Development of an advanced Quasi-Dimensional SI Engine Combustion Model

GT-Power User Conference Frankfurt
October 10, 2005

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Agenda

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- Model requirements
- Model assumptions
- Quasi-Dimensional model description
- GT-Power - LUSIE Software Architecture
- Results
  - Turbocharged Engine
  - Normally aspirated Engine
- Conclusions
- Further Work

Motivation:

Normally a Wiebe function is used to define a heat release curve.
Wiebe functions are based on empirical data.

- They are not predictive.
- They are simple and computationally efficient.

- LUSIE (***L***eeds ***U***niversity ***S***park ***I***gnition ***E***ngine software)
  sits between CFD (3-Dimensional) and Wiebe function (0-Dimensional).
  - Retains some of predictive capability of CFD with minimal complexity
  - Retains speed of execution of the Wiebe function

- The motivation for using a Quasi-Dimensional code such as LUSIE is to enable the prediction of changes in combustion performance caused by changes in cylinder conditions

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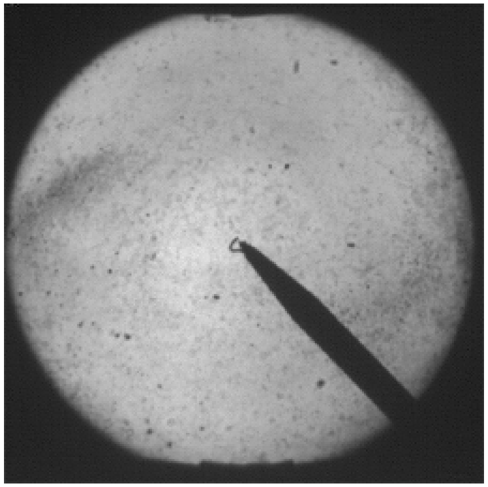
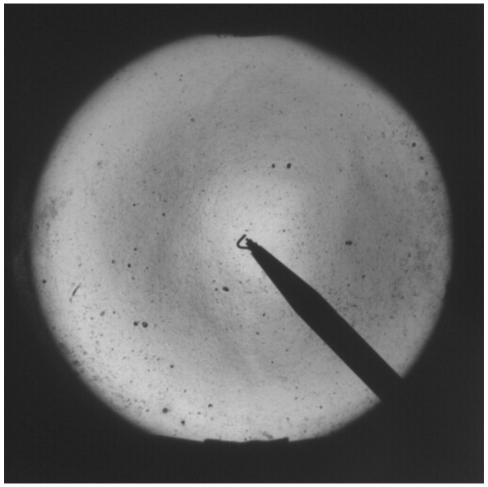
Model Assumptions:

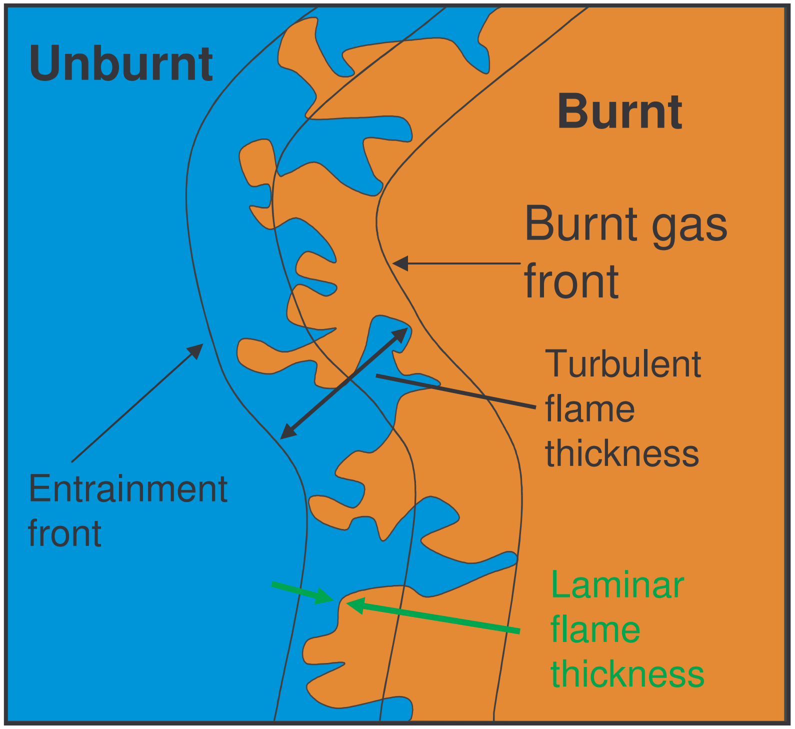
- Surface of the flame is wrinkled by the action of turbulent eddies
- Rate of mass burning proportional to amount of entrained mass which is unburnt
- Burn up behind the entrainment front governed by a characteristic burning time

