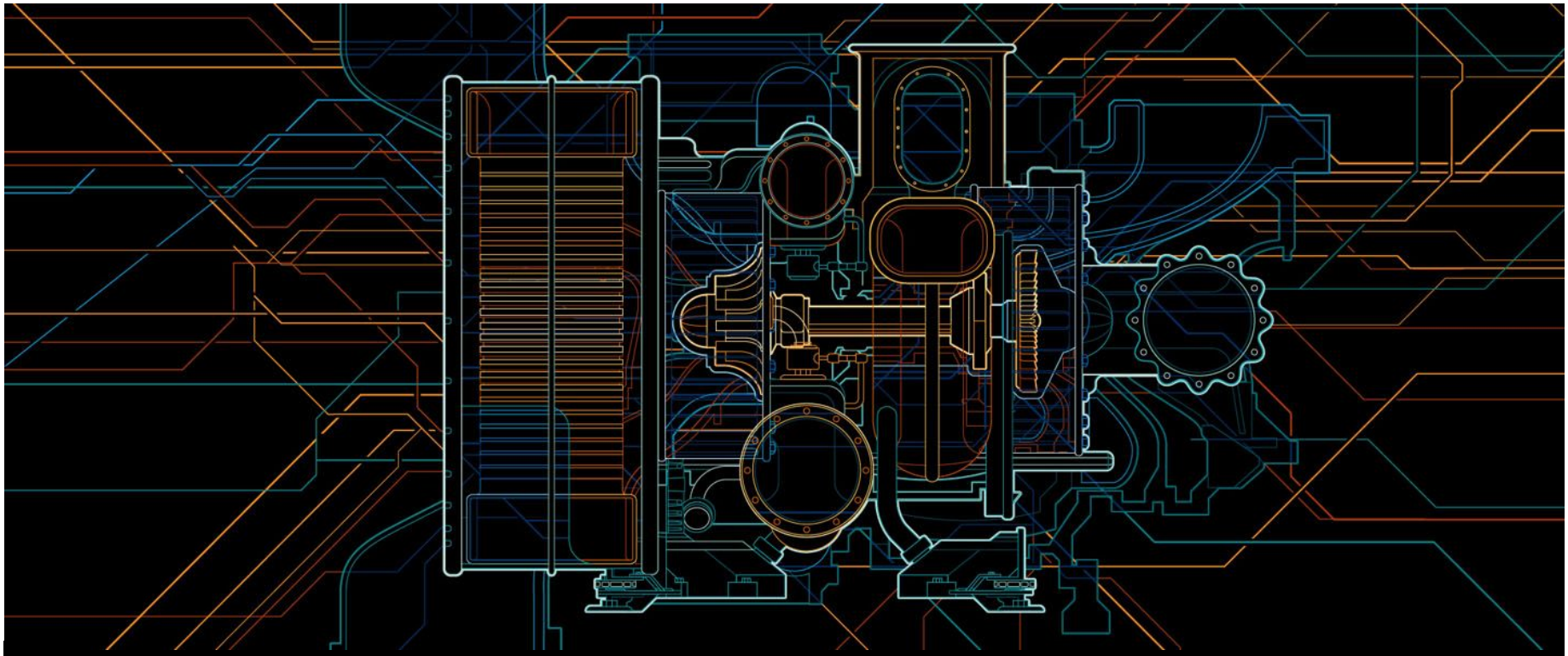


CIMAC Cascades 2014, London, ABB Turbo Systems Ltd., Michael Gisiger

VCM
The key for enhancing gas engines for demanding applications

Power and productivity
for a better world™

VCM – the key for enhancing gas engines
Content

- 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.

VCM – the key for enhancing gas engines
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

