July 12, 2006
International Seminar on Low Emission Aspect and Combustion Control for Engine Systems

HITACHI
Inspire the Next

Development of a Gasoline HCCI Engine Control System

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2. Multivariate Analysis
3. HCCI Control Concept
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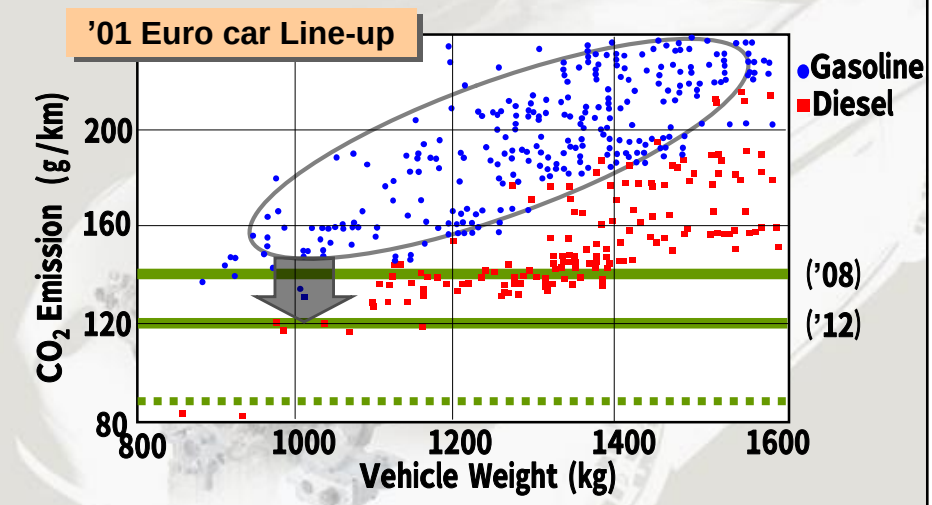
CO_2 Emission in Euro Car

1



Low Fuel Consumption Technology in Gasoline Engine (Down-Sizing, Direct Injection…..)

Development Target

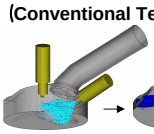
2

Comparison : L4 / 2.0L (DS: L3 / 1.5L + Turbo), EuroV

		Gasoline PFI	Gasoline DI		Diesel	Gasoline HCCI
Main Compo-nent	Intake	Intake VTC	Intake VTC (DS: Turbo)		Turbo, Intercooler	Int. / Ex. VEL + VTC
	Fuel Supply	0.3 - 0.5 (MPa)	10 – 15 (MPa)		180 – 220 (MPa)	10 – 15 (MPa)
	Exhaust (Catalyst)	3way	3way	3way, DeNOx	DPF, Oxi. DeNOx	3way
Fuel Consumption @ NEDC		0% (Base)	NA : -6% DS : -10%	-15%	-30%	-20%
System Cost Index (approximation)		1.0 (Base)	NA: 1.1 DS: 1.1-1.2	1.2- 1.4	1.6 – 2.0	1.2 - 1.3
Features		Emission Cost	Fuel Economy		Fuel Economy High Power	Fuel Economy Torque Res.

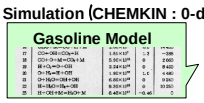
Approach

(Conventional Technology)

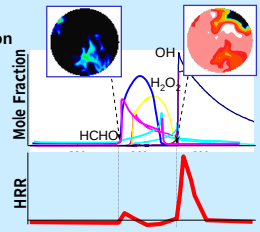


Direct Numerical Simulation

Chemical Reaction Process Simulation (CHEMKIN : 0-dim.)



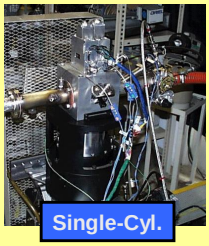
Development of 3-Dim. HCCI Simulator



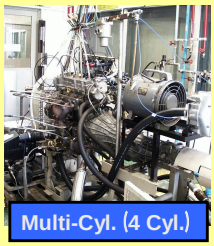
Combustion Analysis Parameter Survey

Concept Decision (System, Component)

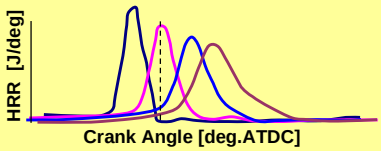
Experimental Approach



Single-Cyl.