Turbulent flame propagation



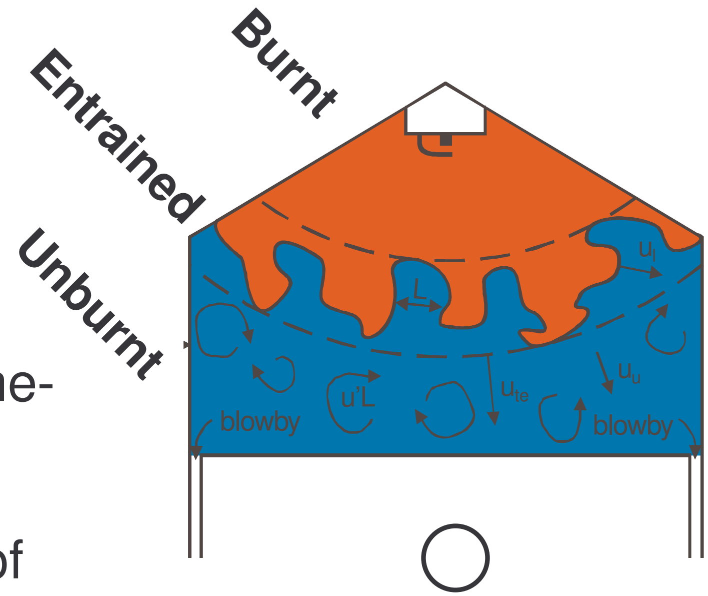
Laminar flame propagation



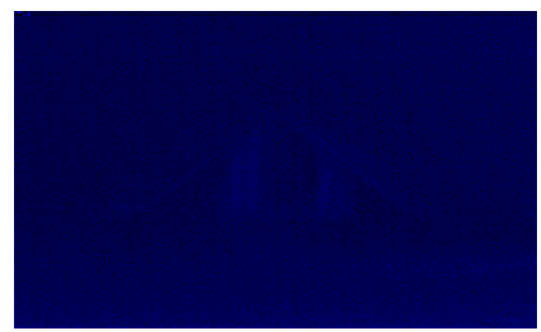


Quasi-Dimensional model description:

- Combustion chamber split into “burnt”, “entrained” and “unburnt” zones
- Each zone is normally of fixed (but differing) composition and temperature
- Requires a sub-model for burning velocity
- Requires a sub-model for flame geometry / flame-cylinder interaction



- The benefits include more realistic predictions of burnt / unburnt gas temperatures, heat transfer, etc.
- The model has the capability to react to changes in in-cylinder conditions
- Computationally efficient enough to be used in conjunction with software requiring many cycles, e.g. GT-Power



Quasi-Dimensional model description:

- Closed part of cycle only – breathing routines by GT-Power
  Includes:
    - Flame and cylinder geometry
    - Thermodynamic and chemical equilibrium, enabling:
        - Adiabatic flame temperature
        - Pressure equalisation between burnt and unburnt zones
    - Thermodynamic properties such as specific heat polynomials
    - Molecular transport coefficients such as mass and thermal diffusivities

Model requirements

- Based on model assumptions 4 main sub-models are necessary:
  1. Flame geometry sub model
     - Based on numerical integration
  2. Laminar burning velocity sub model
     - Based on Metghalchi & Keck or Rhodes & Keck correlations
  3. Turbulent burning velocity sub model
     - Several options avaliable
       - Empirical correlation: Leeds K, Leeds K-Le
       - Theory: Zimont-Lipatnikov
  4. Turbulence sub model
     - Fitted to experimental Data