VCM – the key for enhancing gas engines
Challenges variable speed operation

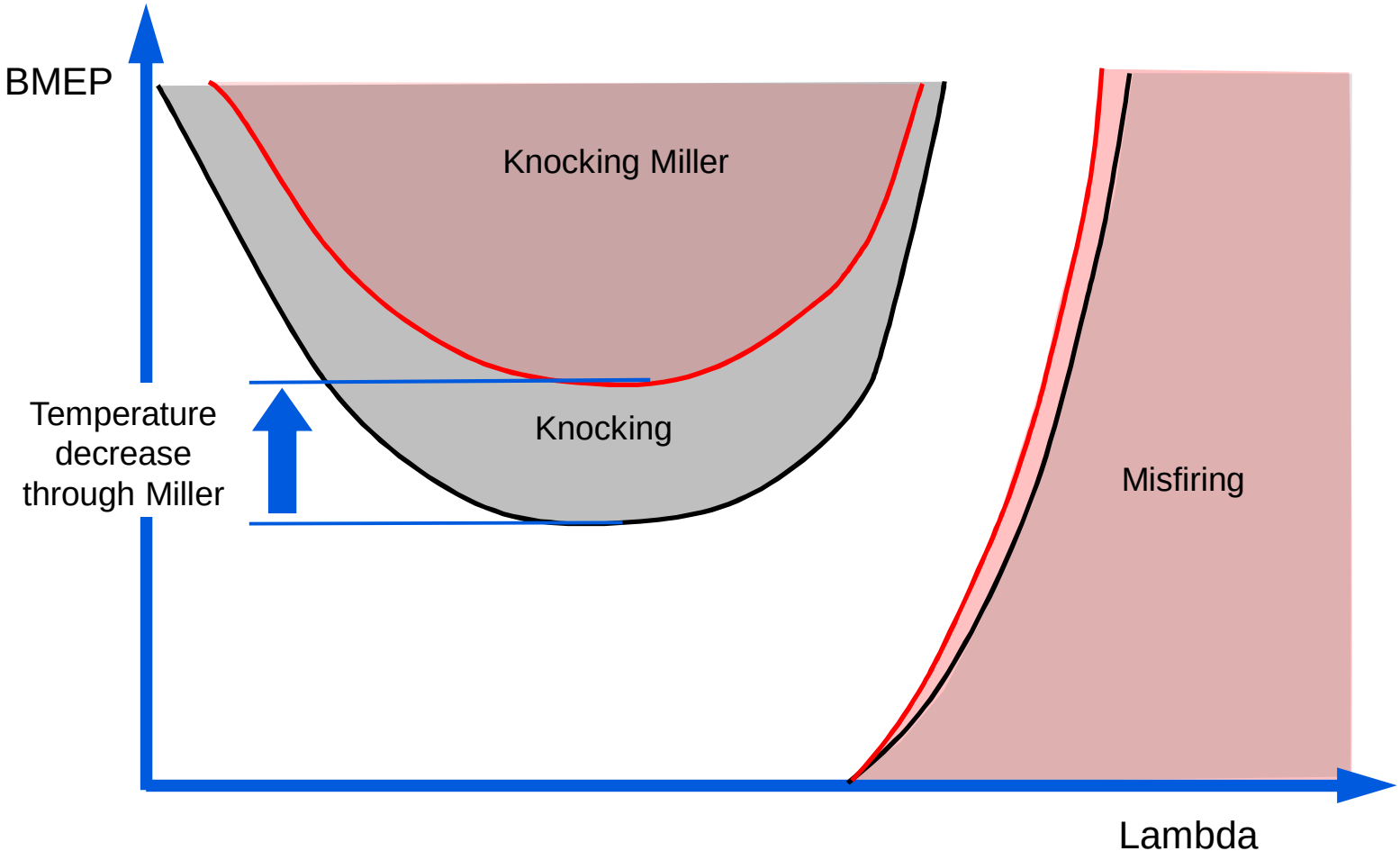
General challenges

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

Particular challenges and potential enablers for gas engines

Knock control	Miller timing at high bmep	Variable valve timing (VCM)
Power density	Miller timing, turbocharging	High pressure turbocharging
Load response	Variable volumetric efficiency	

VCM – the key for enhancing gas engines
Increased knock margin through Miller Cycle



