Scavenging to improve Low-End Torque of a Direct Injected Turbocharged SI-Engine

Martin Brandt (CR/AEE2), Martin Rauscher (CR/AEE-M)
David Lejsek (GS/ENA3), Michael Nau (GS-ENS-CC), Michael Bäuerle (GS/ENA1)

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Outline

- Motivation
- GT-Power Engine Model
- Heat Release Model
- Knock Model
- Results
- The Principles of Scavenging
- Conclusions

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Motivation

- Turbocharged SI-Engines show insufficient Low-End-Torque
- DI-technology enables scavenging

- Can SCAVENGING be used to increase Low-End-Torque ?
- Why does SCAVENGING increase Low-End-Torque ?

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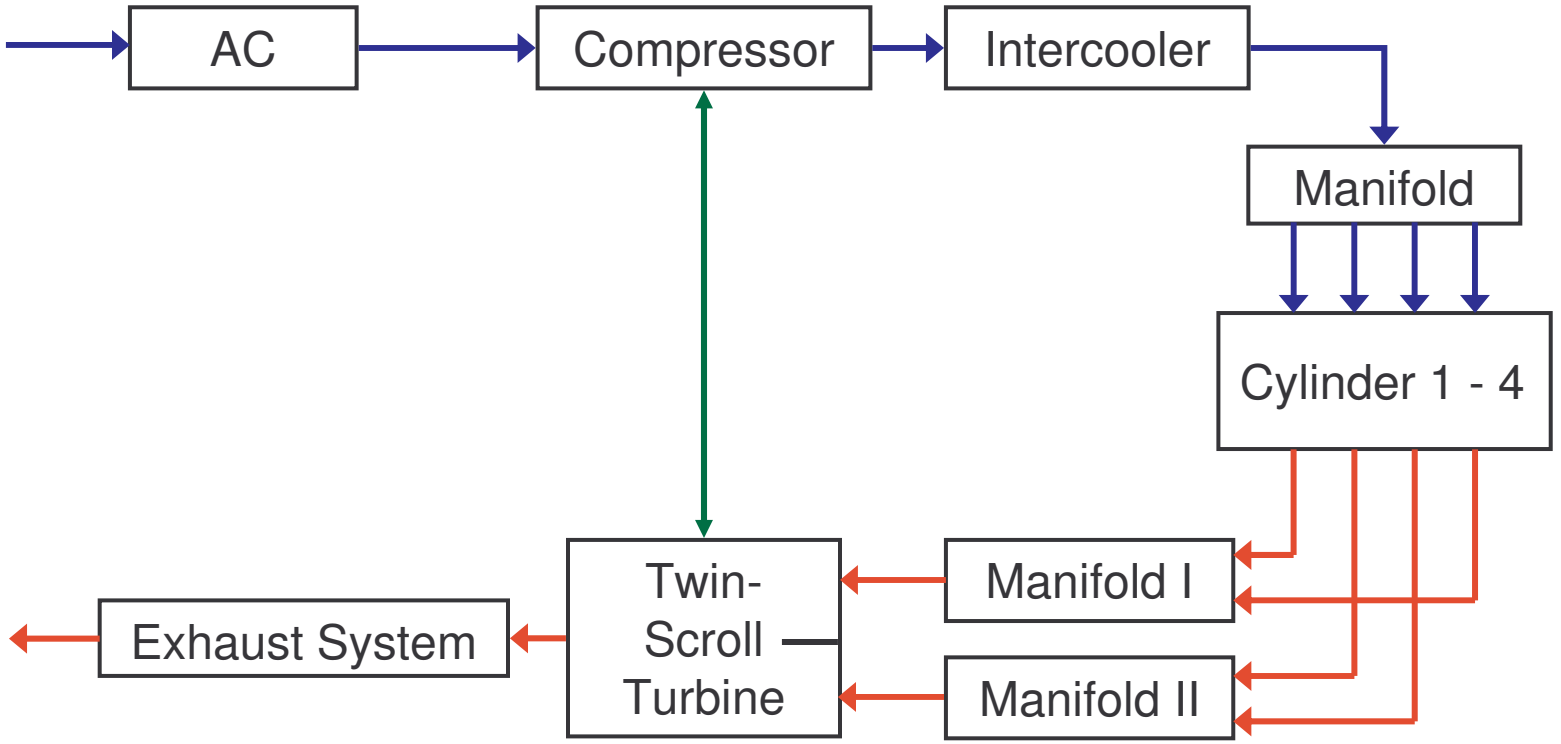
GT-Power Engine Model

