Development of Gasoline HCCI Using Blow-Down Super Charging System

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Back ground – (1)

- Advantages of gasoline HCCI engine
  - High thermal efficiency
  - Low exhaust gas emission
- Issues of gasoline HCCI engine
  - Extension of driving load
    - High load limitation
      - Increase in dP/d θ and NOx emission
    - Low load limitation
      - Incomplete combustion; Increase in instability of combustion and CO, HC emission
  - Control of auto-ignition timing

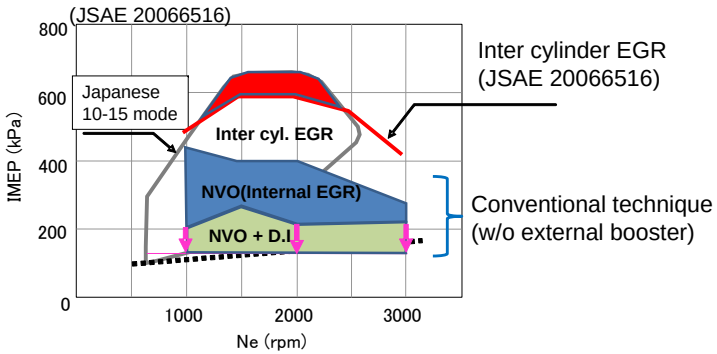
Back ground – (2)

- Previous attempts to solve HCCI problems

Extension of high load limit	Supercharge	Hyvonen, j., et al., SAE Paper No. 2003-01-3214, etc…
	Inter cylinder EGR (EGR + Supercharge)	Takanashi, J., et al., JSAE Annual congress 2006., Spring, JSAE 20066516
	Thermal stratified	Nakano. H., et al., I.C. Engine symposium 19th, No. 06-251, A6-4, pp.387-392, etc…
	Direct inj.	Urata, Y., et al., SAE Paper No. 2004-01-1898 etc…
	Fuel stratified + Spark assist	Urushibara, T., et al. JSAE Annual congress 2004, Spring, JSAE 2004 5114, etc…
	NVO(Internal EGR)	Urata, Y., et al., SAE Paper No. 2004-01-1898 etc…
Extension of low load limit	DI during NVO period	Jacques, L., et al., SAE2000-01-1837, etc…
	Fuel stratified	Marriott, D.C., and Raitz, D. R, SAE Paper No. 2002-01-0418, etc…

Back ground (3)

- HCCI operational range without supercharge

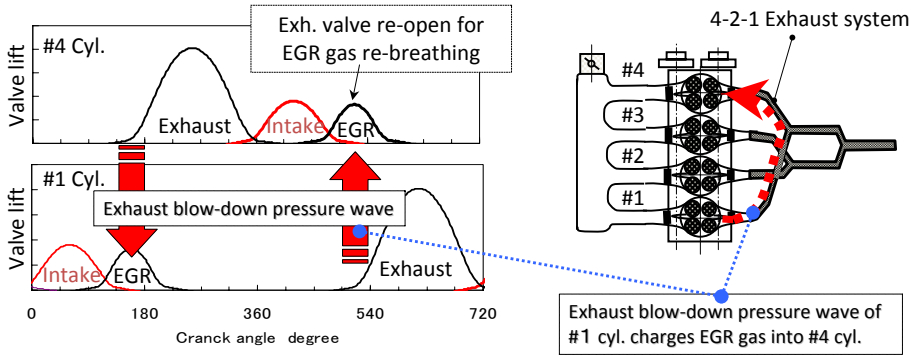


Objective

- To extend the high load operation limit of a gasoline HCCI engine, a new system which contains two new techniques is proposed. The first technique is "***Blow-Down Super Charging (BDSC) system***" and the other one is "***EGR guide"*** for generating a large in-cylinder thermal stratification. In the present study, the performance of the proposed system is experimentally demonstrated.