VCM – the key for enhancing gas engines
Miller Cycle variation

Introduction

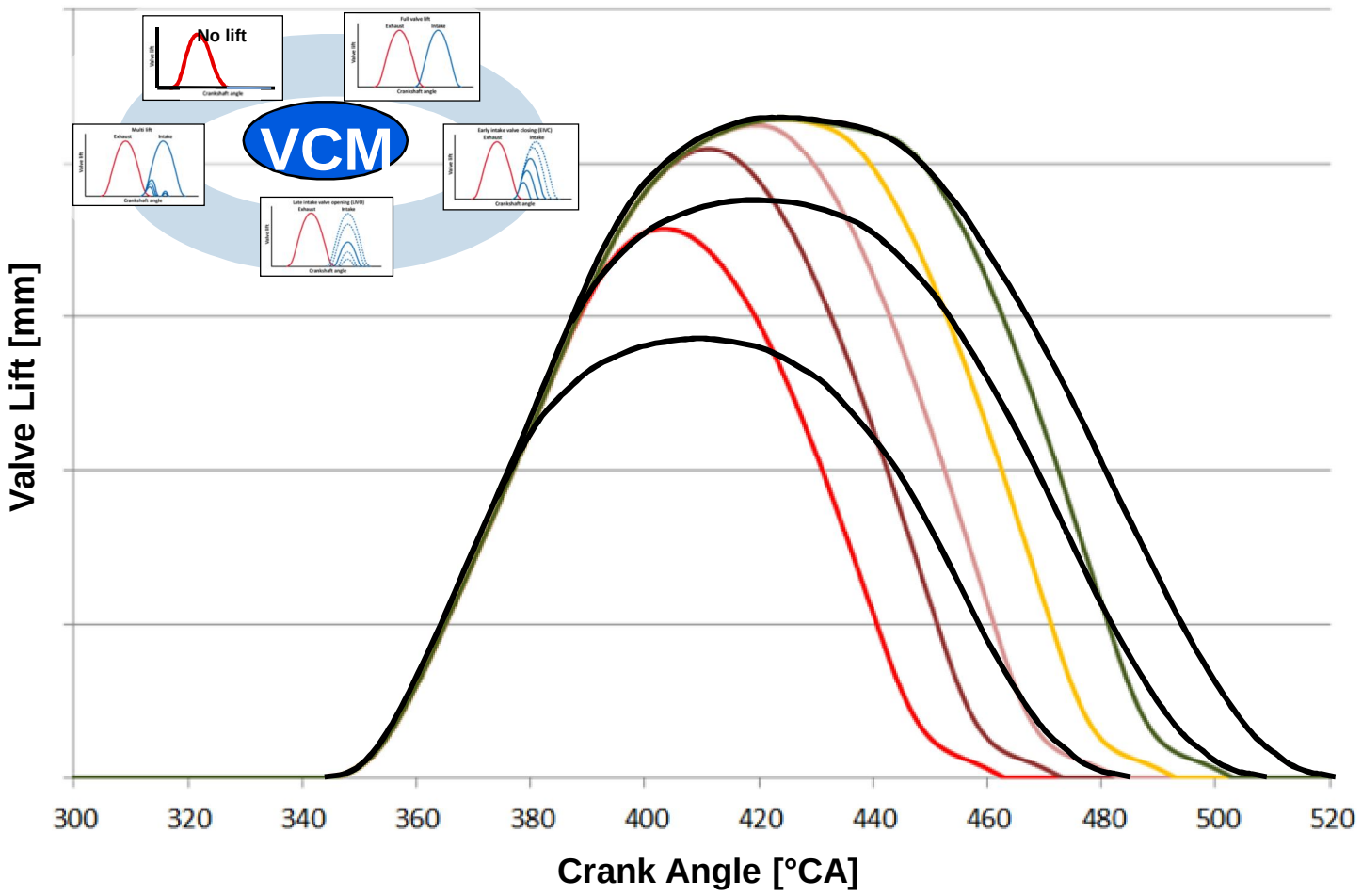
Opportunities/

Challenges

VCM

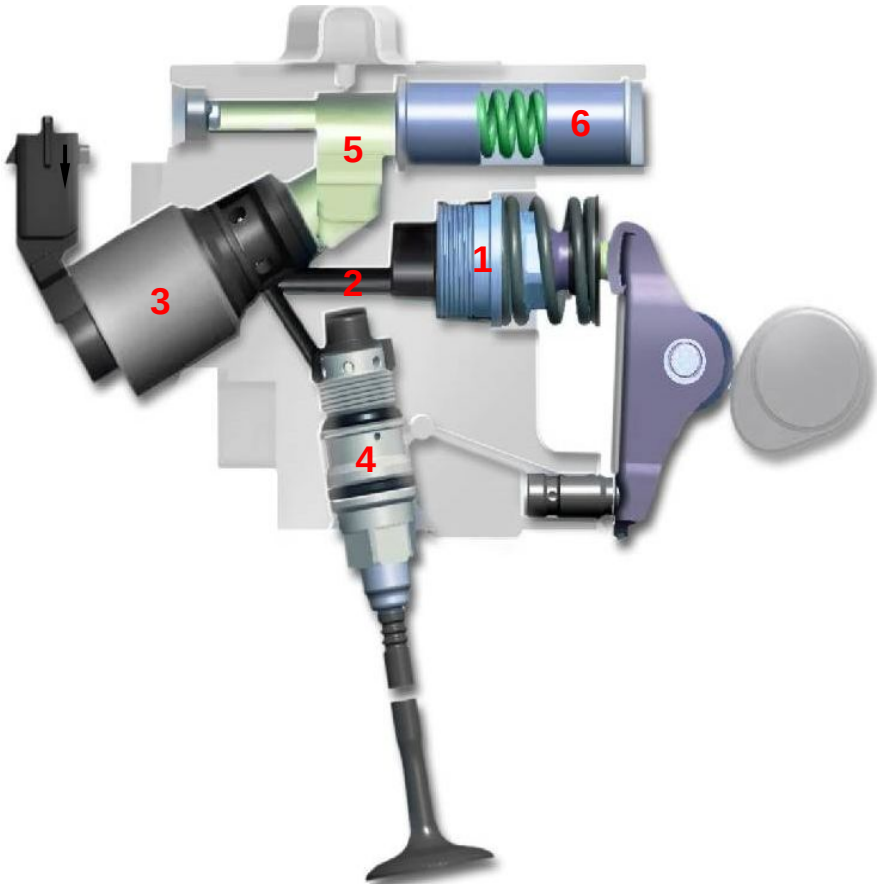
Investigation

Summary



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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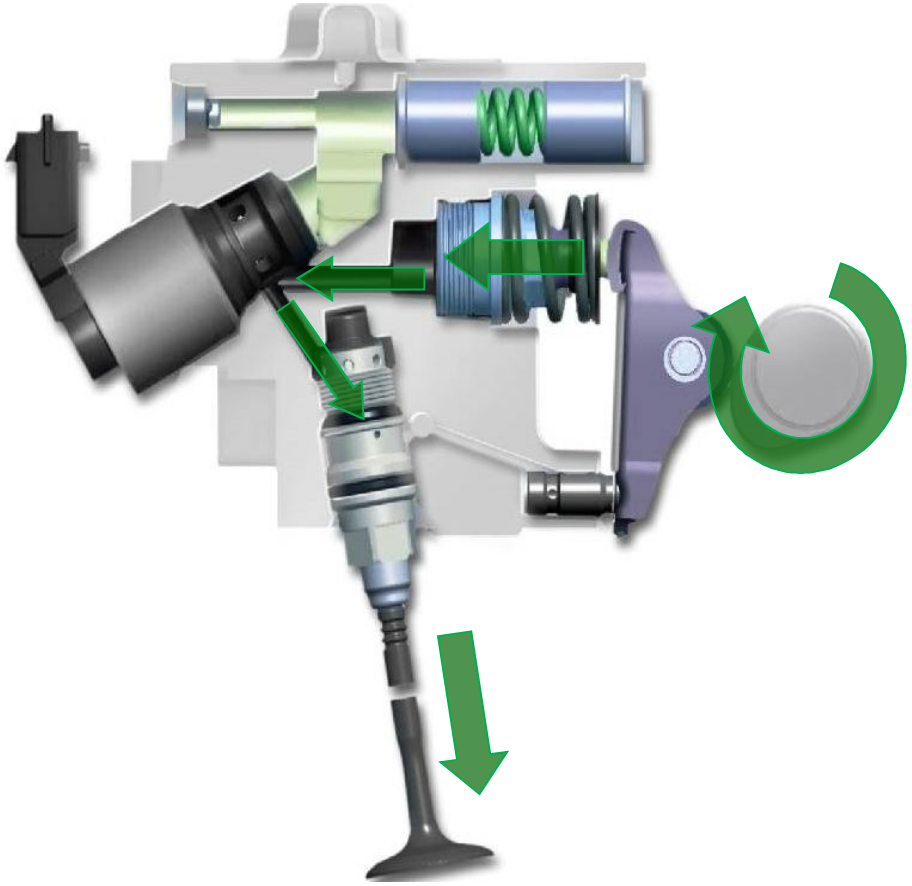
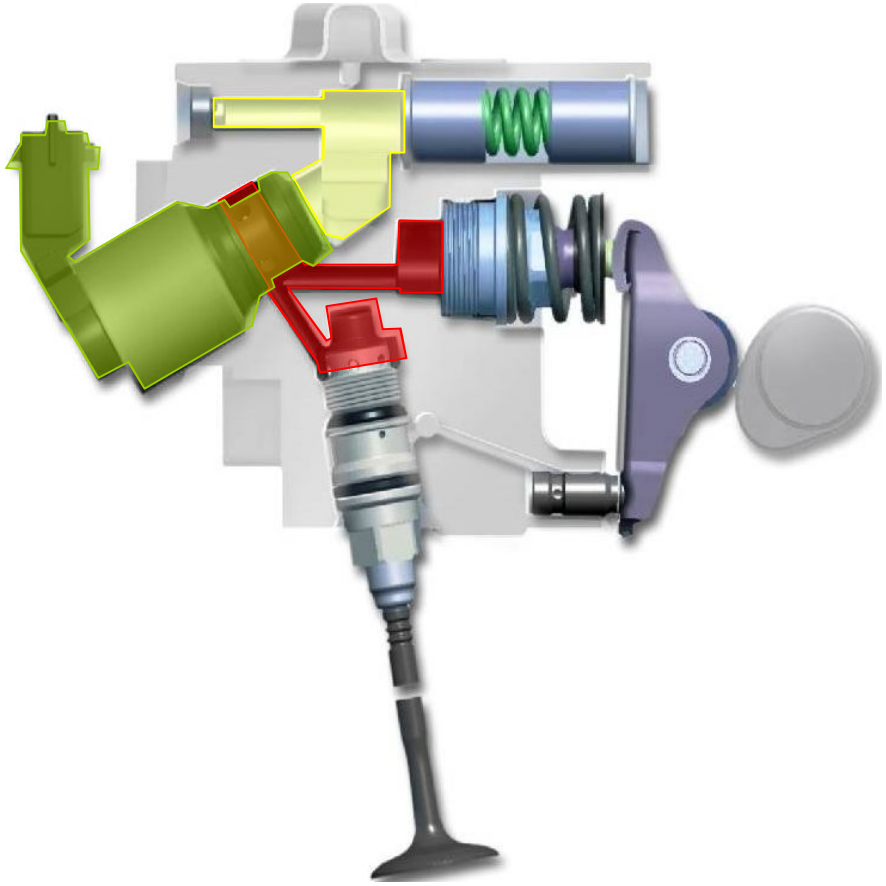
Functional principle