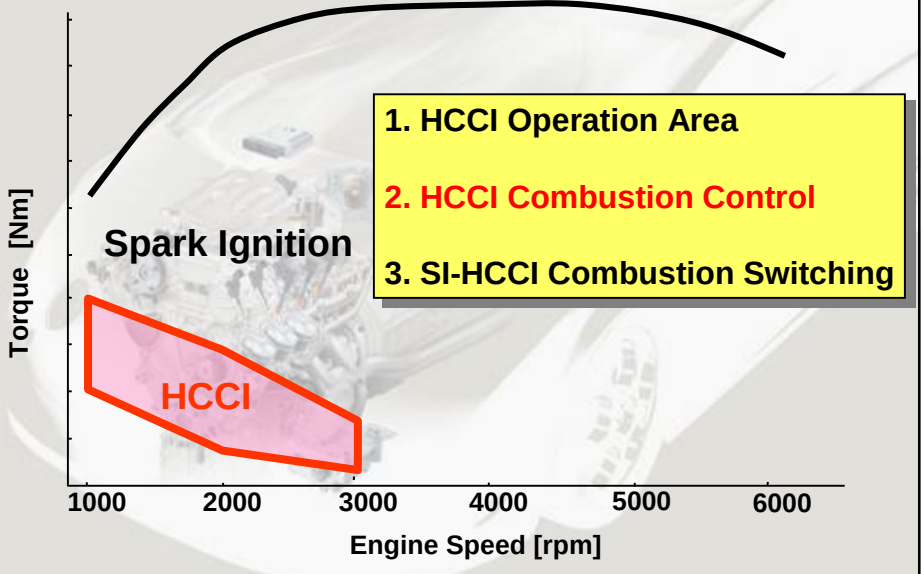


Multi-Cyl. (4 Cyl.)



- Single : Parameter Survey, Visualization
- Multi : Combustion Control Method
  Engine Performance Evaluation

Challenge for HCCI Engine

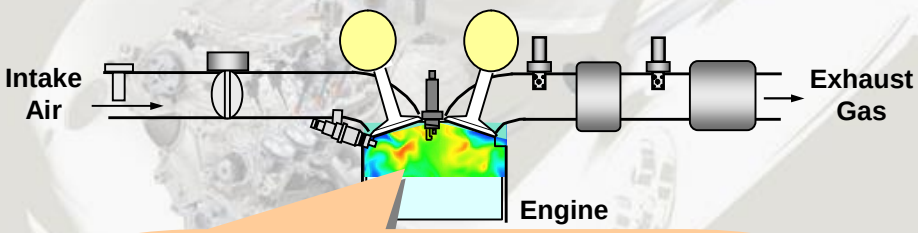


1. HCCI Operation Area
2. HCCI Combustion Control
3. SI-HCCI Combustion Switching

HCCI Combustion Control

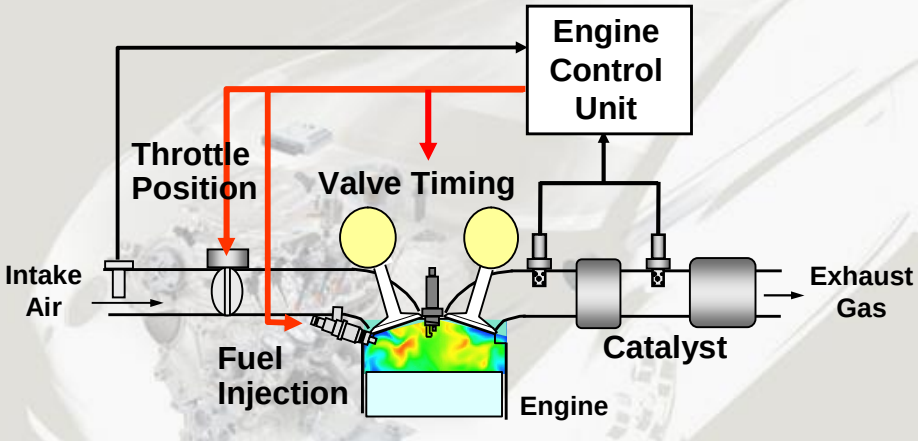
Auto-ignition and combustion occurs through chemical reaction processes.