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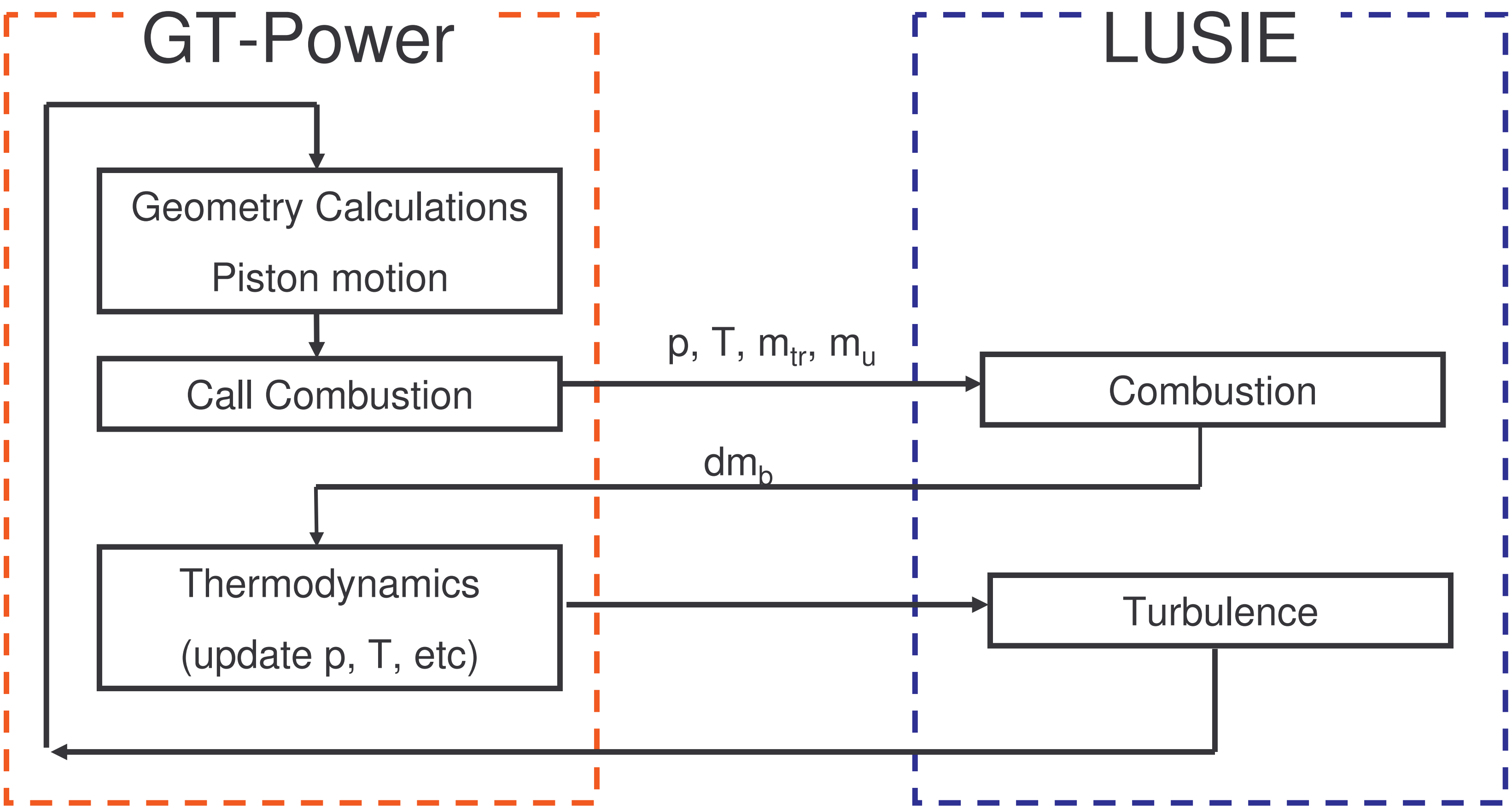
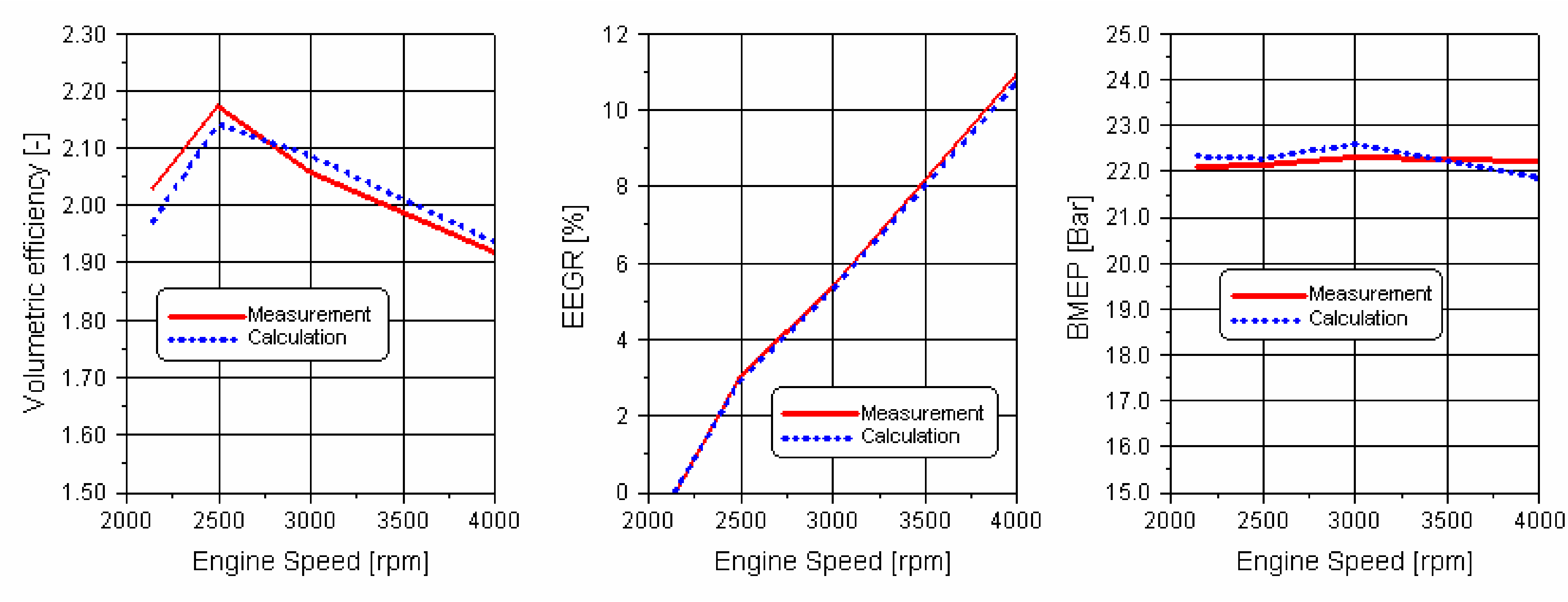
GT-Power - LUSIE Software Architecture:



Calculation results for a turbocharged I4 engine:

Pre turbine temperature controlled via cold external EGR / λ=1



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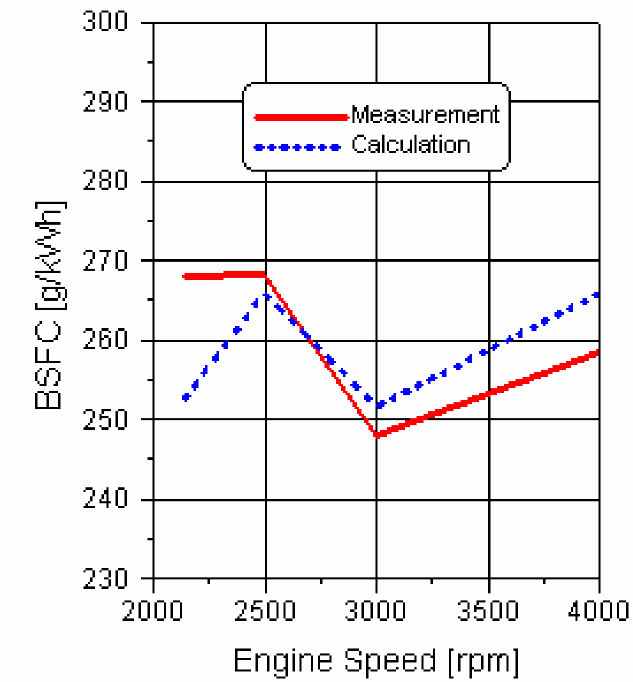

