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Expectation for Diesel Passenger Cars in Thailand

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Abstract— **Due to the sub-prime economic crisis, many countries introduced tax incentives for fuel efficient cars which also reduce CO2 emission. In Japan, many hybrid cars were sold in 2009. In Europe, diesel passenger cars are very popular because of their fuel economies. Diesel emission regulations have become more stringent and new emission technologies have been proposed which will be satisfied with Euro5. In Thailand, Euro4 emission regulation will be introduced in near future. Tax incentives for clean and fuel efficient diesel passenger cars in Thailand can be expected.**

Keywords— **passenger car, diesel, emission, CO2, tax incentive, fuel economy**

I. Introduction

In Japan, tax incentives have been introduced for electric, hybrid and clean diesel cars (Eco Cars) in 2009. As a result, hybrid car sales were so successful that the number one sale was Toyota Prius 208,876 and 8th was Honda Insight 93,283 (new car sales were 4.6million in 2009). In Thailand, Toyota started to produce Camry hybrid in 2009 and 60% of sales of Camry became hybrids. On the other hand, diesel engines became very popular for luxury passenger cars. BMW Thailand said that two thirds of sales were of diesel-engine vehicles. But there are few choices of diesel engine for popular passenger car category in Thailand. Because of lower CO2 emissions, diesel engine vehicles became over 50% in Europe and tend to increase in USA and Japan. On the other hand, diesel emission regulations have become more stringent as shown in Fig.1, and new emission technologies have been proposed. Using high pressure common rail injector and large amount EGR (Exhaust Gas Recirculation) control system, combustion was improved to reduce emissions. Because of emission system deteriorations, controlling low level PM and NOx emissions seems a very difficult problem. To keep emissions lower, after treatment system will be needed concurrently. Considering diesel emission control system applicable for Thailand's Euro4 regulation, tax incentive for clean diesel will be discussed which will be effective to reduce CO2.

II. DIESEL EMISSION TECHNOLOGIES

Car manufacturers continue developing diesel emission technologies to satisfy stricter emission regulations. Gasoline emissions became very low using TWC (Three Way Catalyst). On the other hand, diesel exhaust contains high oxygen percentage, so that TWC cannot be applied. Main strategy to reduce PM and NOx has been used to continue to improve combustion. Continuously, EGR with turbo charging, DOC (Diesel Oxidation Catalyst) and CRS (Common Rail System) have been introduced.

A. SUBJECTS OF DIESEL EMISSIONS

TWC for gasoline engine has given quite high reduction performance, over 95% for CO, HC, NOx after having been activated. Hence, main strategy is to target at reducing raw emissions during cold period before TWC activates, and control A/F to stoichiometry after TWC has activated.

Diesel exhaust gas contains less CO, HC and more PM and NOx than gasoline engine. Diesel combustion is very lean, so CO and HC can be oxidized with DOC. Hence, main strategy is to target reducing PM and NOx. There is a trade off relationship between PM and NOx. PM will increase during incomplete combustion (lack of oxygen, low combustion temperature), NOx will increase during complete combustion (Nitrogen oxidization occurs at high combustion temperatures). Reducing emissions, there are three technologies like improvement of combustion, improvement of after treatment and improvement of fuel.

B. IMPROVEMENT OF COMBUSTION

Using CRS, multiple injections could be applied according to engine load and revolution as shown in Fig. 2 and 3(1). Pilot injection will be used for PCI (Premixed Compression Ignition) and post injection will be used for controlling temperature of after treatment devices. Fuel injection pressure became higher, 200MPa when using piezo type injector as compared to 160MPa when using solenoid type injector.