Physical parameters influence HCCI combustion



Temperature, Pressure, Turbulent Flow, Air / Fuel Mixture…..

HCCI Combustion Control



HCCI operation must be controlled by engine parameters

Objectives

+ Clarify the correlation between engine parameters and HCCI combustion stability

+ Construct the HCCI control concept

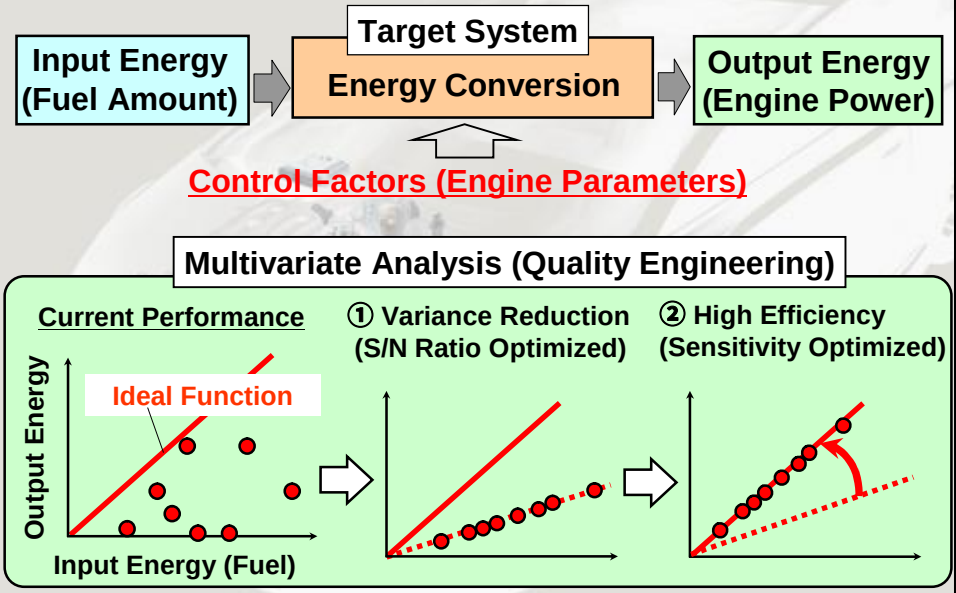
+ Evaluate the engine performance

The Possibility for the Future Engine System

Multivariate Analysis

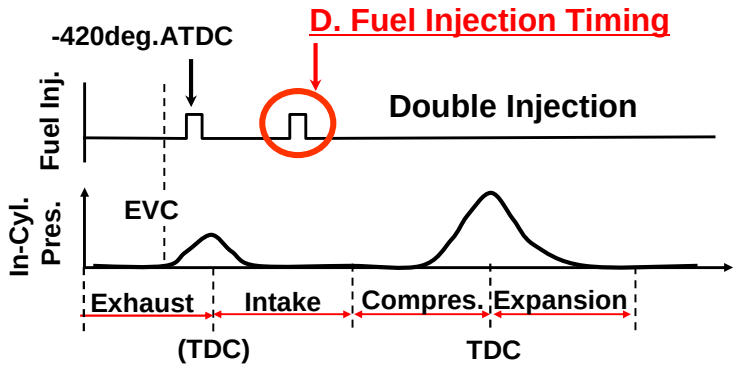
- Correlation of Engine Parameters and HCCI Combustion Stability -

Multivariate Analysis



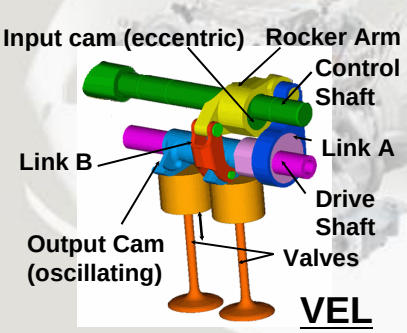
Experimental Design

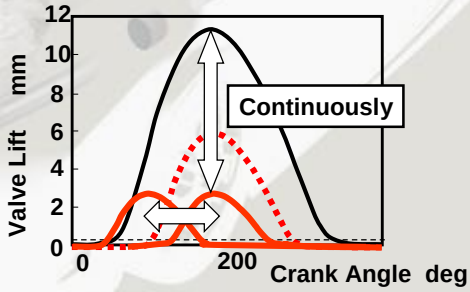
Input Energy - Amount of Fuel / Cycle (12, 16, 20mm^3)
* Engine Speed (1000, 2000, 3000r/m)
Output Energy - Indicated Engine Power [kW]
Noise Factor - Octane Number (91, 100)