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



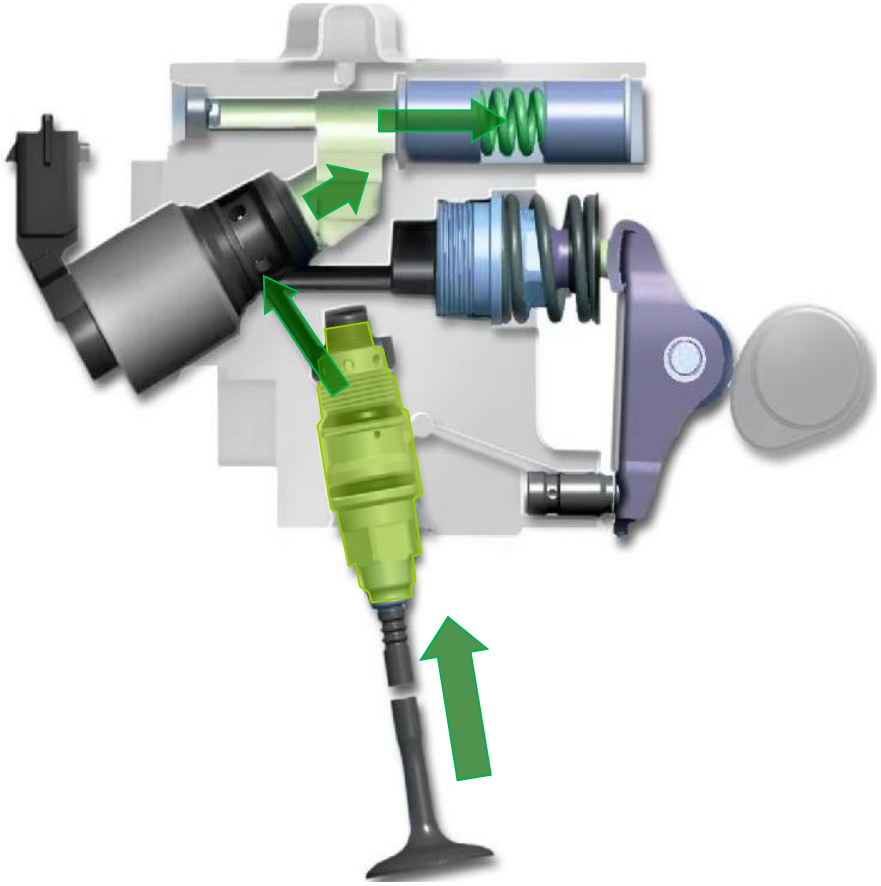
VCM – the key for enhancing gas engines
Functional principle

- 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)



VCM – the key for enhancing gas engines
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



VCM – the key for enhancing gas engines
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