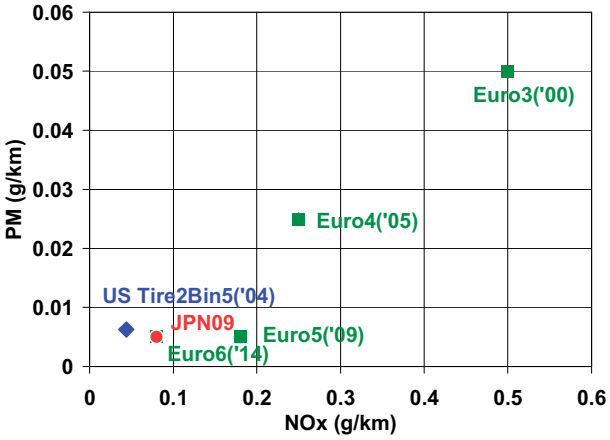

Fig.1 Diesel Emission Regulations for Passenger Cars

Utilizing optimum multi-stage injection, cooled EGR and VGT (Variable Geometry Turbocharger) contributed to lower emissions and high engine performance. Some cars reached to Euro4 emission level with these improvements and modified DOC (Fig.4). Heavy vehicles like SUV need additional after-treatment system. EGR is very important for reducing NOx, but there are some subjects like carbon deposit inside the passage which will change EGR rate. One countermeasure is "clean EGR", introducing exhaust gas after DPF (Diesel Particulate Filter). In this case, EGR passage becomes longer and its response becomes slower, so a modern control technology must be taken. There are new technologies like two-stage turbocharger or dual-loop EGR which will cover wider range with higher performance.

PCI is useable for reducing PM and NOx simultaneously but applicable for only low load condition (Fig.5). Pilot injection and high EGR rate (for example 60%) will help low temperature slow combustion which cause quite low PM and NOx emissions. Controlling the ignition timing is so important that combustion pressure control will be needed against fuel specification dispersion and EGR/injection deterioration. Further, there is a subject of control method during transient mode between PCI combustion and conventional combustion. Due to the difference of responses between air (especially EGR) and fuel injection, emissions and noise will increase during transient period. For example, EGR rate will change from 60% to 30% at certain combustion switching point. Hence, switching control method to overcome these subjects is very important.

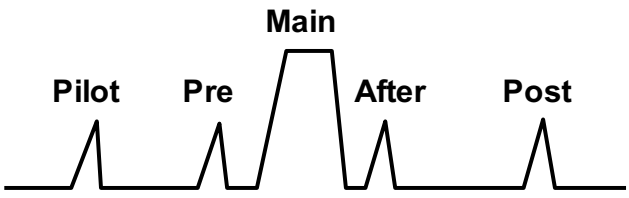

Fig.2 Multiple Injections

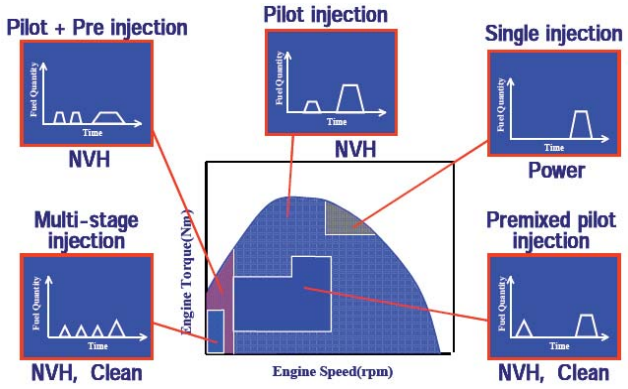

Fig.3 Examples of Multiple Injections (1)