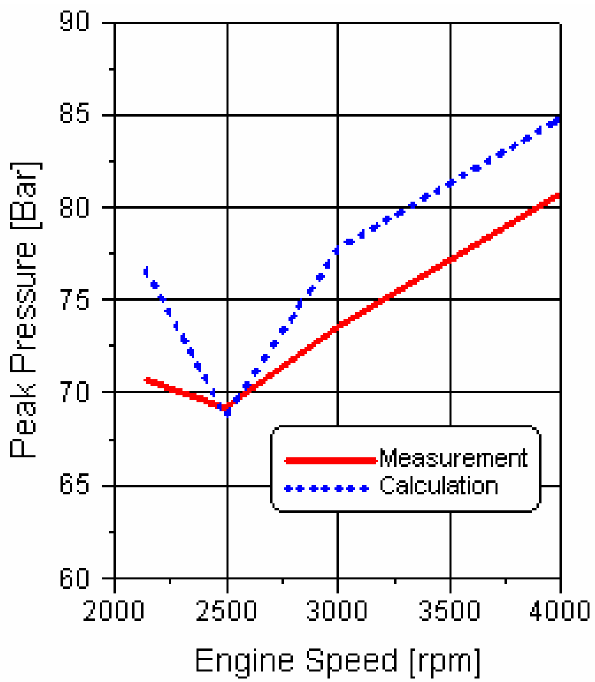

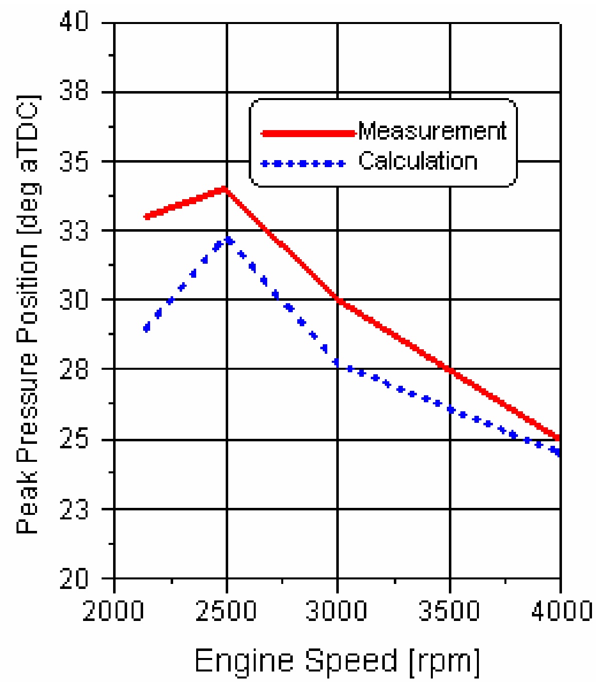

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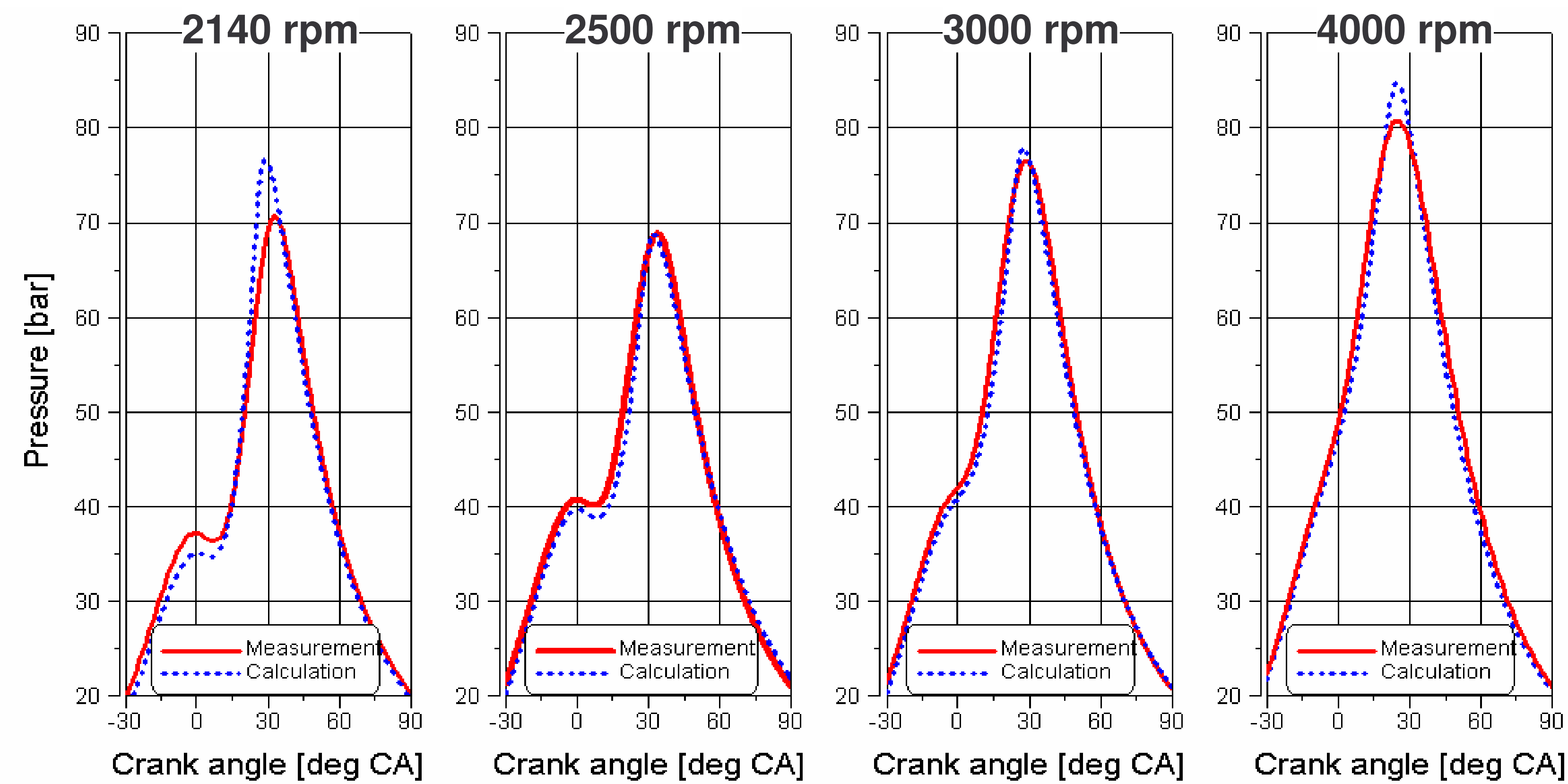

