VCM
The key for enhancing gas engines for demanding applications
VCM – the key for enhancing gas engines

Introduction
- Introduction and motivation
- Opportunities and challenges with gas engines
- Solutions based on variable valve timing. What is VCM*?
- Simulation based marine propulsion application
- Summary and outlook

*VCM is a registered trademark of ABB Turbo Systems Ltd.
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Introduction and motivation

Opportunities
- Cost advantage: gas cheaper than Diesel fuel
- Emission advantage: no aftertreatment for NOx abatement, no particulates

Demanding application segments
- Marine propulsion (e.g. FPP operation)
- Compressor drive (e.g. constant torque operation)
- Off-highway

Application requirements
- Providing enhanced engine performance:
  - Wide engine operation map (e.g. speed turn down)
  - Load response for optimized agility and maneuverability
  - But with higher fuel efficiency
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Challenges variable speed operation

General challenges
- Width of engine operation map
- Fuel efficiency
- Emission compliance
- Load response

Particular challenges and potential enablers for gas engines
- Knock control
- Power density
- Load response
- Miller timing at high bmep
- Miller timing, turbocharging
- Variable volumetric efficiency
- Variable valve timing (VCM)
- High pressure turbocharging
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Increased knock margin through Miller Cycle
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Miller Cycle variation

Introduction
Opportunities/
Challenges
VCM
Investigation
Summary

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Valve Control Management (VCM)

- VCM is a cam driven electro-hydraulic valve train
- Components
  1. Pump unit
  2. High-pressure chamber
  3. Solenoid valve
  4. Brake unit
  5. Medium-pressure chamber
  6. Pressure accumulator
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Functional principle

- Cam profile transmitted via pump through the high pressure chamber to the engine valve (solenoid valve closed)
Cam profile transmitted via pump through the high pressure chamber to the engine valve (solenoid valve closed)

High-pressure area closed and opened towards middle pressure area by fast switching solenoid valve (SV)
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Functional principle

- Cam profile transmitted via pump through the high pressure chamber to the engine valve (solenoid valve closed)
- High-pressure area closed and opened towards middle pressure area by fast switching solenoid valve (SV)
- Engine valve closing not cam controlled (ballistic phase); seating velocity controlled by hydraulic brake
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Simulation based marine propulsion application

Approach

- Investigation of steady-state and transient gas engine performance for propulsion application

- Basic engine configuration:
  - Lean burn
  - Port injection
  - Variable valve timing (simplified lift curves)
  - FPP load characteristic ($P \sim n^3$)

- Basic engine operation map from typical HS Diesel propulsion engine:
  - Gas engine uprated by 15% (bmeP 20bar@1800rpm)
  - Constant combustion parameters
  - Knock indicator based on max. temperature in unburned zone and max. cylinder pressure
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Engines topology and operation map
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Engine topology and operation map

- Engine operation map, FPP operation line

- Gas max. torque
- Gas FPP
- Diesel max. torque
- Diesel FPP

+15%
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Steady-state operation

- Load- and $\lambda_V$-control through VCM and gas admission valve:
  - No losses due to control elements (de-throttling)
  - Improved engine efficiency
- High pressure turbocharging enables strong Miller cycling:
  - Increased knock margin
  - Optimized engine compression ratio
  - Effective control margin for load response
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Steady-state operation

- VCM control
  - FPP
  - max. torque
- Throttle control
  - max. torque
- Based on engine tests:
  - 40% speed turndown @100% load
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Transient operation, control system

Acceleration principles

- Max. gas injection without falling below min. \( \lambda_V \)
  (knock- and exhaust gas temperature limits)
- Max. cylinder filling through optimized IVC timing
  without exceeding max. firing pressure and knock limits
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Transient operation

- Acceleration 900-1800rpm and 1400-1700rpm
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Transient operation

Knocking indicators: steady-state and transient operation

- trans. 900-1800rpm
- trans. 1400-1700rpm

max cylinder pressure

max temperature in unburned zone

knocking border (schematic)
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Summary and Outlook

VCM enables high-bmep gas engines for
- variable speed operation
- wide operation field
- enhanced application range

and allows
- replacement of conventional control elements
- improvement of engine efficiency
- simple and compact installation

Gas engines are thus attractive for demanding applications