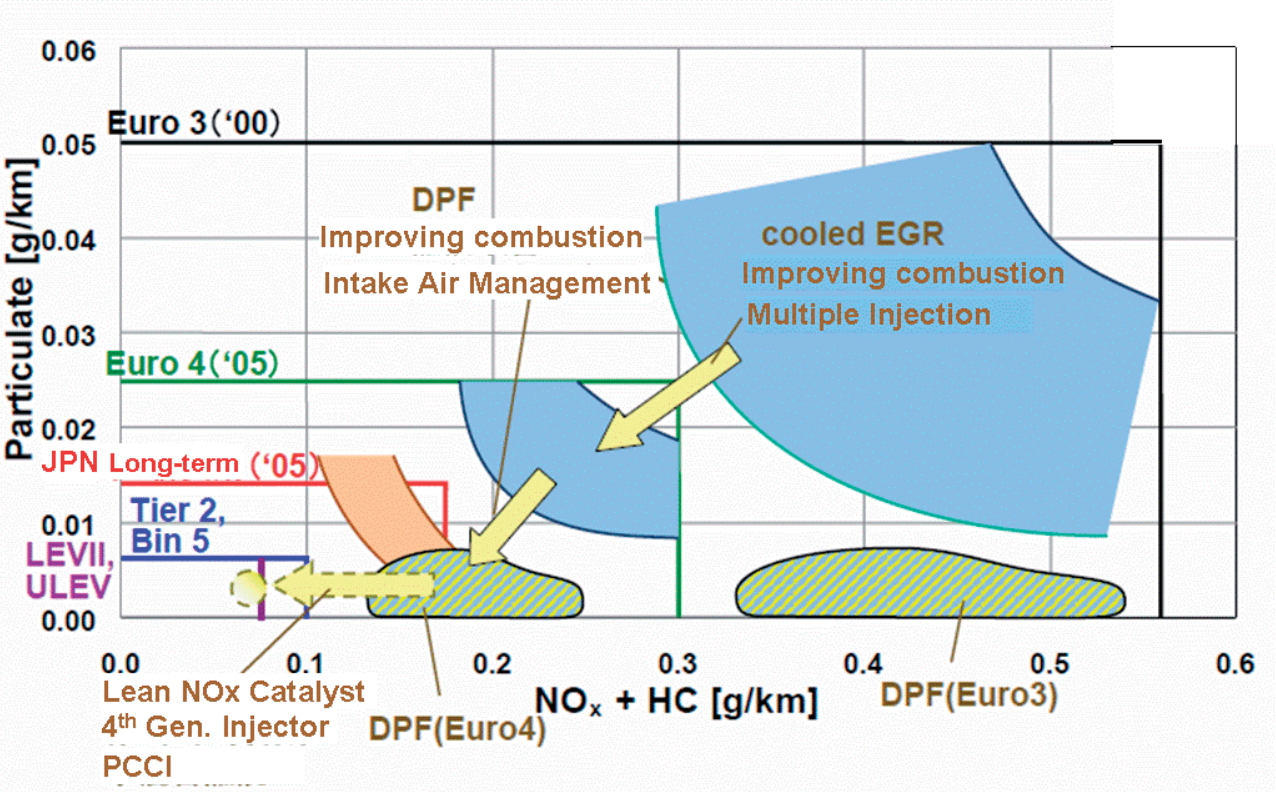

Fig.4 Improvement of Emission System

C. AFTER TREATMENT SYSTEMS

1) Temperature Management System

Comparing with gasoline engine, diesel exhaust gas temperature is very low. With current technology for a gasoline engine, a closed couple catalyst may activate within 20seconds after cold start of US EPA federal test mode. For diesel engine, it will take longer and catalysts temperature will drop during deceleration and idling. For the purpose of early catalysts warming up and keeping catalysts activated, a temperature management system using special combustion contributing catalysts temperature and post injection is necessary. It will be useful for DPF regeneration, too.