VCM – the key for enhancing gas engines
Engine topology and operation map

Introduction

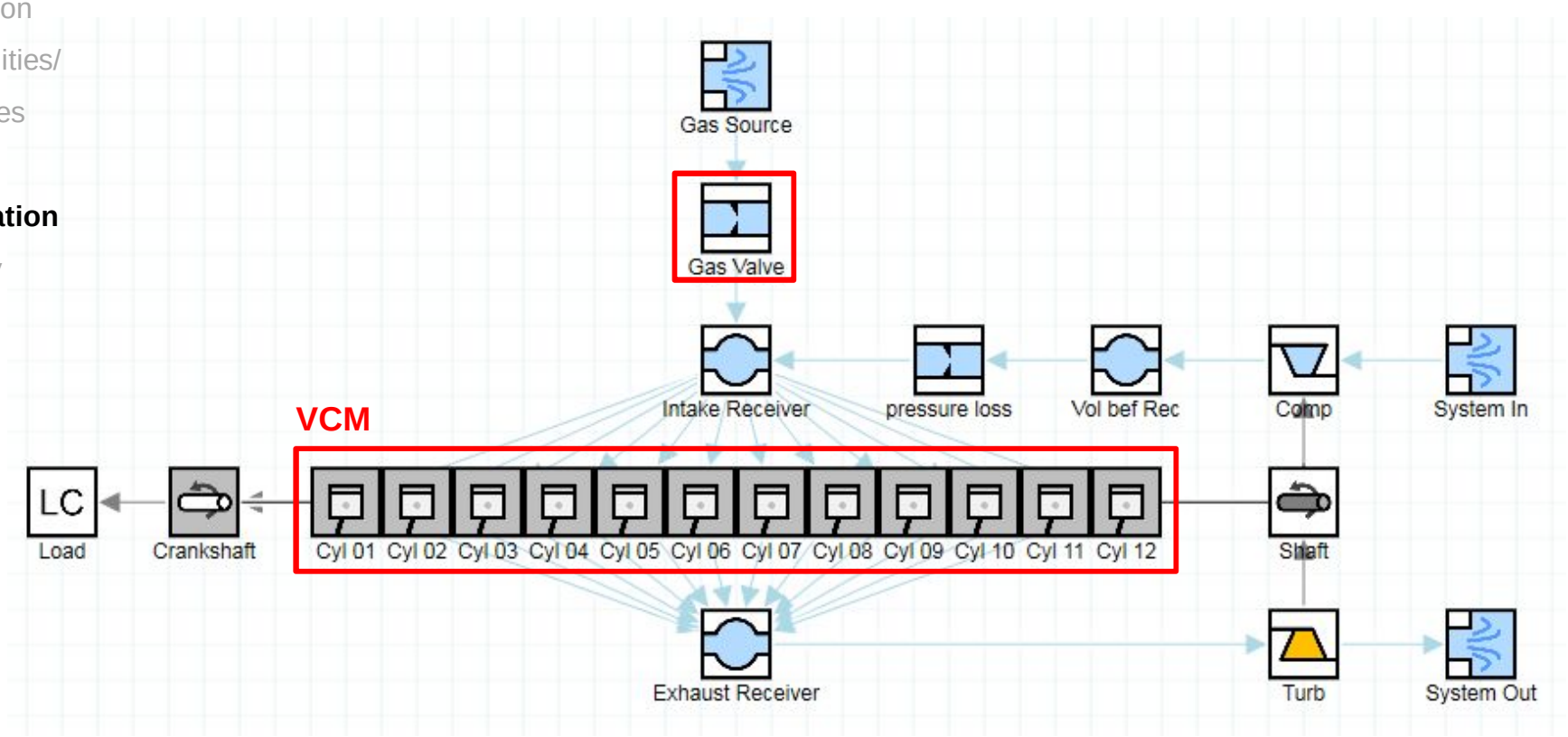
Opportunities/

Challenges

VCM

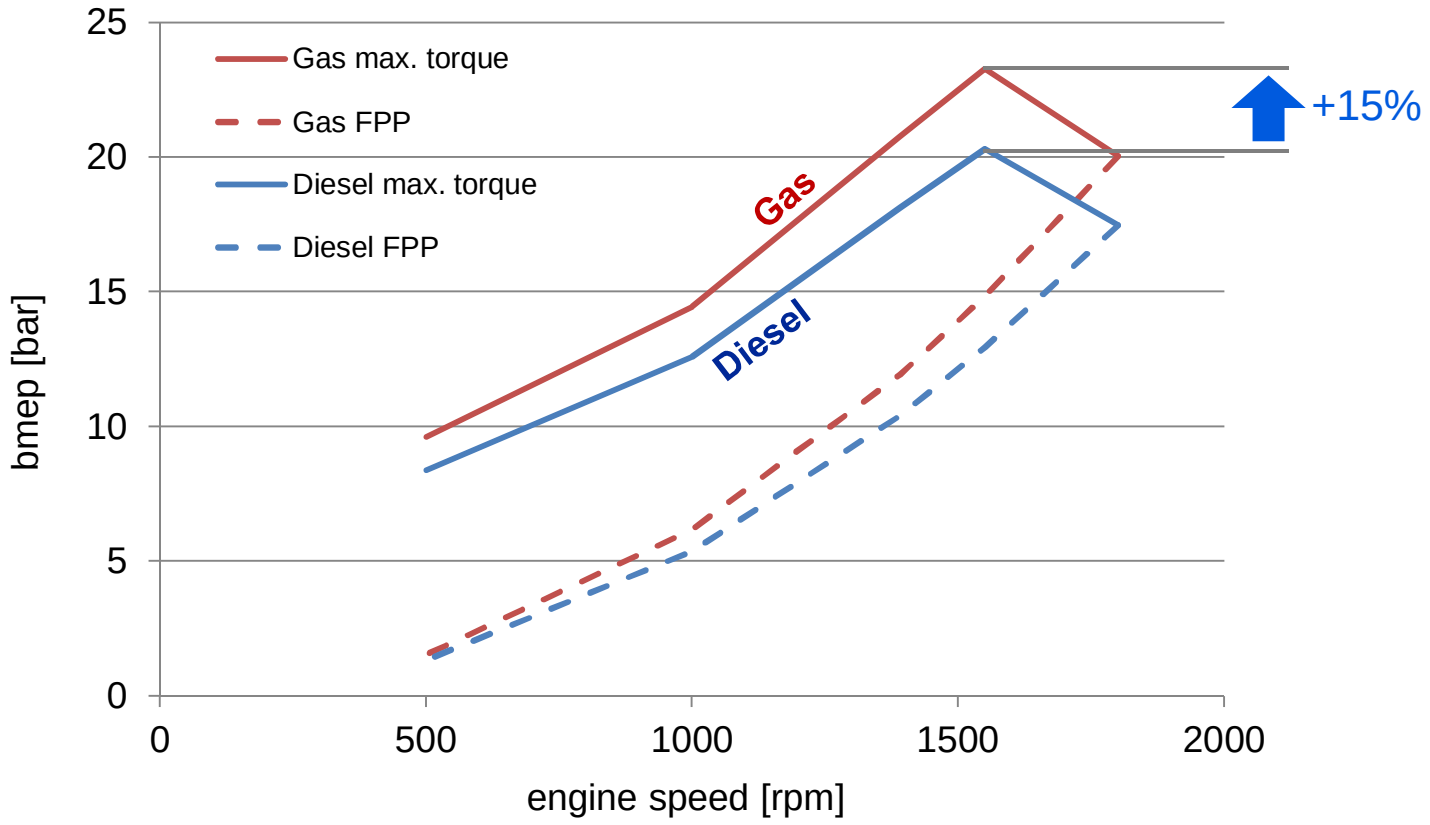
Investigation

Summary



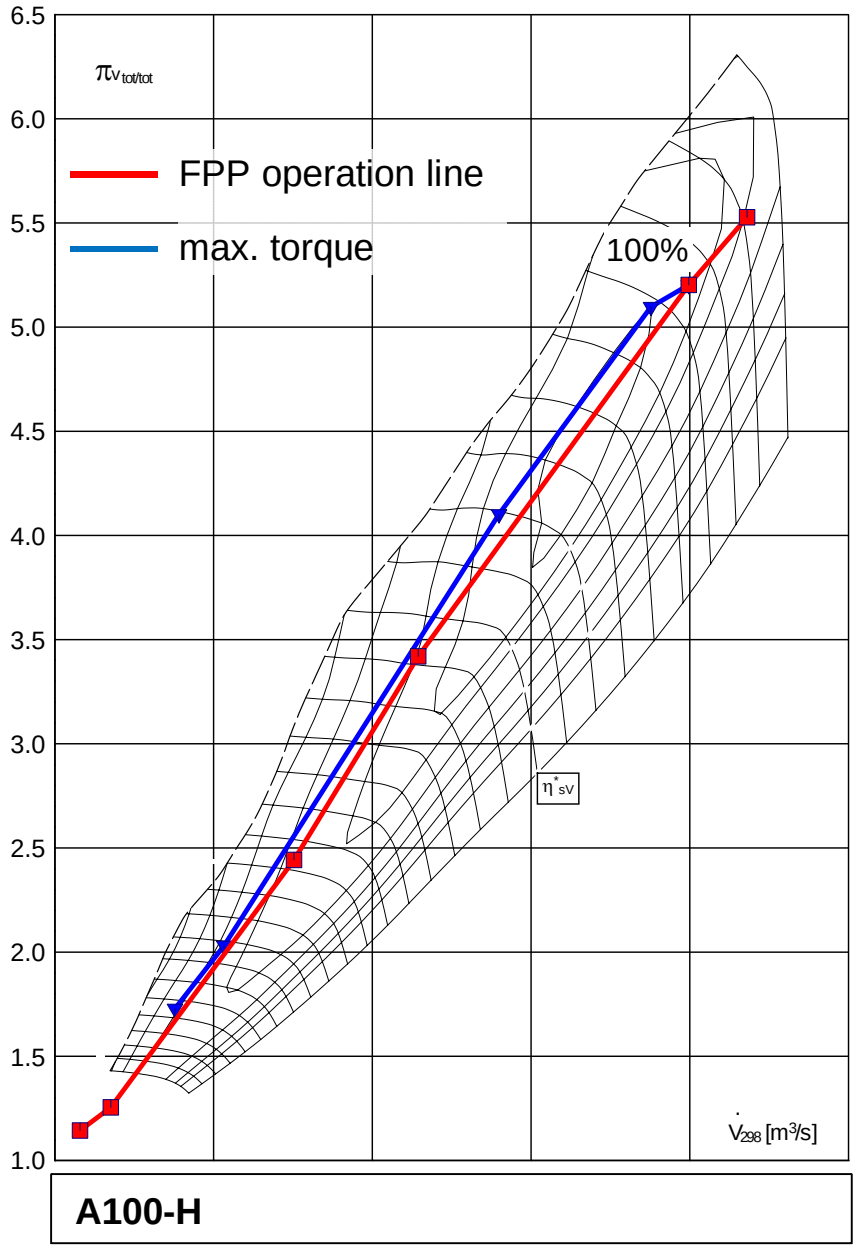
VCM – the key for enhancing gas engines
Engine topology and operation map

