HCCI* Modeling, Calibration and Analysis by Integrating GT-Power and Matlab-Simulink Capabilities

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* Also known as Controlled Auto Ignition (CAI)
Agenda

• HCCI Motivation
• Setup of a HCCI engine model in GT Power with EHVS and GDI
• Use of a Wiring Harness together with Matlab-Simulink®
• Integrated Arrhenius approach to predict combustion
• Validation of the simulation with measurements
• Summary
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→ **Principle**
  - Hot charge (air, fuel, residuals) is compressed
  - Near TDC hot spots start auto-ignition
    → volumetric reaction takes place

→ **Fast heat release with**
  - High efficiency (dethrottling)
  - Near zero NOx (no hot flame)
  - Low HC+CO (lean operation)

→ **Critical Issues:**
  - Lack of a ignition trigger (no direct initiator of combustion)
  - Limited operation map area (lean operation, press. grad., noise, low temp.)
  - Transient control of combustion and switch between two combustion modes

→ **GOALS**
  - Develop a system to understand & address these critical issues
  - Provide a setup for offline simulations which predicts the HCCI behaviour
Setup of HCCI engine model in GT Power with EHVS and GDI

1 Cyl. 450cc Research Engine with GDI & EHVS

- SOI Fuel mass
- Inlet Exhaust
- Engine Parameters e.g. rpm, bore, stroke
- Combustion Parameters e.g. Anchor Angle

Wiring Harness
Integrated Arrhenius approach to predict combustion

Arrhenius Integral

\[ \int_{IVC} A e^{-\frac{E_a}{RT} \left[ F \right]^a \left[ O_2 \right]^b} = k \]

Vibe Function

\[ x_b = 1 - e^{-a \left( \frac{\theta - \theta_0}{\Delta \theta} \right)^{m+1}} \]

- \( x_b \) → Mass fraction burnt
- \( \theta_0 \) → Crank angle at SOC
- \( \Delta \theta \) → Combustion duration
- \( m \) → Shape factor
Validation Process

High Order Reference Model for HCCI

1 Cyl., 450cc, Research engine
Experiments validated

Characteristic values of Experiments

- Speed
- Fuel Parameters
  - Split Inj.
  - SOI
The simulations show a very good accuracy & most important of all, a consistent tendency!
Summary

• HCCI Modeling and Simulation was realized with relatively few steps
• The **Wiring Harness** functionality was used extensively for Analysis which helped us
  • understand the basic principles of **HCCI combustion**, for e.g. the Start of Combustion, using the integrated Arrhenius approach
  • gain a deeper insight in studying various factors of influence
• Measurements at the test bench **confirm the results & reaffirm the need of 1-D Simulation Tools** for extensive use in the Automotive industry
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Thank you for your time & attention

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