2) PM Reduction System

DPF system shown Fig.6 is a mainstream after treatment to reduce PM emission (1). PM trap rate will be over 90%. DPF will be filled with soot according to vehicle mileage, so DPF regeneration is an important technology. For the purpose of continuous regeneration, catalysts tend to be equipped with DPF to improve soot oxidization efficiency at lower temperature. But in case of urban traffic, average vehicle speed tends to be very slow that DPF temperature may not be sufficient for continuous regeneration. Hence, active regeneration must be conducted to burn soot before clogging will occur. Soot will start to burn very slowly around 300degC but DPF temperature will be controlled around 600degC for more efficiently active regeneration. DPF temperature must be controlled under certain temperature limit of DPF to prevent a thermal damage. Regarding materials, SiC (Silicon Carbide) is better than cordierite because of thermal resistance. Cordierite has a cost merit so it's under development. Active regeneration consists of two stages, one is catalyst activation stage the other is DPF temperature control stage. Using intake air shutter valve and fuel injection arrangement with post injection, catalyst temperature will become activated over 200degC. Next, DPF temperature will be controlled around 600degC using post injection which will be burnt in the catalyst to produce heat. During active regeneration, fuel economy and emissions become worse. Because of post injection, fuel will return to intake air passage through EGR. This will affect engine torque and EGR valve thermal deterioration. Additionally, down-flow catalysts may be deteriorated by the heat of DPF regeneration. Estimating catalysts deterioration, heat and interval of DPF regeneration must be taken account.

