after retrofit.

3. Exhaust gas performance test result, we gain improved result of CO-58%, HC-35%, NO_X-62% compare to the before 02' 06. regulation. The result is also satisfying after 02' 07. regulation.

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