4 Cylinder, 1.6l, Direct Injection, Turbocharged



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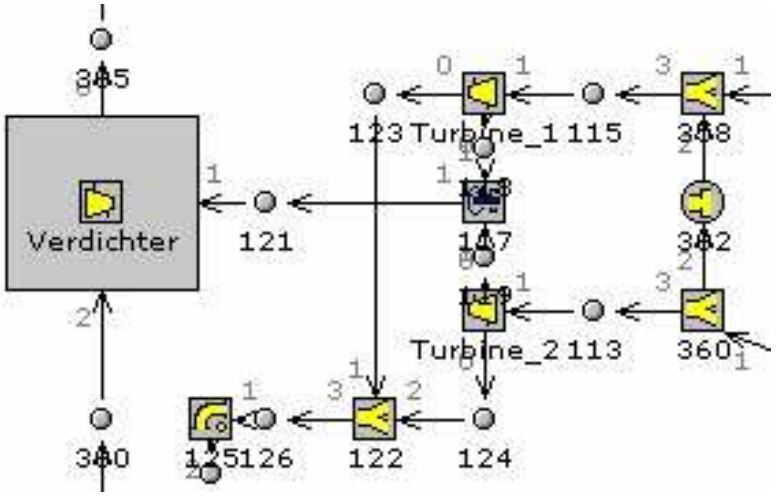
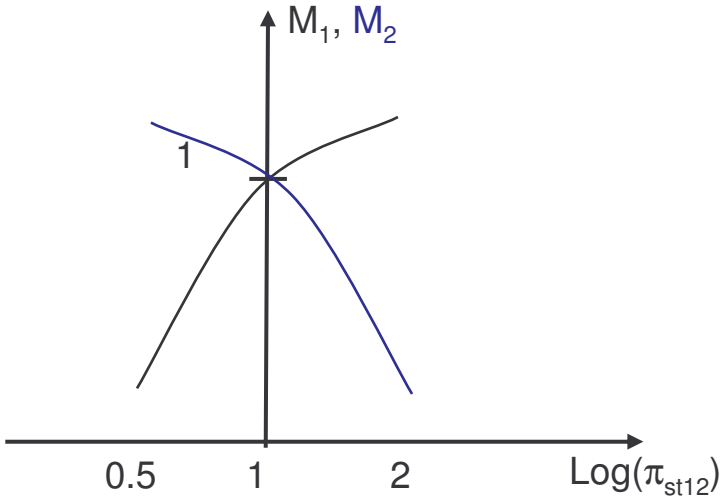
Twin-Scroll Turbine

- Turbine admission varies due to unequal pressure ratios at the volutes
- Normally more detailed turbine map necessary
- Using a mass multiplier based on the pressure ratios at the two volutes



GT-Power Twin-Scroll Turbine model



Applied turbine mass multipliers

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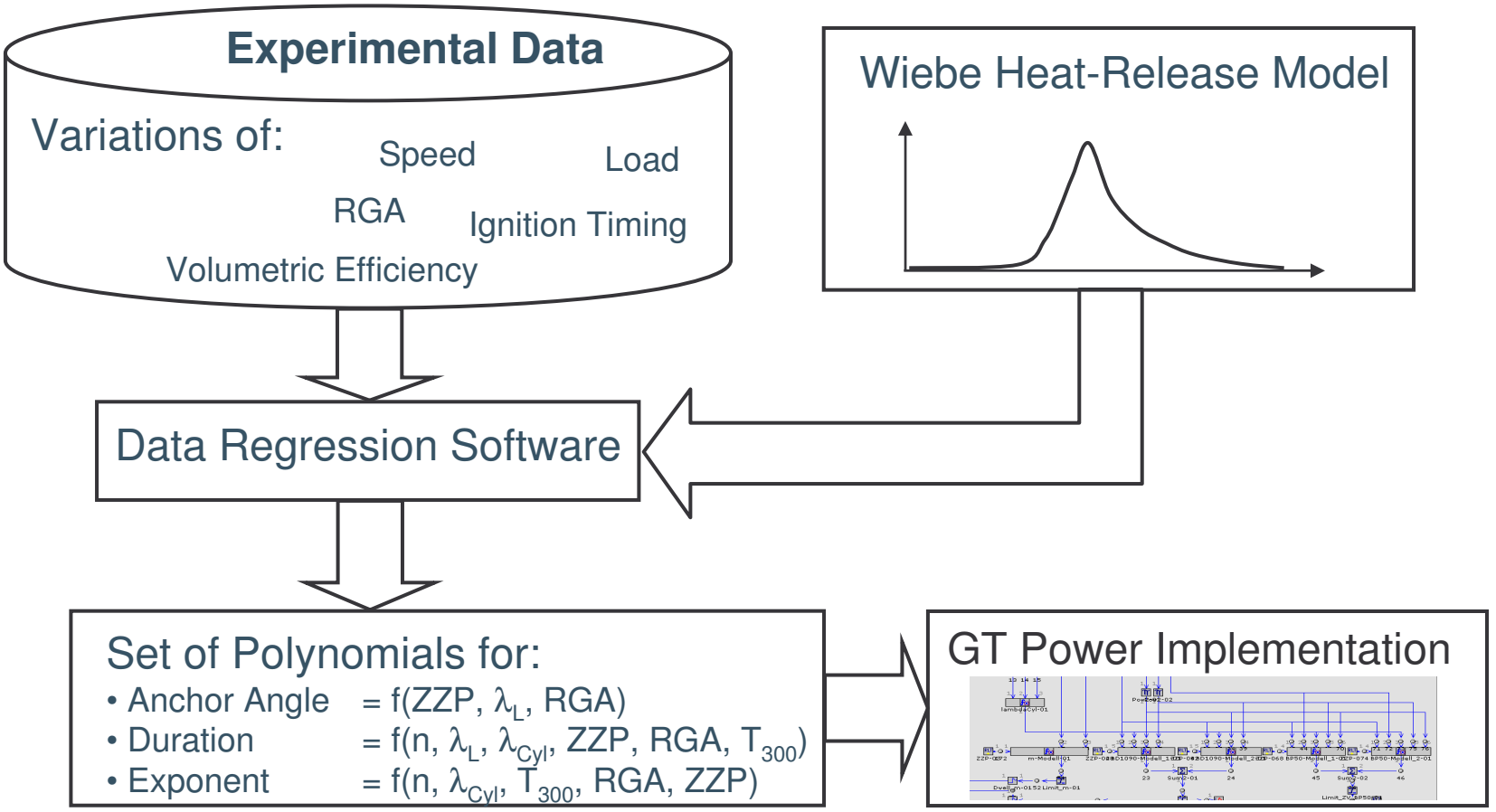
Heat Release Model