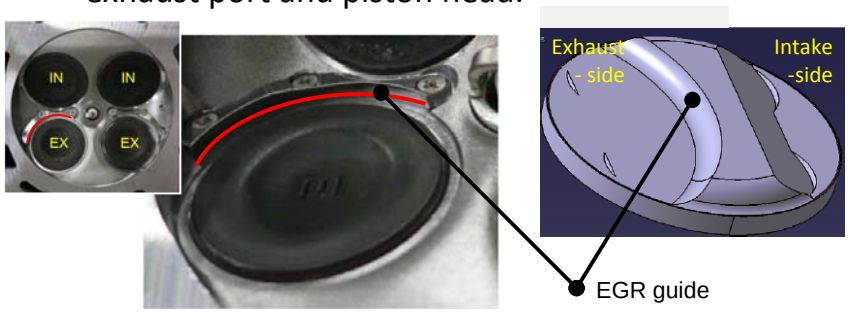
Blow-Down Super Charging System (BDSC system)

- Exhaust valves re-open during early compression stroke to boost EGR by using the blow-down pressure wave of the other (360 deg. phase-shifted) cylinder.
- EGR boost is possible without external super charger.



EGR guide for creating in-cylinder thermal stratification

- Thermal stratification has a high potential to reduce steep pressure rise.
- To generate a large thermal stratification inside the cylinder, EGR guide is attached on the edge of the exhaust port and piston head.

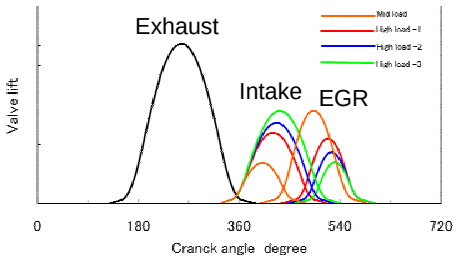


Test engine & conditions

Base engine	Honda K20A
Engine type	Inline 4 cylinder
Bore x Stroke	86 mm x 86 mm
Displacement	1998 cm^3
Compression ratio	12 (HCCI)/ 11.5 (Base)
Fuel injection	Port injection
Fuel	Gasoline (RON91)
Engine speed	1500 rpm
Valve timing	Fixed cam

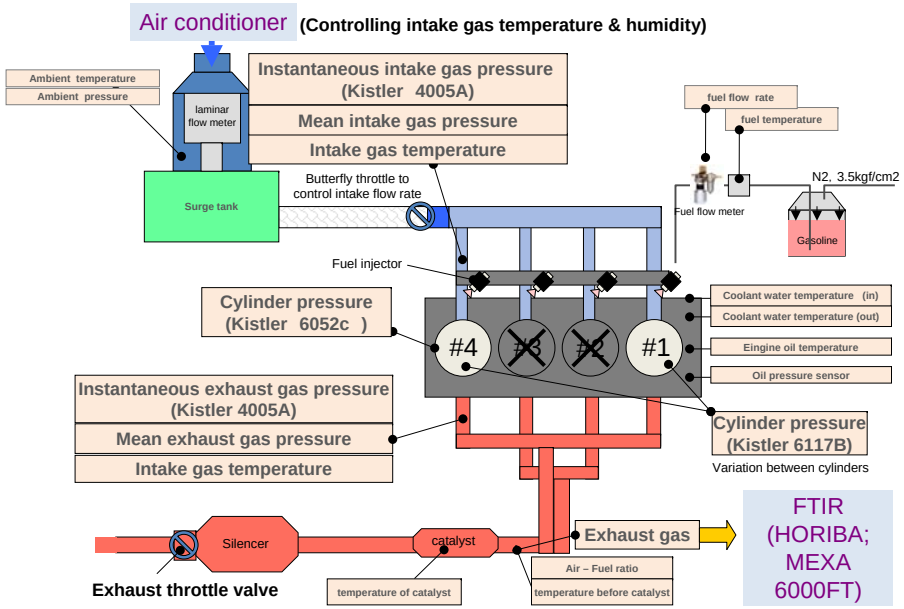
Optimized valve lift & timing

➢ **The valve timing used in the present study was optimized by using an optimization software (mode-FRONTIER) & 1-D numerical simulation code (GT-Power) for each target IMEP.**



- High load operation
  - High intake valve lift and low EGR valve lift
- Low & mid. load operation
  - Low intake valve lift and high EGR valve lift
- Exhaust valve actuation;
  - Fixed (Independent of the load).