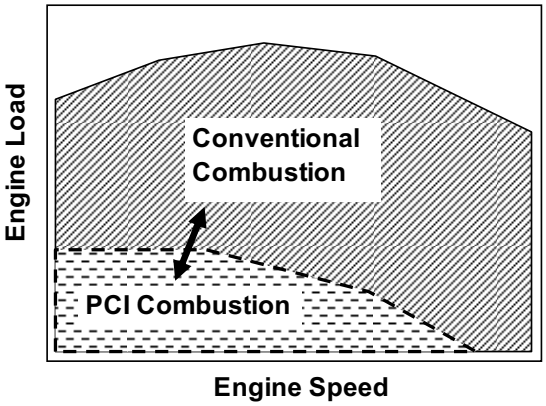

Fig.5 PCI Combustion Zone and Switching

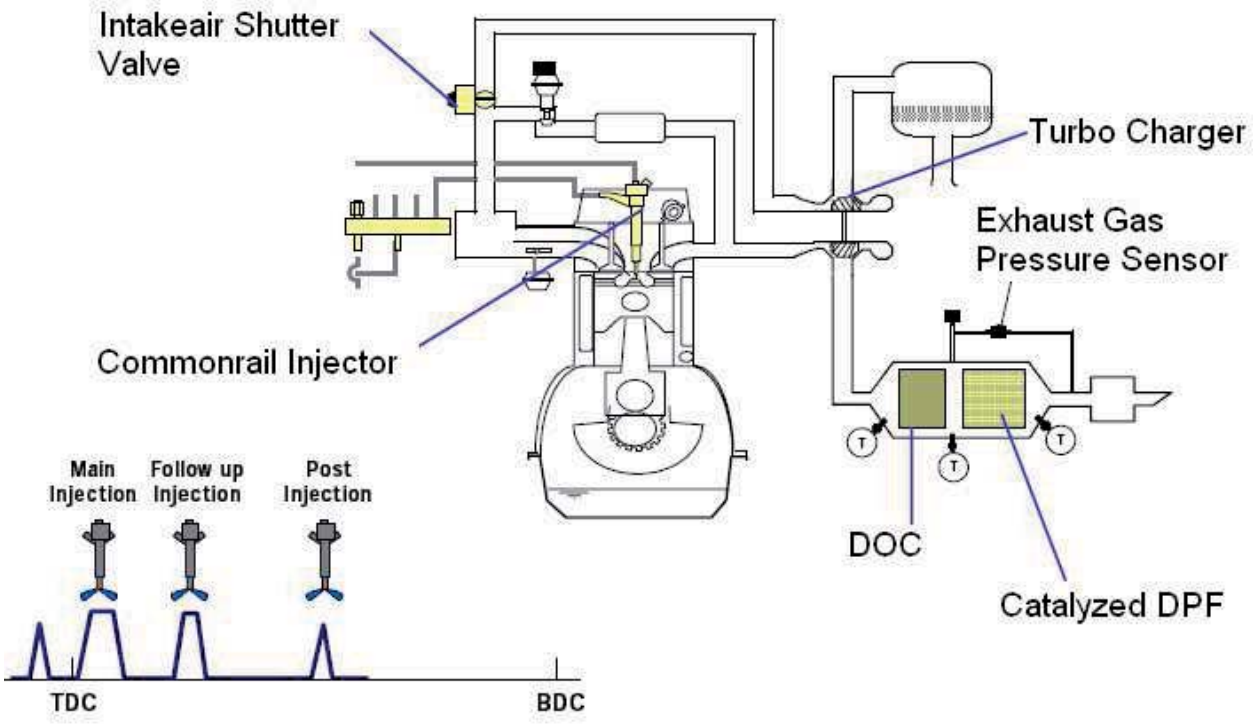

Fig.6 DPF system (1)

3) NOx Reduction Systems

There are two majority of NOx after treatment systems. One is Urea SCR (Selective Catalytic Reduction) system using urea solution for reductant which starts to be fitted with heavy duty vehicles and some passenger vehicles. The other is LNC (Lean NOx catalyst) system under development for diesel passenger vehicles. LNC is very sensitive against sulfur contents in fuels. NOx after treatment system will be needed for Euro5 emission level.

III. EURO4 EMISSION SYSTEM IN THAILAND

Emission standard of passenger vehicle will be enforced from Euro3 to Euro4 in 2012. Sulfur content limit of diesel fuel is currently 350ppm which will change to 50ppm after 2010 (Table.1). This amount is acceptable for Euro4 emission regulation but too high for Euro5 to apply LNC. As shown in Fig.4, 2L class diesel passenger vehicle will meet Euro4 with neither DPF nor LNC. For heavy weight SUVs, DPF application may be needed. If the regulation will be enforced further, government has to consider reducing sulfur content or infrastructure of urea solution.

IV. TAX INCENTIVES IN THAILAND

Based on the energy policy increasing biofuels, auto excise taxes were decreased in 2008 (Table.2). Biofuel prices were kept lower with tax incentives. These factors accelerated gasoline passenger car sales in 2009. But Ethanol-containing fuels will make fuel economy worse because of the lower heat of combustion of ethanol (Fig.7). In case of E20, fuel economy will decrease 7%.

Customers tend to choose better fuel economy vehicles due to higher fuel prices. As well known, diesel engines are 20 to 30% better than gasoline engines in fuel economy. For example, Table.3 shows a compareson of Ford Focus. There are difference of transmissions, 5MT or 4AT for gasoline engine and 6DCT (Dual Clutch Transmission) for diesel engine. Comparing 5MT gasoline and 6DCT diesel, fuel economy of diesel (50.4mpg) is 27% better than gasoline (39.8mpg). But there is tax incentive for E20 adapting gasoline engine car, excise tax is 25% against 30% of diesel model. Sales price of diesel model is 200,000THB higher that includes the additional equipment of traction and stability control system. For UK model, a price difference between diesel engine and gasoline engine is £1278 (70000THB).

Most of customers in Thailand may not be aware of the current diesel passenger car performance. Japanese manufacturers, accounting for 90% market share, do not introduce diesel model passenger cars in Thailand, because they sell largely US model cars in Thailand.

Fuel price of B5 (5% biodiesel) is approximately 10% cheaper than E20 (Table.4). Supply of E20 and E85 are still limited around Bangkok. In case the difference of price between diesel and gasoline become more appropriate, consumers could get a benefit of choosing diesel models because of their better fuel consumptions. Introducing tax incentive in Thailand for Euro4 fuel efficient diesel cars will help increasing customer's choice, their sales and CO2 reduction.