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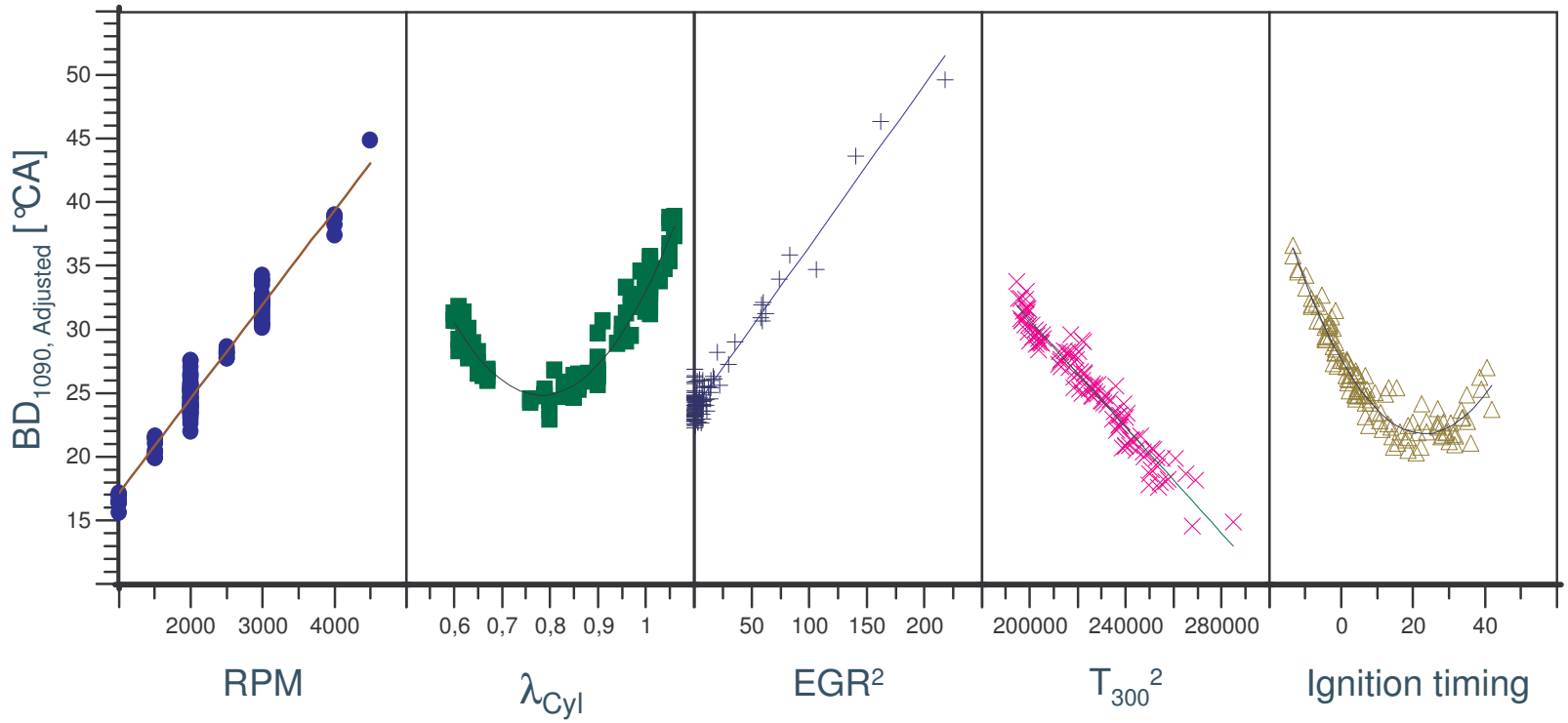
Heat Release Model

Comparison: BD1090 experimental vs. modeled data



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Knock Model I

➔ Knock index I

$$I_K = \int_{t=t_0}^{t=t_{KBG}} \frac{dt}{\tau}$$

different ignition delay time correlations can be found in literature

General form:

$$\tau = A \cdot \left(\frac{ON}{100}\right)^a \cdot p^b \cdot e^{\frac{T_A}{T_u}}$$

ON: Oktan-number
p: pressure
T_A: activation temperature

Examples:

	A	a	b	T_A
Douaud & Eyzat	0.0178	3.402	-1.7	3800
Spicher & Worret	0.002714	0	-1.262	3964

Strong pressure influence

Knock Model II

- Knock intensity KI (Spicher & Worret)
  - Conversion of the knock index via 75 % heat release CA:

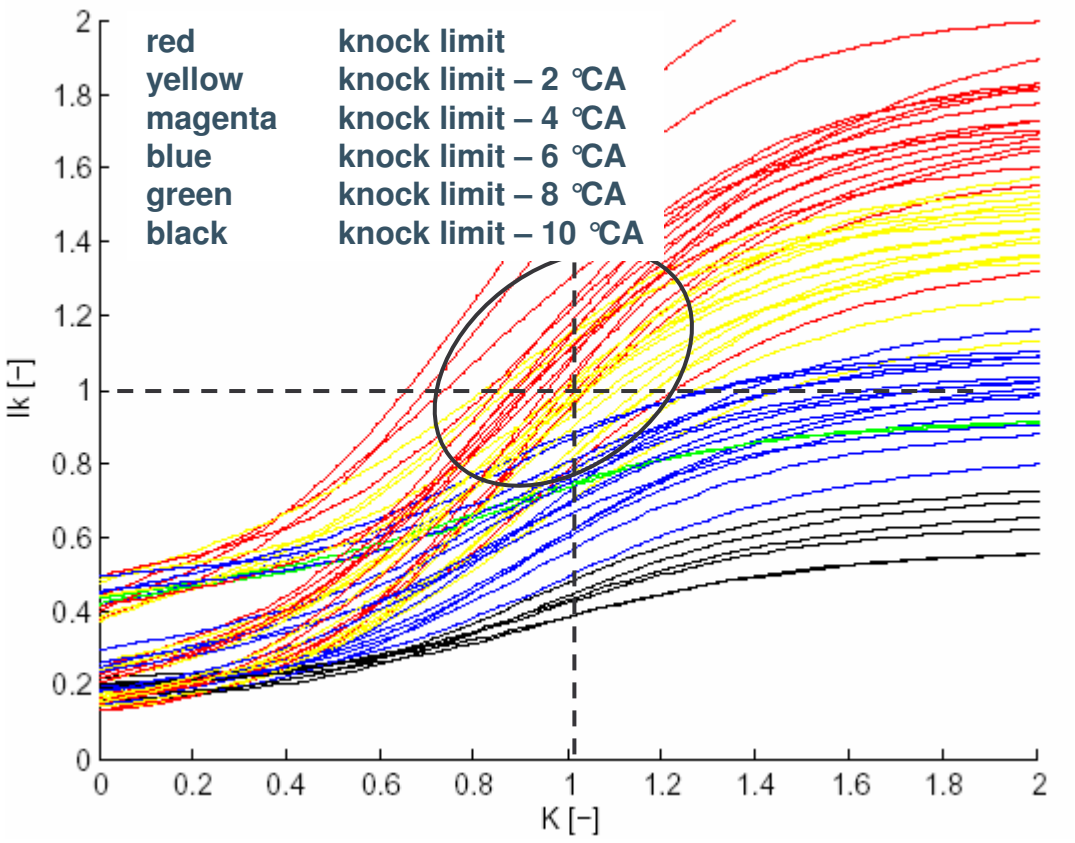
$$\frac{I_K}{I_{K\,ref}} = f(75\%CA)$$

  - Normalized crank angle during heat release:

$$K = \frac{\alpha - BP_{1\%}}{BE - BP_{1\%}}$$

α	Crank angle
$BP_{1\%}$	Heat release start
BE	Heat release end
	e.g. $BP_{75\%}$ ref. Soltic

Knock Model: Results



- ➔ Ignition delay time correlation of Douaud & Eyzat
- ☹ Operating points with different firing angles can not be separated
- ➔ Conversion of normalized crank angle ?

$$\frac{K}{K_{Ref}} = f\left(BP_{50}, \lambda\right)$$

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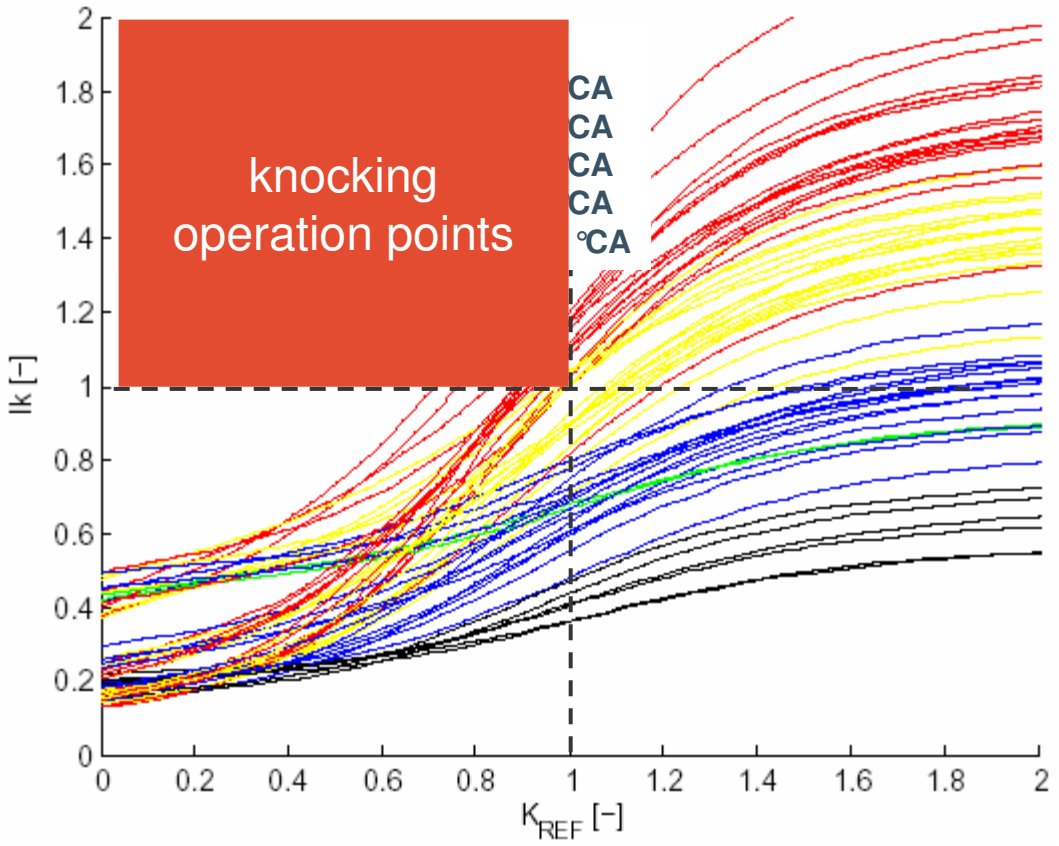
Knock Model: Results with conversion of K