Engine Specifications

4-Cylinder Engine (L4 : 4-Stroke)	
Bore x Stroke	89 x 80.3 mm
Displacement	1998 cm^3
Fuel Supply System	Direct Injection
Valve timing	Variable



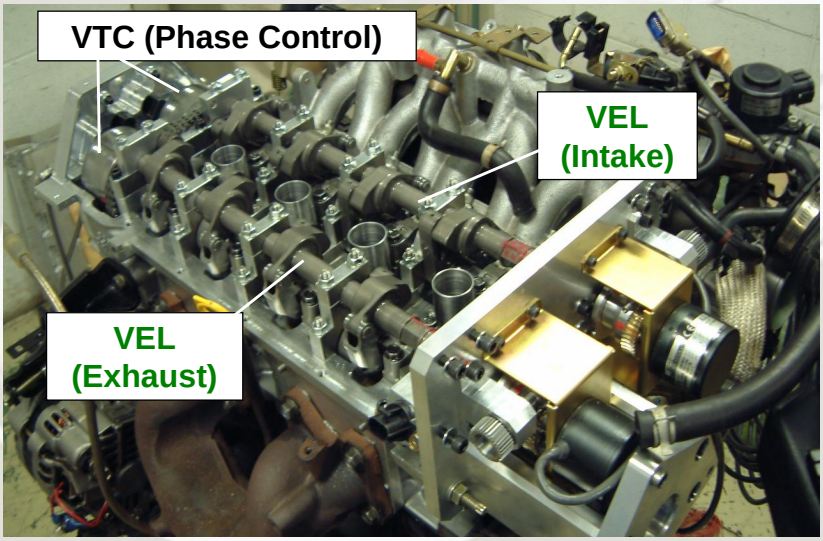


VEL : Variable valve Event & Lift

Y. Yamada, etc, JSAE Transactions 20015065, 2001

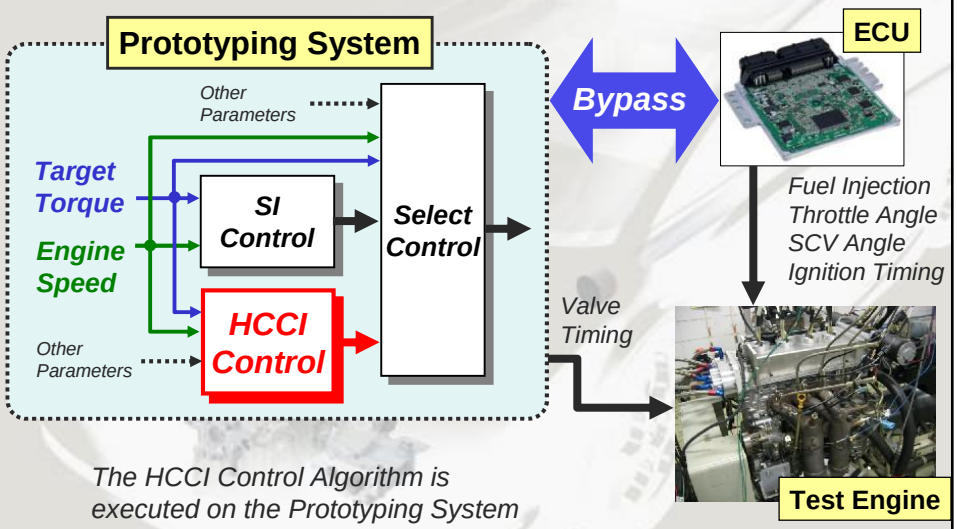
Engine Appearance

L4 / 2.0L (80 * 89.3mm), Direct Fuel Injection (Side, Swirl Type)