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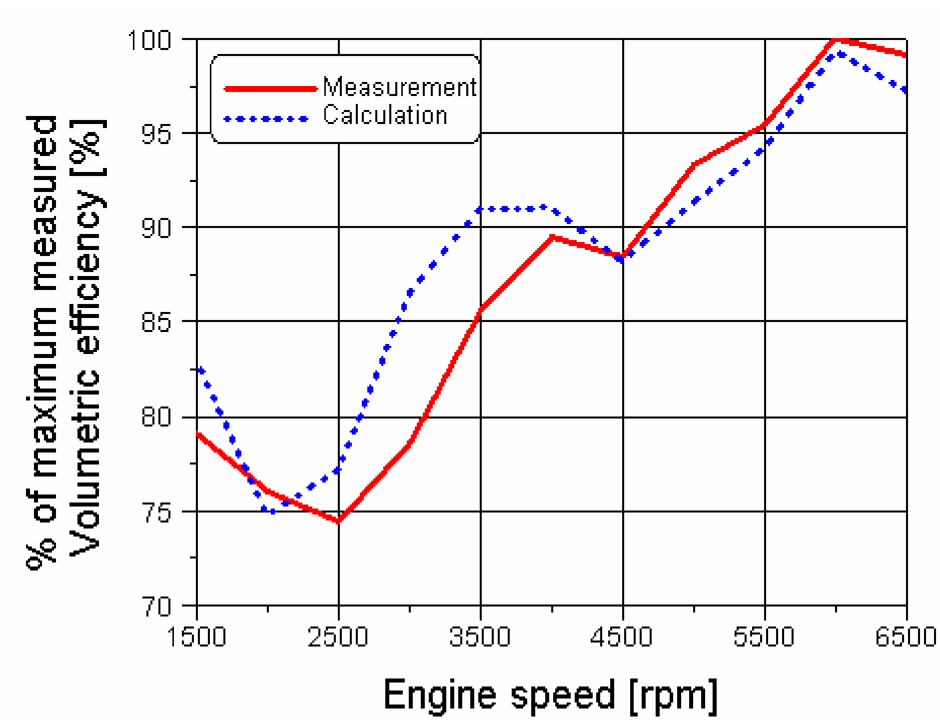
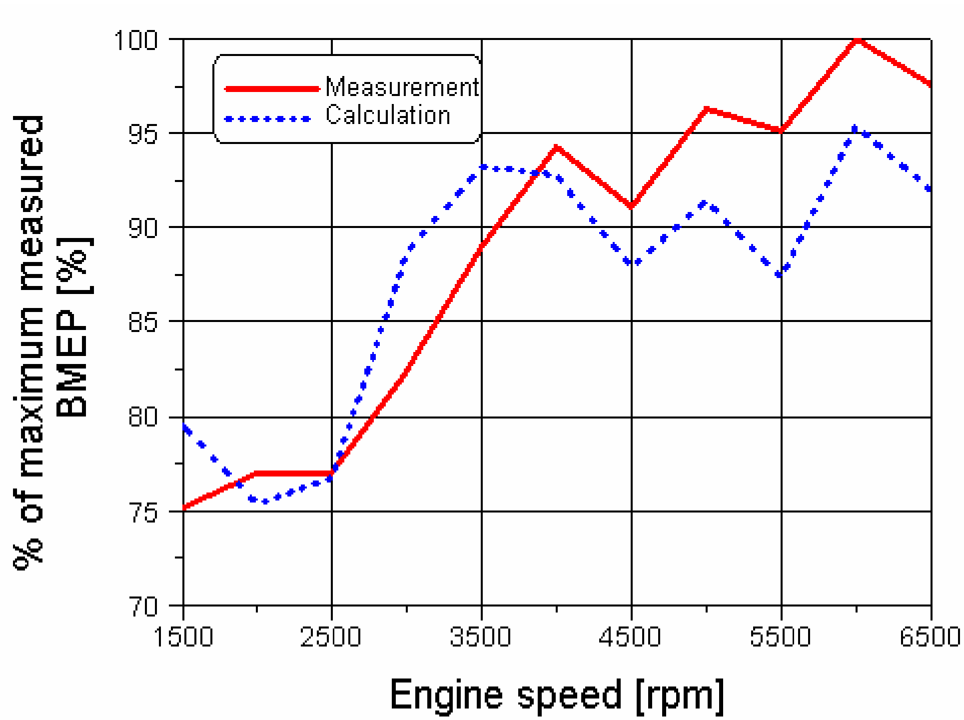
Calculation results for a multi cylinder high output N/A Engine:





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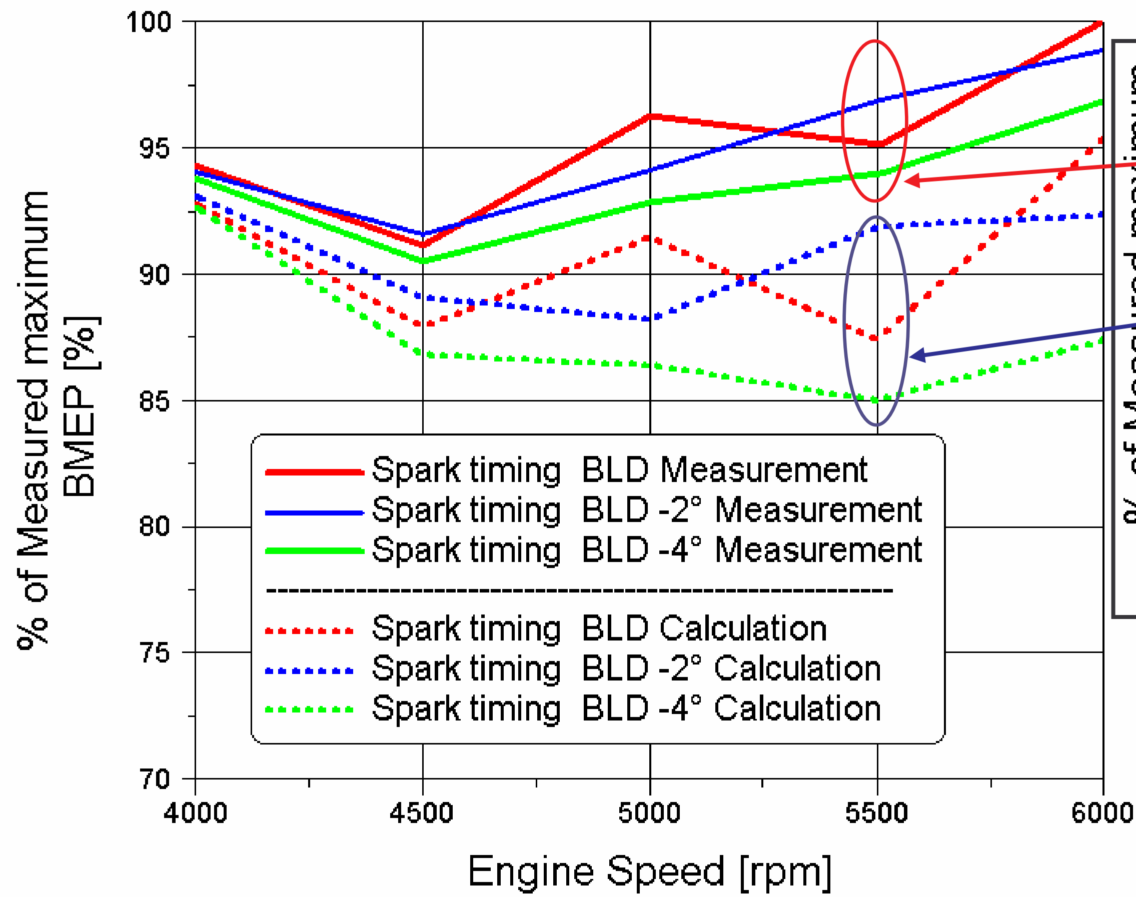
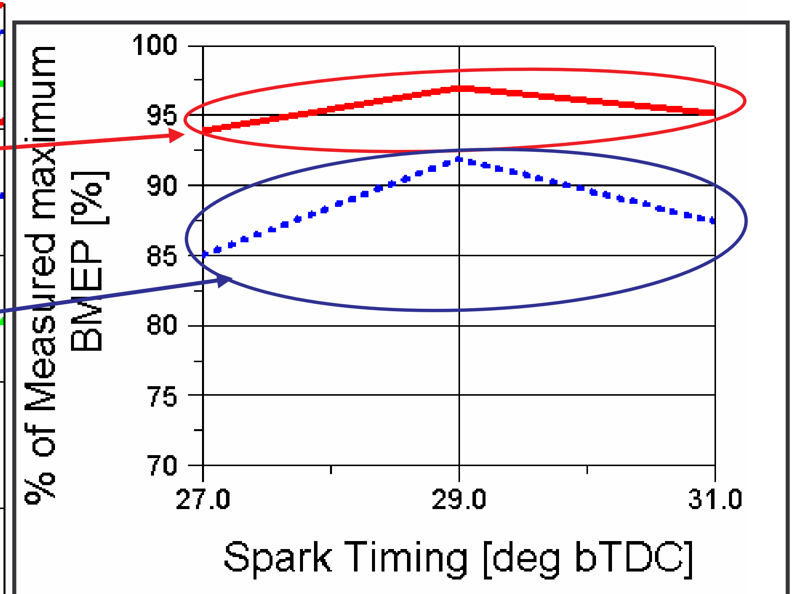