- ➔ Ignition delay time correlation of Douaud & Eyzat

- ☺ Operating points with different firing angles can now be separated

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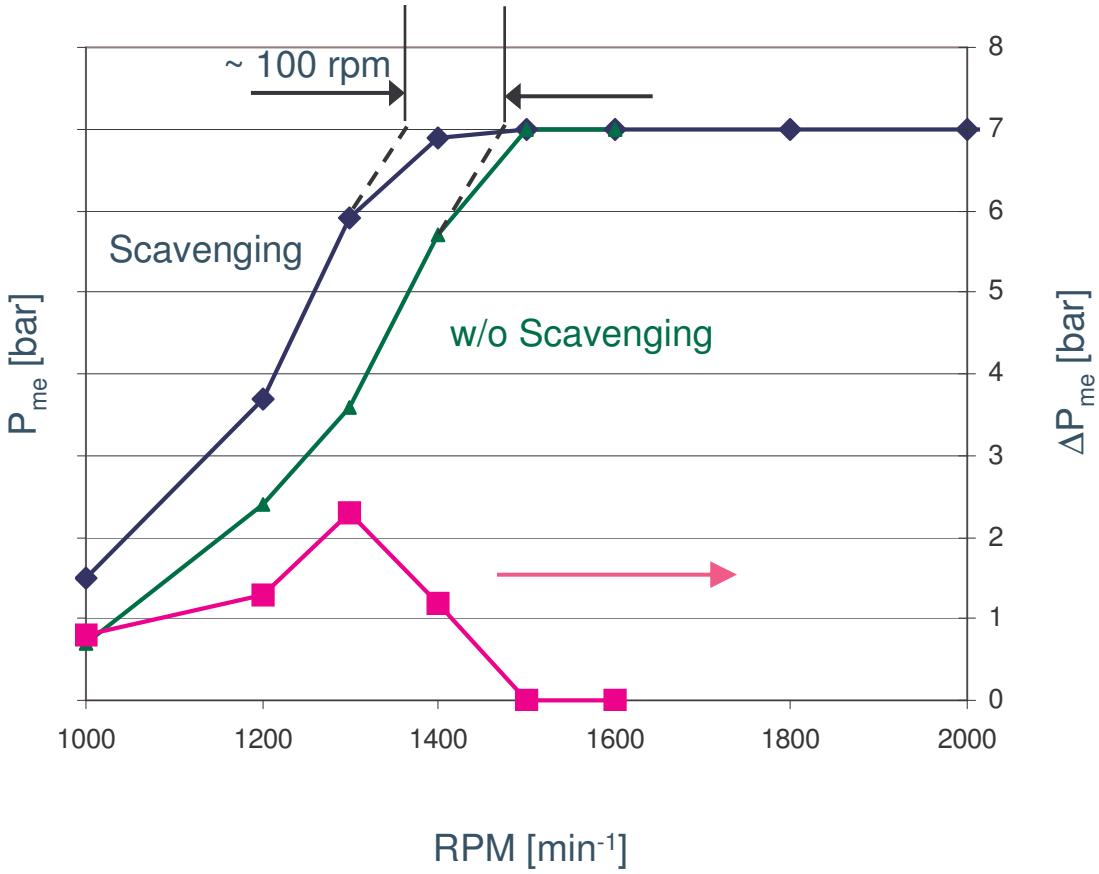
Results: p_{me} with and without scavenging



- Scavenging was limited to 5 %
- Low-End-Torque increased approx. 1.3 bar
- Maximal p_{me} reached at ~100 rpms lower speeds