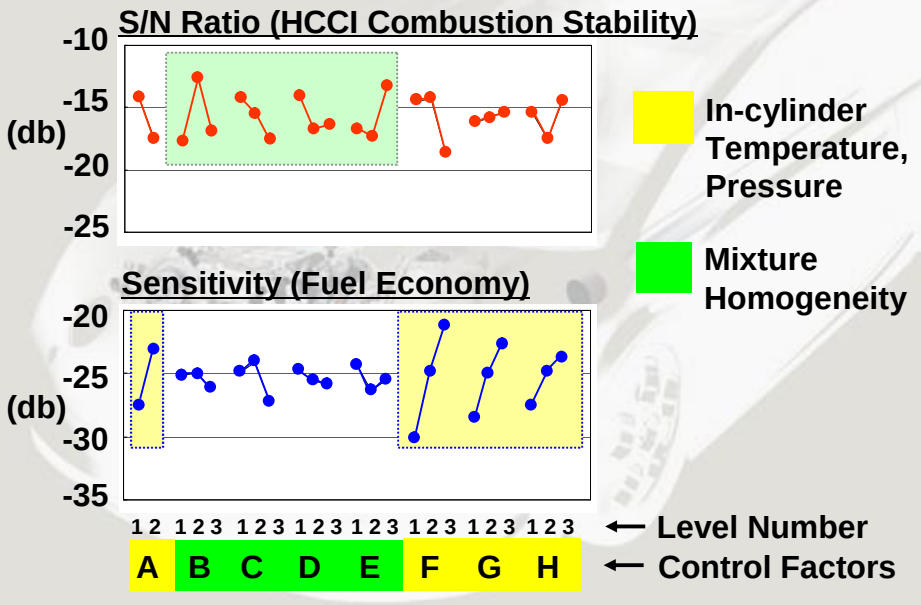
VTC : Valve Timing Controller

HCCI Control System

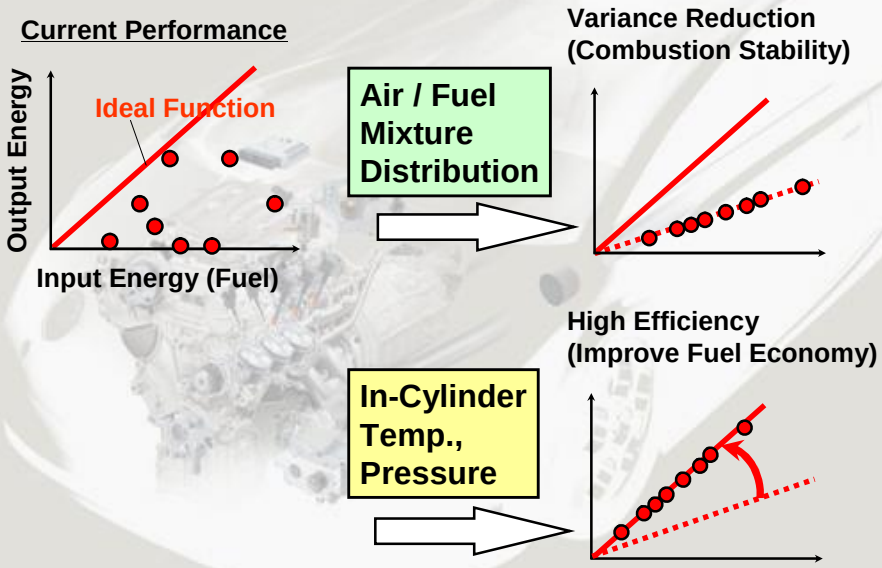


The HCCI Control Algorithm is executed on the Prototyping System with the Bypass method.