- Engine operation map, FPP operation line



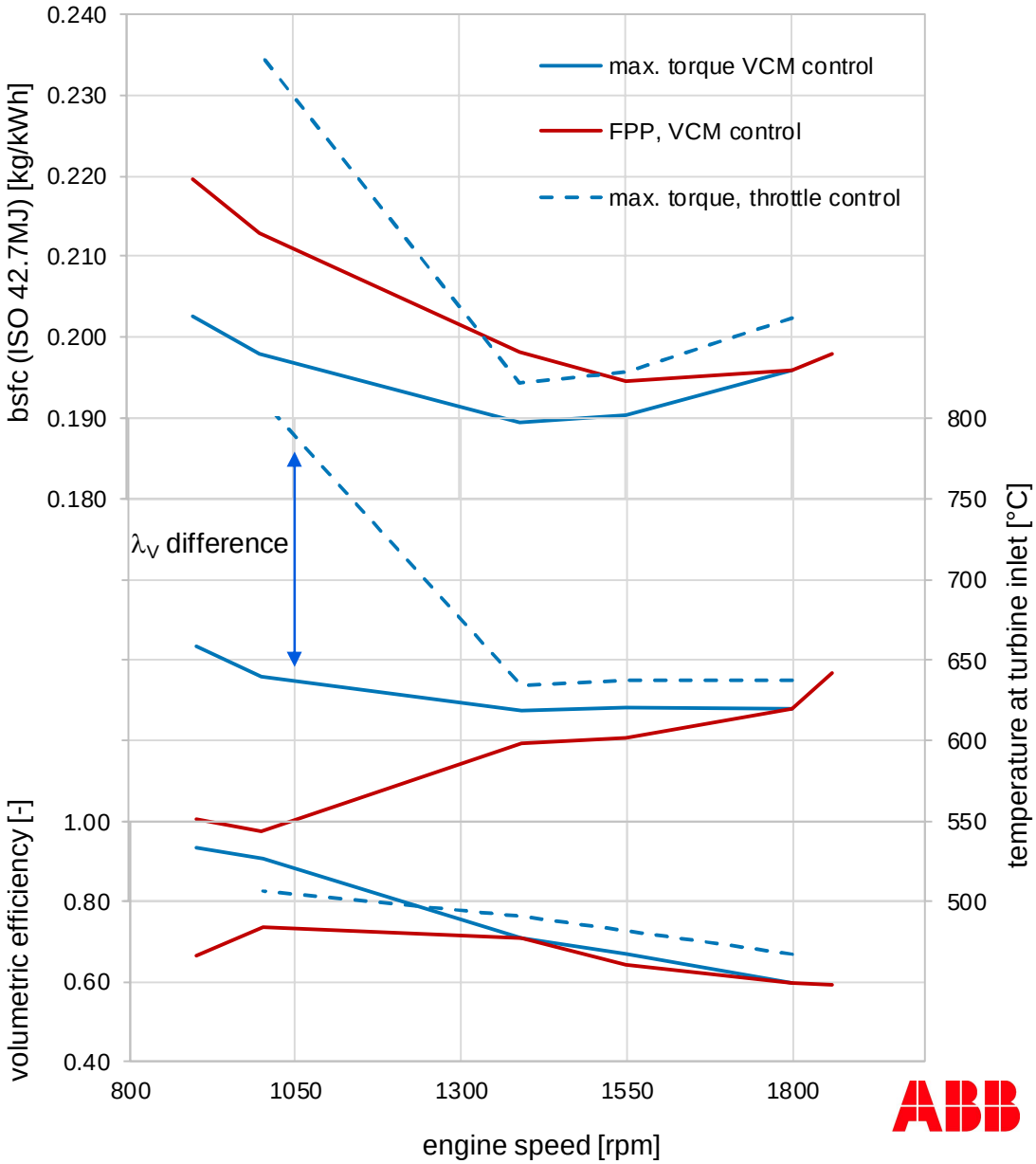
VCM – the key for enhancing gas engines
Steady-state operation