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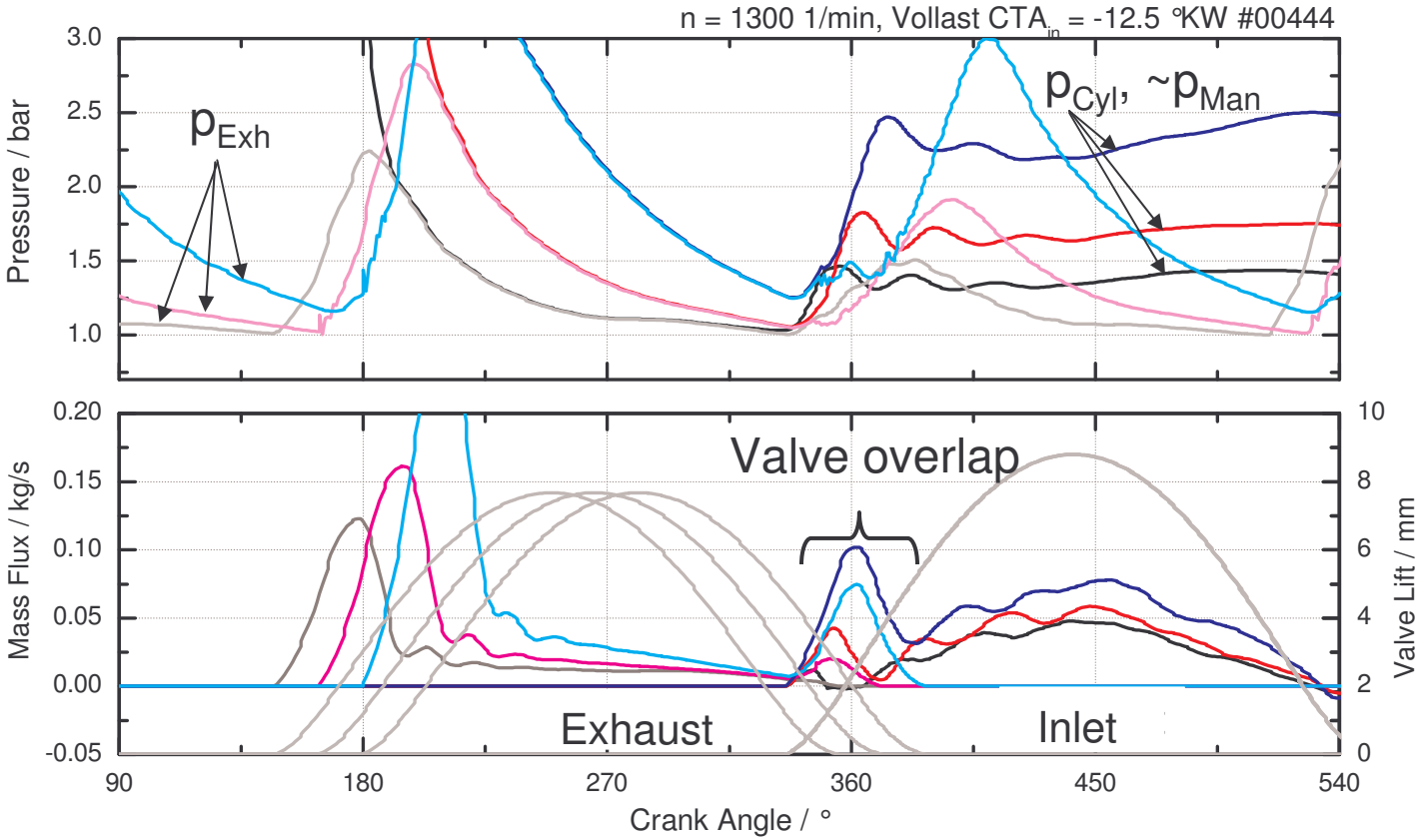
Results: cylinder pressure, valve mass fluxes