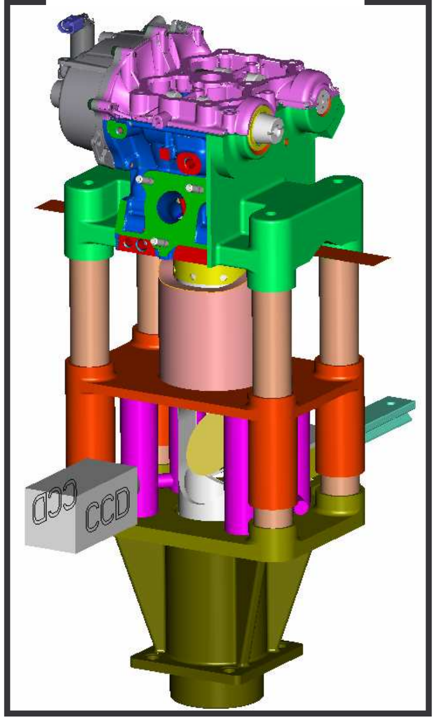
BLD = Detonation borderline

Spark timing in model equals the measured spark timing

Further Work:

- Improve the model's predictive capability further
- Improve correlation to CFD turbulence Data
  - Verify in cylinder turbulence with optical engine (Ongoing MPT project)
- Implement the included Knock model (Douaud and Eyzat)
- Use LUSIE for virtual Calibration activities

Optical engine



Conclusions:

- LUSIE shows a reasonable correlation over a wide range of engine operating conditions.
- Prediction of IMEP is possible within a reasonable accuracy range if the in cylinder turbulence data is available.
- Trends are predicted correctly.