- Load- and λ_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

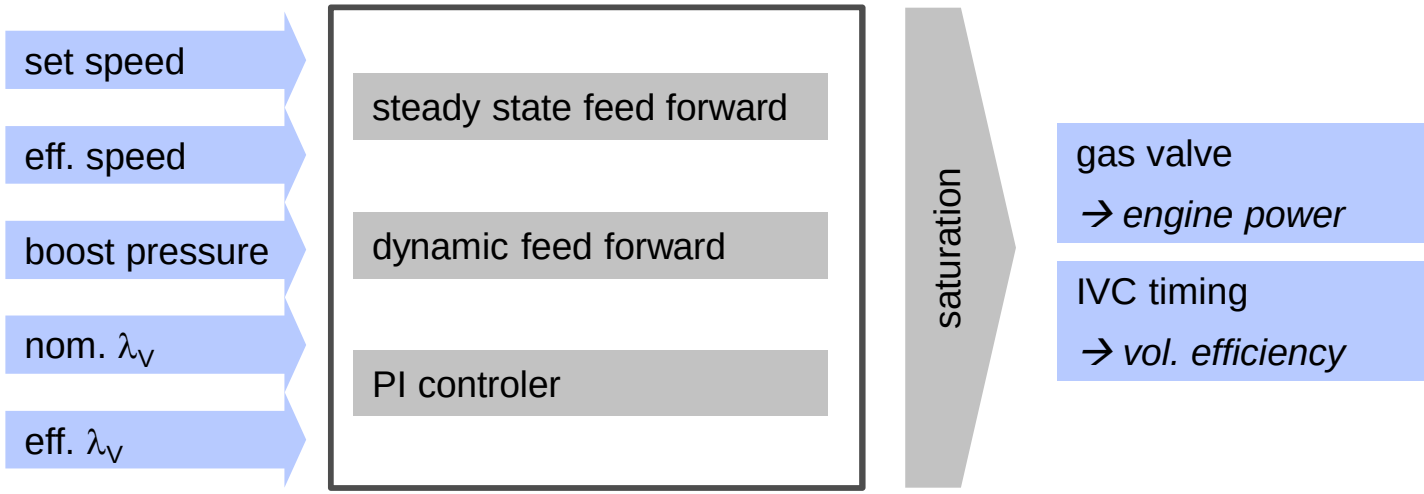


VCM – the key for enhancing gas engines
Steady-state operation

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

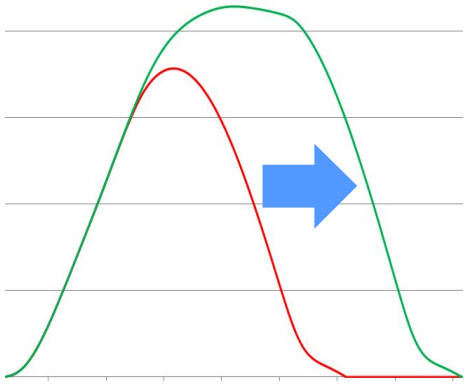


VCM – the key for enhancing gas engines
Transient operation, control system



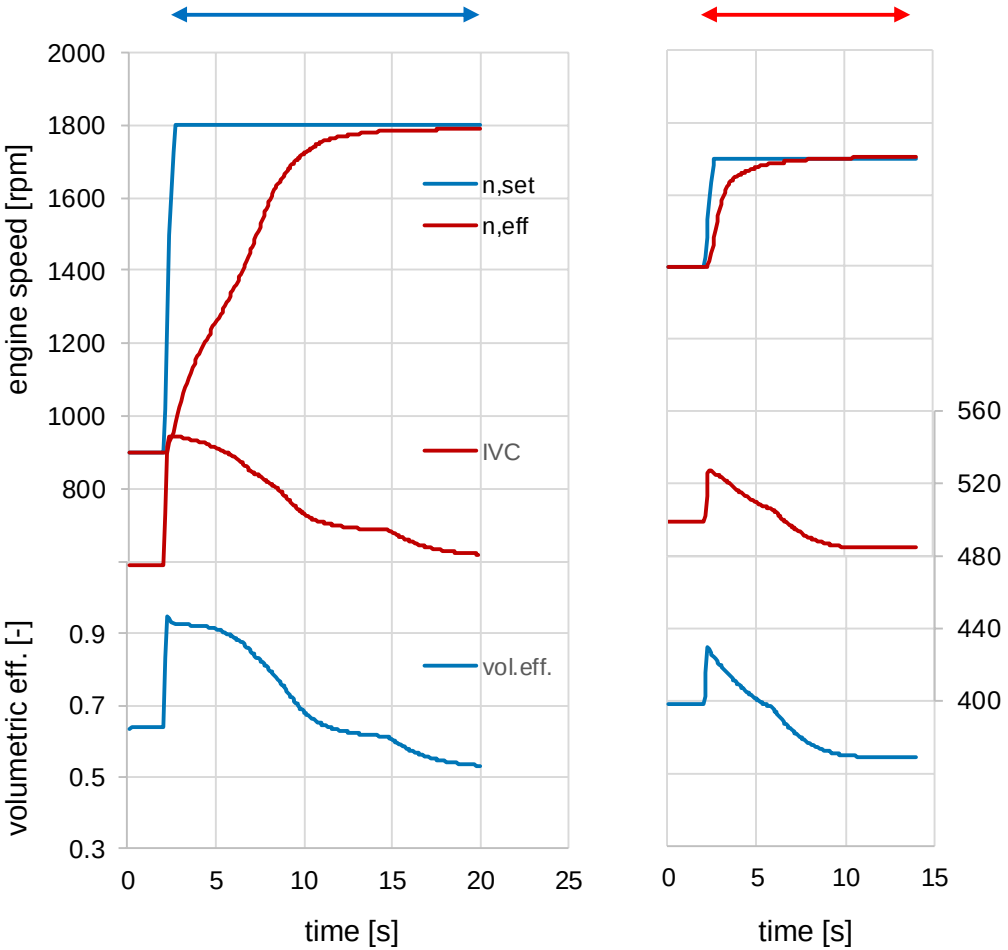
Acceleration principles

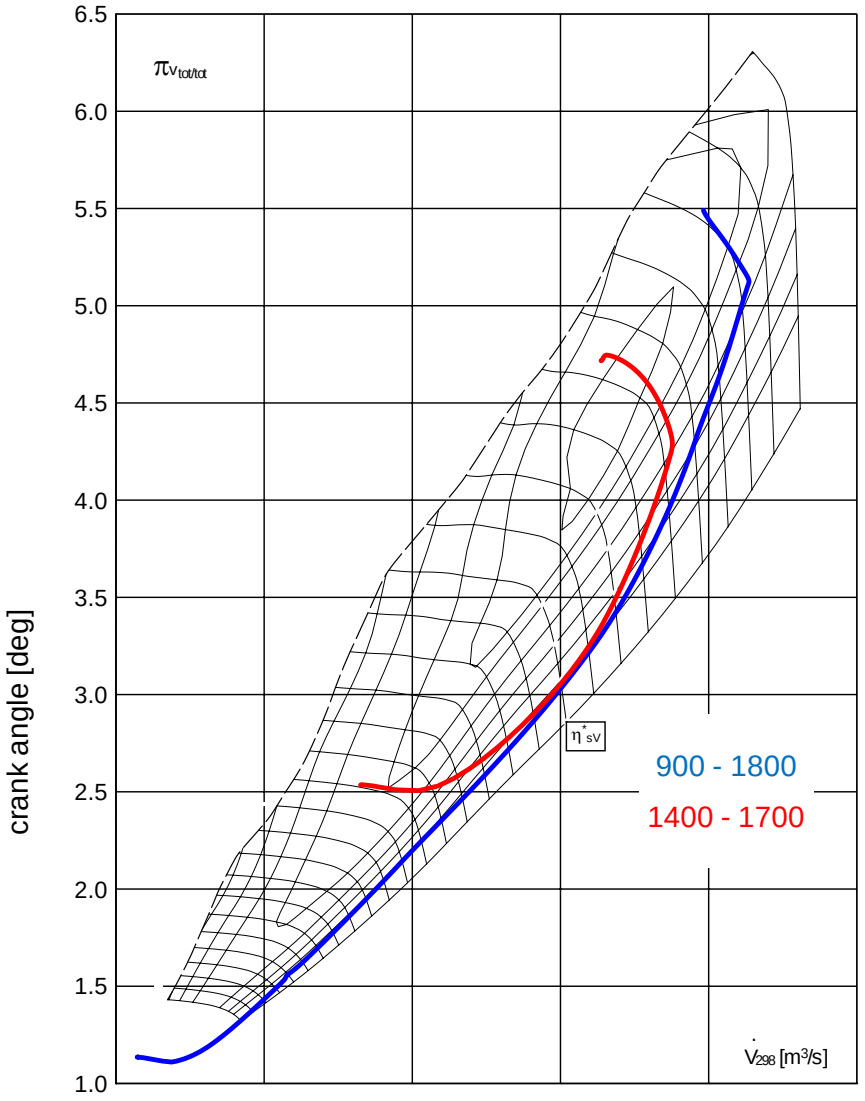
- Max. gas injection without falling below min. λ_V (knock- and exhaust gas temperature limits)