Measurement system

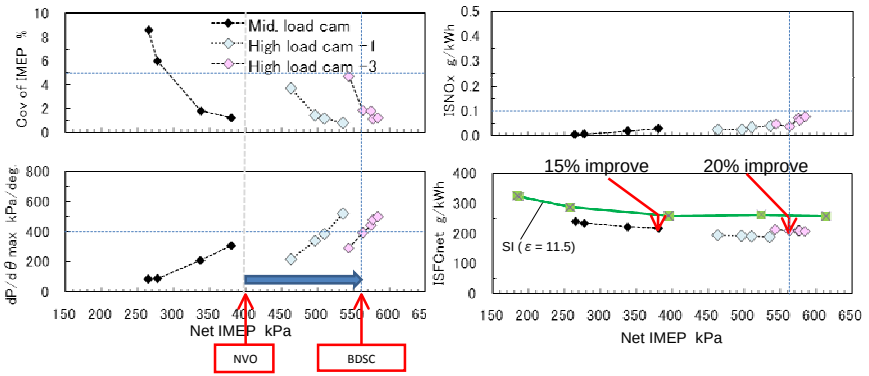


Definition of operational HCCI

- Limit of maximum pressure rise rate
  - ➢ dP/d θ max ≦ 400 kPa/deg.
- Limit of combustion variation
  - ➢COV. of IMEP ≦ 5 %
- Limit of NOx emission
  - ➢ ISNOx ≦0.1 g/kWh

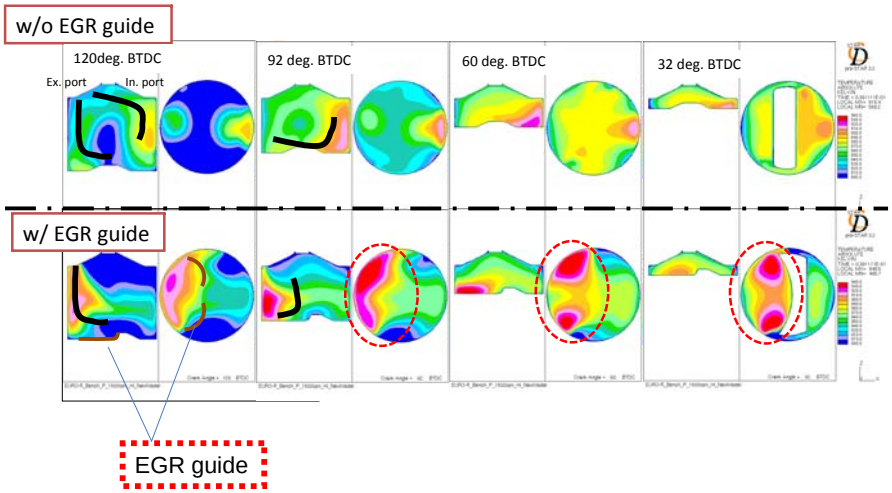
Performance of BDSC-HCCI engine

- Pex = 130 kPa
- High load limit → dP/d θ max limit (< 400 kPa/deg.)
- Without EGR guide