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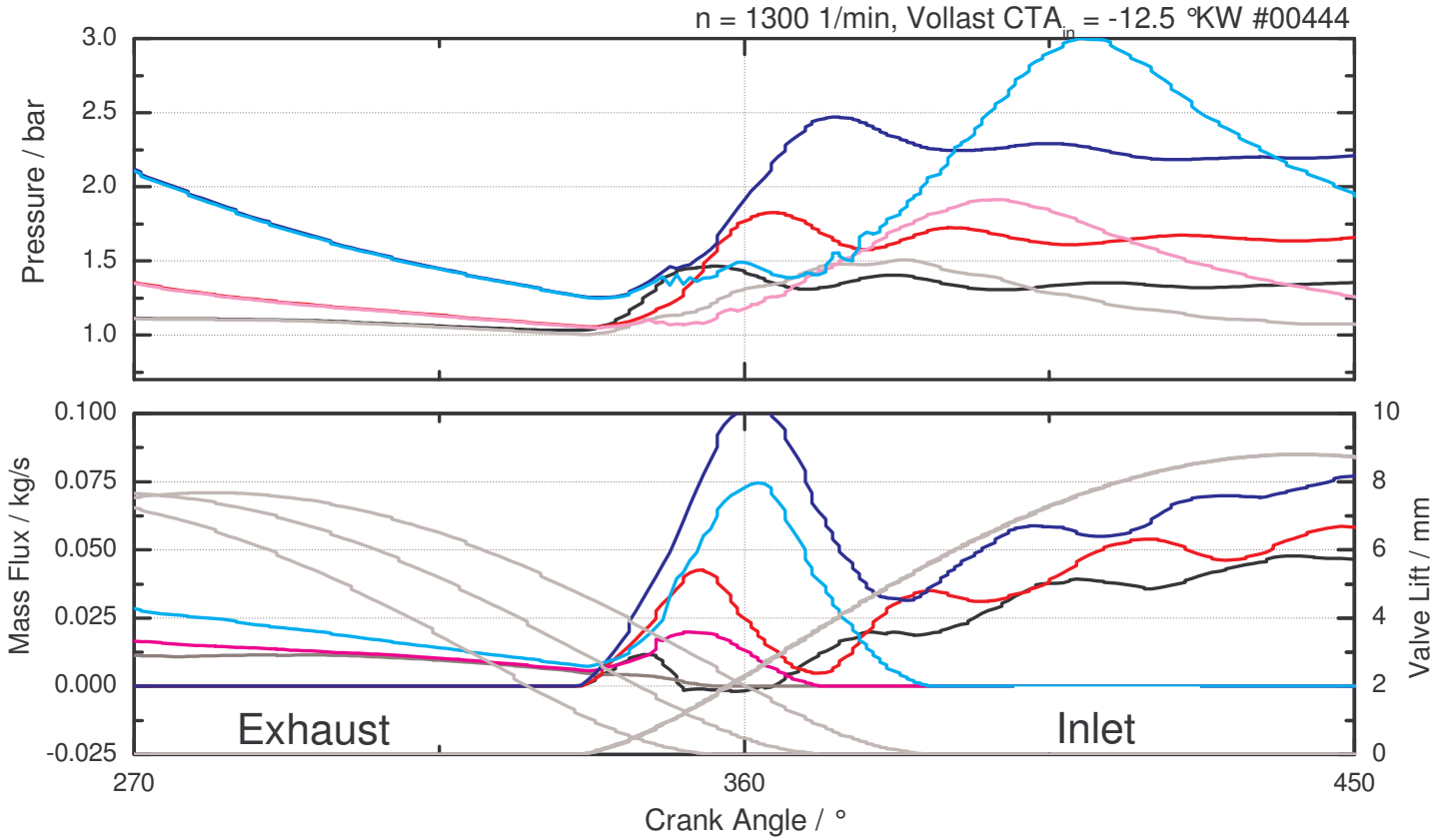
Results: cylinder pressure, valve mass fluxes



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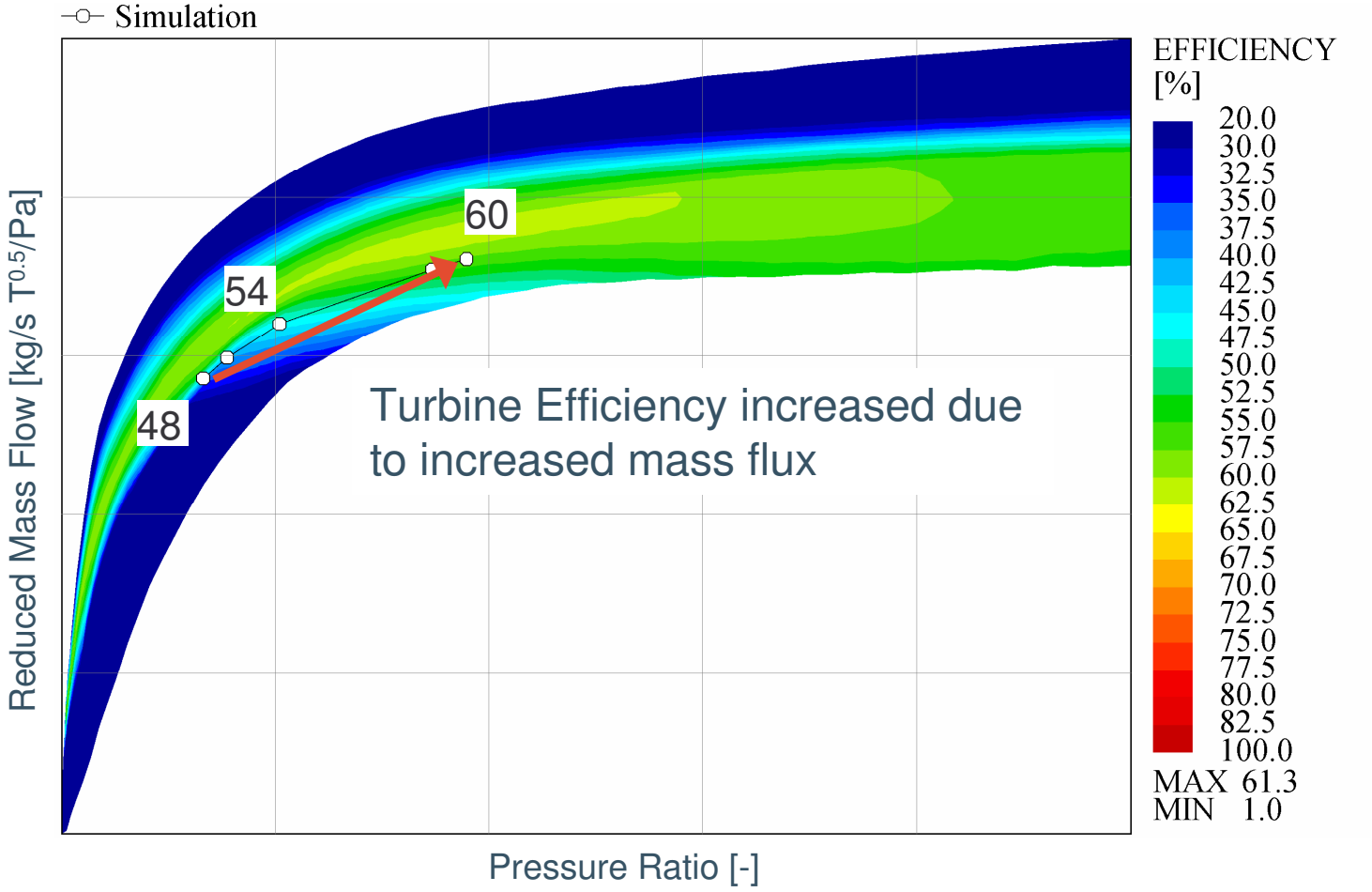
Scavenging: Increase of TC efficiency