- Max. cylinder filling through optimized IVC timing without exceeding max. firing pressure and knock limits



VCM – the key for enhancing gas engines
Transient operation

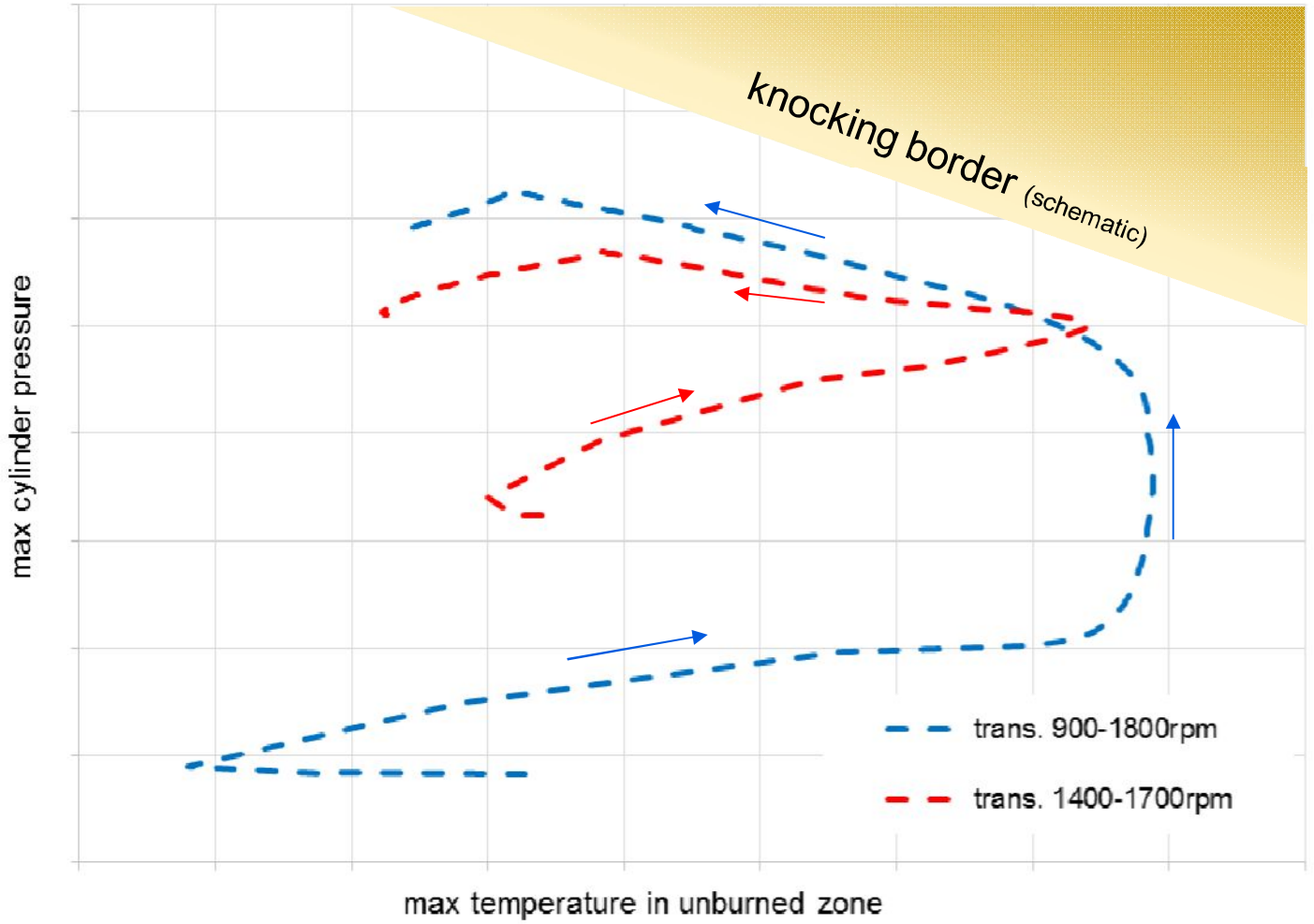
- Acceleration 900-1800rpm and 1400-1700rpm





VCM – the key for enhancing gas engines
Transient operation

Knocking indicators: steady-state and transient operation



VCM – the key for enhancing gas engines
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