TABLE.1 COMPARISON OF DIESEL FUEL SPECIFICATION

	Thailand	Japan	Europe	USA
Cetane Number	≧ 47	≧ 48	≧ 51	≧ 40
Sulfur Content	350≧ 50≧(2010?)	10 ≧	10 ≧	15 ≧ phase in 80%(2006) 100%(2010)

TABLE.2 TAX INCENTIVES IN THAILAND

Engine Size	Standard	E85	E20	Eco-car
0-2,000cc	30	25	25	17
2,001-2,500cc	35	30	30	
2,501-3,000cc	40	35	35	
>3,000cc	50	35	35	

unit : %

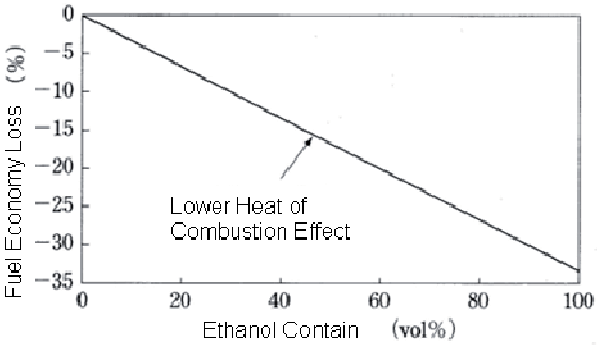

Fig.7 Fuel Economy of Ethanol Contain Fuel (2)

TABLE.3 FORD FOCUS FUEL ECONOMY IN EU MODE

	2L gasoline		2L diesel
Transmission	5MT	4AT	6DCT
Urban(mpg)	28.8	25.2	38.2
Extra Urban(mpg)	52.3	46.3	61.4
Combine(mpg)	39.8	35.3	50.4
CO2(g/km)	169	189	144
Price(THB)	not sale in Thailand	949000	1149000

MT = manual transmission

AT = automatic transmission

TABLE.4 FUEL PRICES IN THAILAND (3)

Retail Prices in Bangkok & Vicinities Unit : Baht/Litre	PTT	BCP	Shell	Esso	Chevron	PT	Susco	Pure	Petronas
Gasohol 95 - E10	32.64	32.64	32.64	32.64	32.64	32.64	32.64	32.64	32.64
Gasohol 95 - E20	30.34	30.34	-	-	-	-	-	-	-
Gasohol 95 - E85	18.72	18.72	-	-	-	-	-	-	-
Gasohol 91 - E10	31.84	31.84	31.84	31.84	31.84	-	31.84	-	31.84
ULG 95 RON	-	-	-	-	41.24[1/]	42.44	42.04	-	41.84
UGR 91 RON	36.24	36.24	-	36.24	36.24	36.24	36.24	36.24	36.24
HSD, 0.035%S	28.59	28.59	-	28.59	28.59	28.59	28.59	28.59	28.59
HSD - B5	27.19	27.19	27.19	27.19	27.19	27.19	27.19	27.19	27.19
Effective Date	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan

V. CONCLUSIONS

Current diesel passenger car performance will be attractive for customer in Thailand. Achieving Euro4 emission for 2L class passenger cars may not be so difficult without DPF which increases cost. Introducing tax incentive in Thailand for not only gasoline cars but also fuel efficient clean diesel cars will help increasing diesel models and their sales. Further more, it will help biofuel usage and CO2 reduction.

ABBREVIATIONS

EGR : Exhaust Gas Recirculation
TWC : Three Way Catalyst
DOC : Diesel Oxidation Catalyst
CRS : Common Rail Syatem
PCI : Premixed Compression Ignition
VGT : Variable Geometry Turbocharger
SUV : Sport Utility Vehicle
DPF : Diesel Particulate Filter
PM : Particulate Matter
SCR : Selective Catalytic Reduction
HDV : Heavy Duty Vehicle
LNC : Lean NOx Catalyst
5MT : 5speed Manual Transmission
4AT : 4speed Automatic Transmission
6DCT : 6speed Dual Clutch Transmission

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