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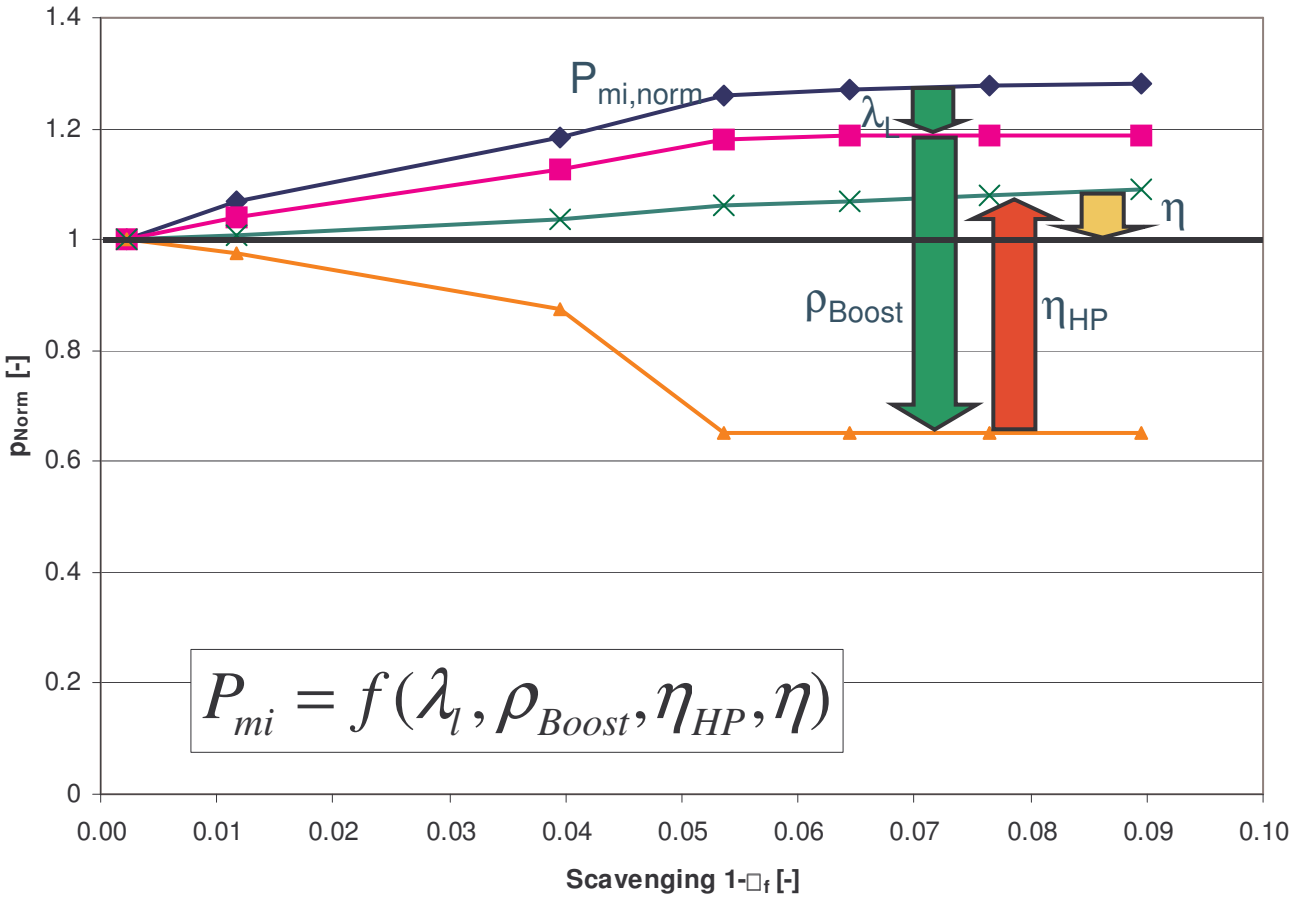
Scavenging



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Conclusions

- Combustion model calibrated and implemented
- Knock model based on Douaud & Eyzat ignition time correlation and conversion from Spicher & Worret enables knock control
- Twin-Scroll model implemented
- Scavenging:
  - TC efficiencies increase at low rpms
  - Increases Low-End-Torque significantly
  - Increased boost pressure can not be used completely due to increased knock sensitivity