Experimental Results



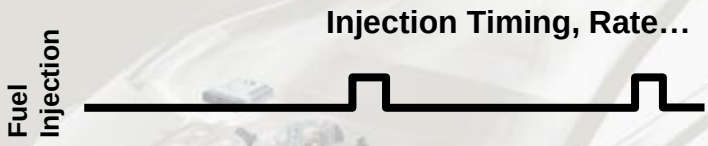
Strategy for HCCI Control



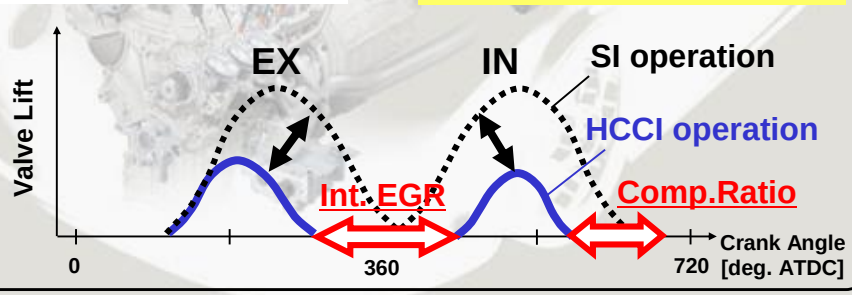
HCCI Control Concept

Real-Time HCCI Control

Fuel Injection Control ⇨ **HCCI Combustion Stability**



Valve Timing Control ⇨ **HCCI Operation Condition**



Experimental Condition

- Engine Speed: 2000[rpm]
- Target BMEP: 1.5[bar]
- ***Injectors: Uneven Performance***

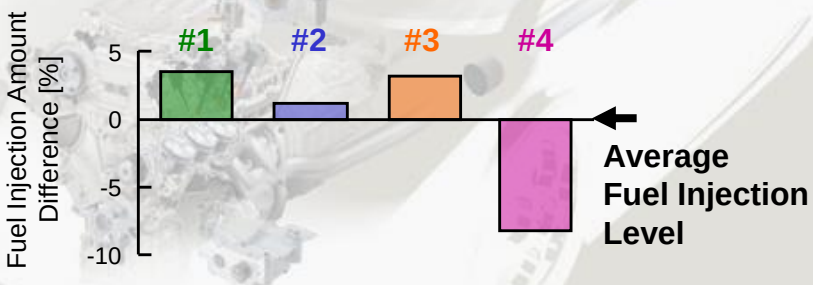
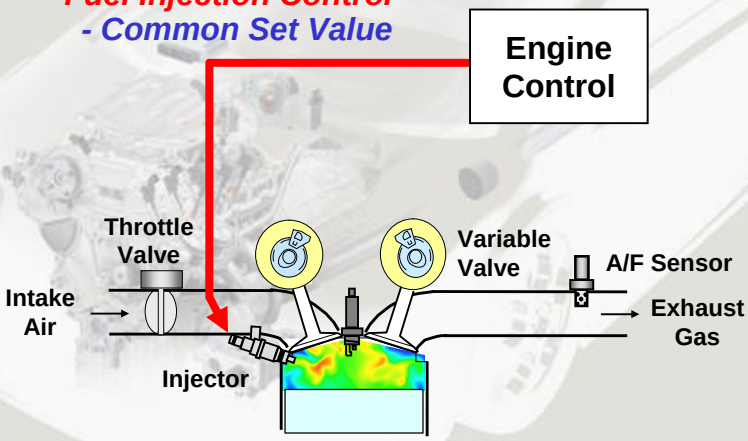