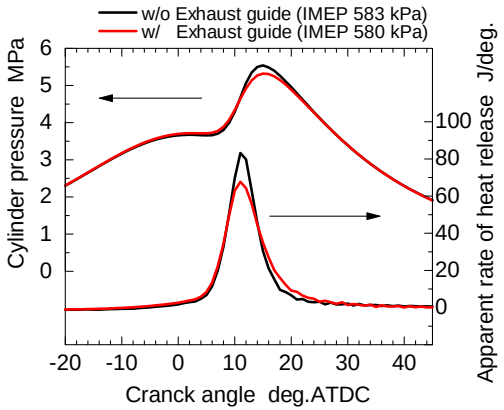


Generation of In-cylinder thermal stratification using EGR guide

- 3-D simulation results



Effect of EGR guide on performance of BDSC-HCCI engine



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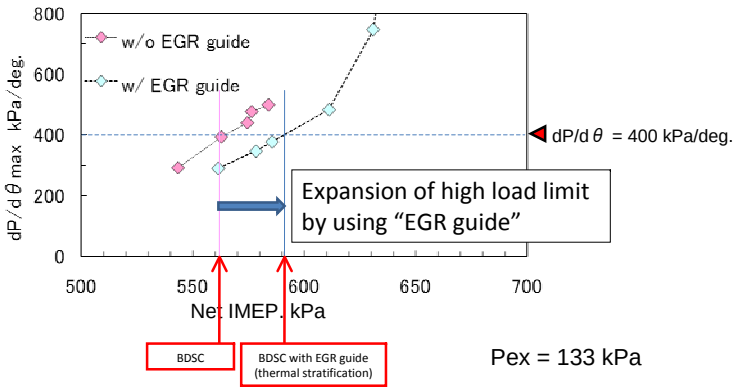
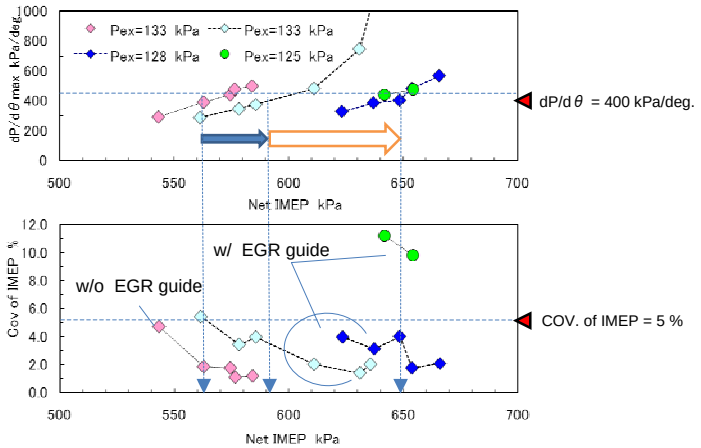


High load operation limit of BDSC-HCCI engine



Summary

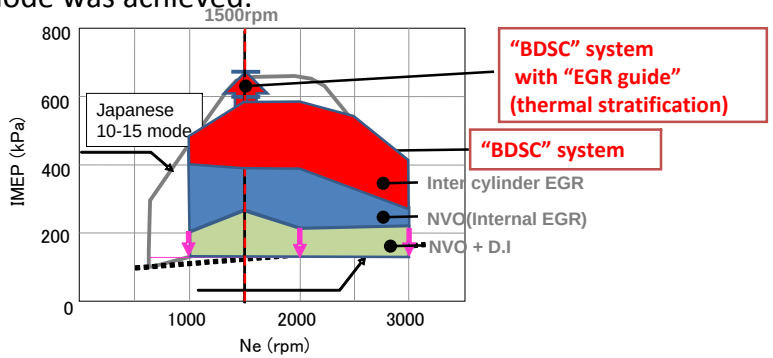
- In order to extend high load operation limit of gasoline HCCI engine, a new system which consists of ***"Blow-Down Super Charging (BDSC)"*** and ***"EGR guide"*** walls for generating a large in-cylinder thermal stratification was proposed. The performance of the proposed system was experimentally demonstrated. Experimental results are as follows;

1. BDSC system was experimentally evaluated as a technique to realize high load HCCI operation.

2. Attaching the EGR guide on the edge of exhaust port and piston head, it is possible to decrease dP/d θ max at high load HCCI operation. This is probably due to a large thermal stratification inside the cylinder generated by EGR guide.

Summary

3. Using the proposed system (BDSC system and EGR guide), HCCI operation at ***IMEP of 650 kPa*** (engine speed of 1500 rpm) which corresponds to the upper load of 10-15 Japanese test mode was achieved.



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