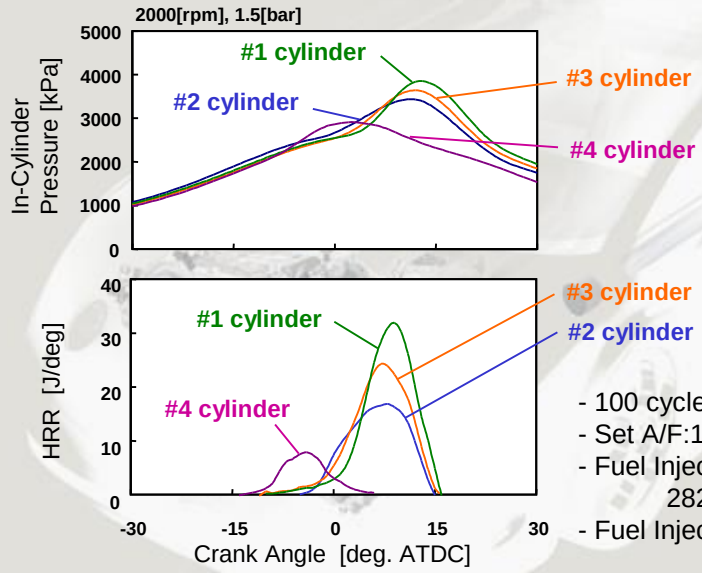
Fig. Performance Variance of Injectors

Influence of Injector Variance

Individual Cylinder Fuel Injection Control - Common Set Value



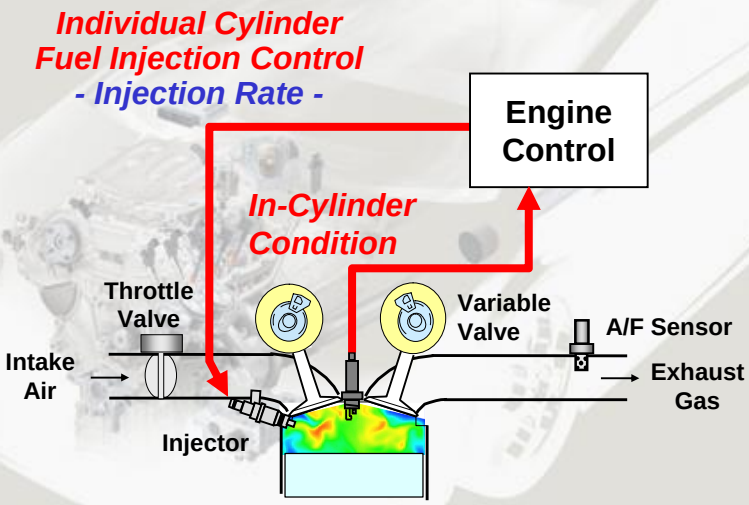
Influence of Injector Variance



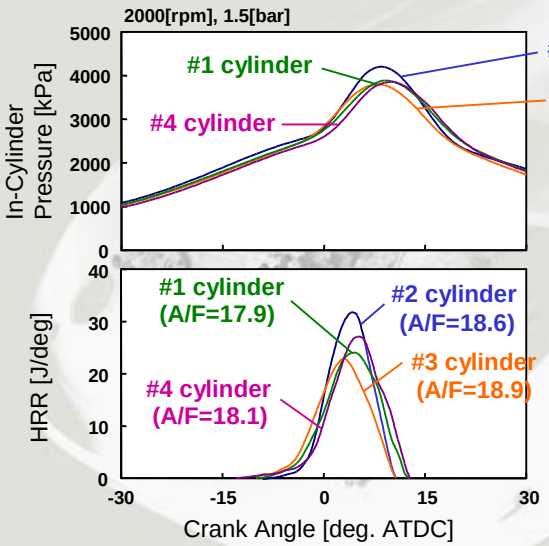
- 100 cycles average
- Set A/F:18.5
- Fuel Injection Timing: 282/440[deg. ATDC]
- Fuel Injection Rate: 1:1

HRR:Heat Release Rate

Effect of Fuel Injection Rate



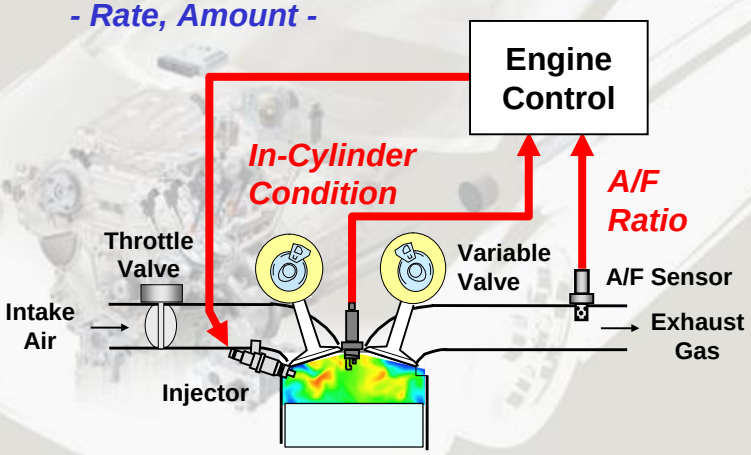
Effect of Fuel Injection Rate



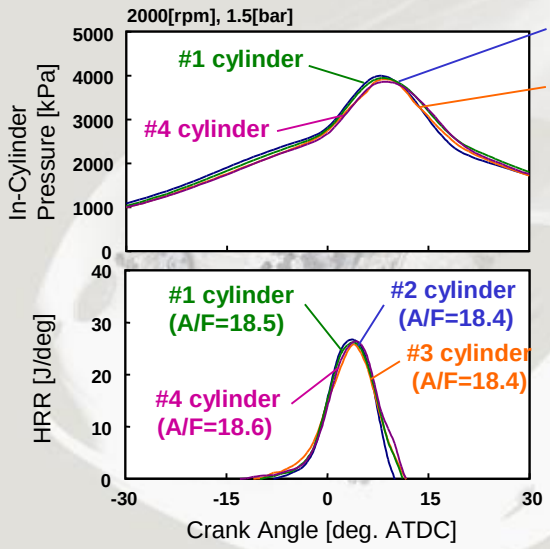
- 100 cycles average
- Set A/F: 18.5
- Fuel Injection Timing:
  282/440[deg. ATDC]
- Fuel Injection Rate: Optimized

Effect of Adjusting A/F Ratio

Individual Cylinder Fuel Injection Control - Rate, Amount -

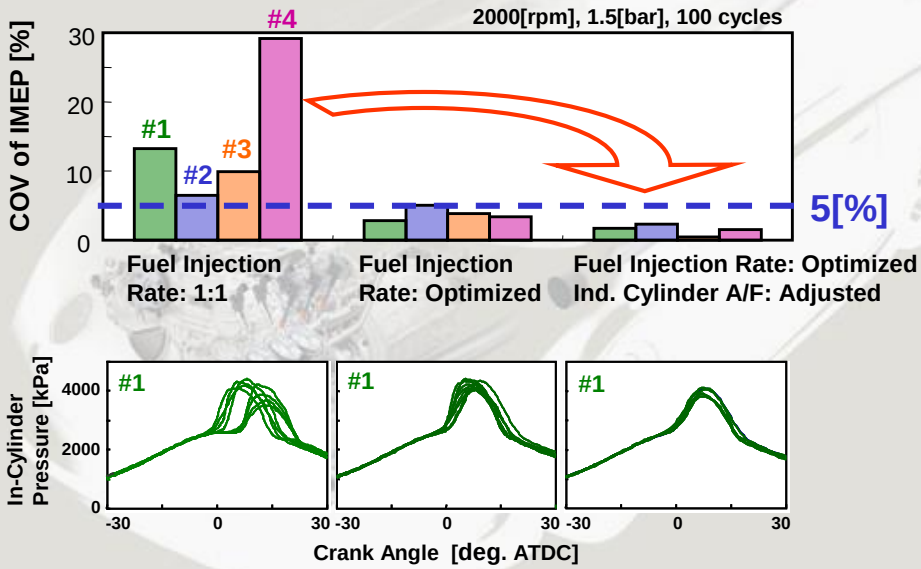


Effect of Adjusting A/F Ratio

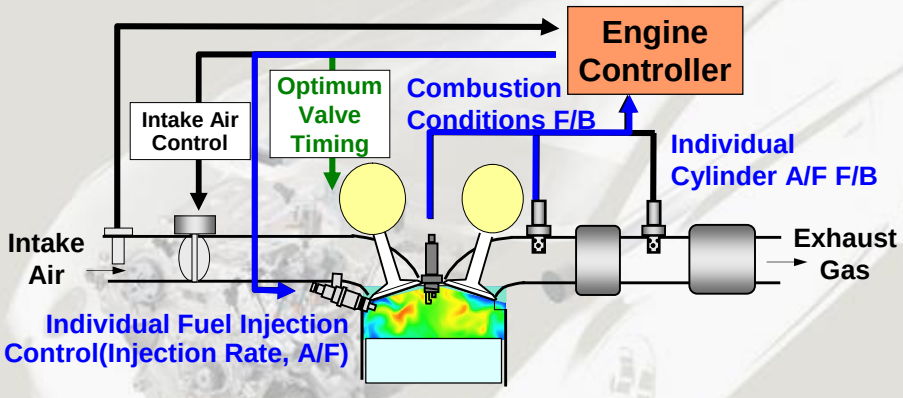


- 100 cycles average
- Set A/F:18.5
- Fuel Injection Timing: 282/440[deg. ATDC]

COV of IMEP



Strategy for HCCI Control



Valve Timing ⇨ *Make HCCI combustion occur*

Fuel Injection ⇨ *Keep HCCI combustion stability*

Summary

The possibility of a gasoline HCCI engine for the future engine system was verified.

1. **Hitachi is now challenging to develop the gasoline HCCI system applying our original technologies.**
   (Engine components, Combution analysis....)
2. **Test engine for HCCI was equipped with VEL on both the intake and exhaust sides.**
3. **Based on the experimental design, the concept of stable HCCI combution control was constructed.**