GT-Power to enhance Single Cylinder Measurements

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Power. Passion. Partnership.

Today‘s Agenda.

- Single Cylinder Measurements
- Automated Toolchain (CalcSC)
  - Pressure Analysis Model
  - Full-Scale Engine Model
- Results
- Conclusion

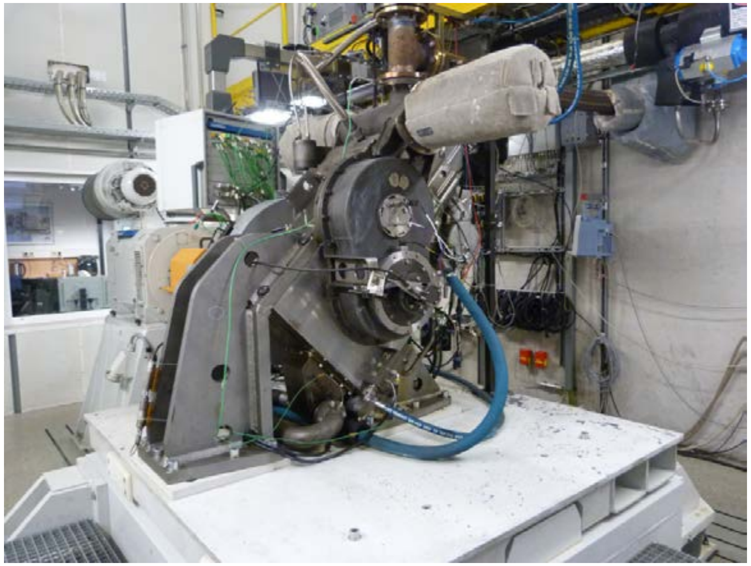
Single Cylinder Measurements Advantages

What is the benefit of single cylinder measurements?

- Less cost intensive
  - Lower fuel consumption
- Reduced effort for the application of measurement equipment
  - Measurement equipment e.g. for the instantaneous cylinder pressure only required for a single cylinder
- Shorter set-up times
  - Allows fast cylinder configuration changes

→ Convenient approach for combustion development

Single Cylinder Test Bed



Single Cylinder Measurements
Boundary Conditions

How to determine the correct set-point for single cylinder measurements?

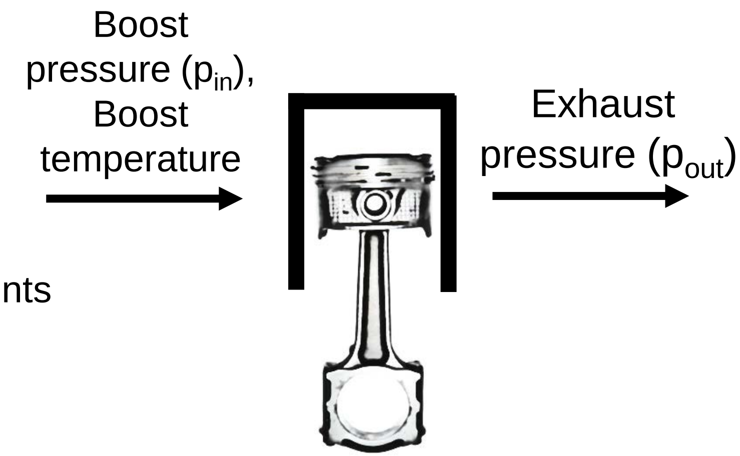
Simple Approaches:

- ➢ Constant scavenging
- ➢ Constant turbocharging efficiency. Utilisation of turbocharger equations to calculate exhaust pressure

Problem:

- ➢ Simple approaches may lead to false engine operation points
  - ➢ Wrong scavenging assumption
  - ➢ Turbocharging efficiency changes not considered
- ➢ Effects like throttle flap position cannot be easily incorporated

Unknowns:

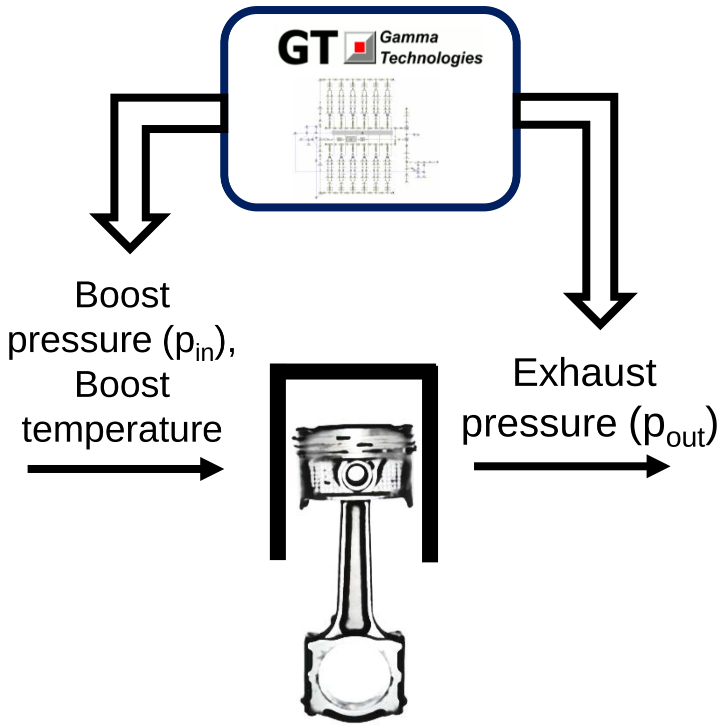


→ Remedy: Sophisticated approach based on a full-scale engine model

Single Cylinder Measurements
Full Scale Engine Model

Advantages of a full-scale engine model

- Engine and turbocharging operation point is automatically computed correctly
- Investigation of turbocharging parameters
- Incorporation of engine devices such as throttle flap or parameter studies in the engine piping system

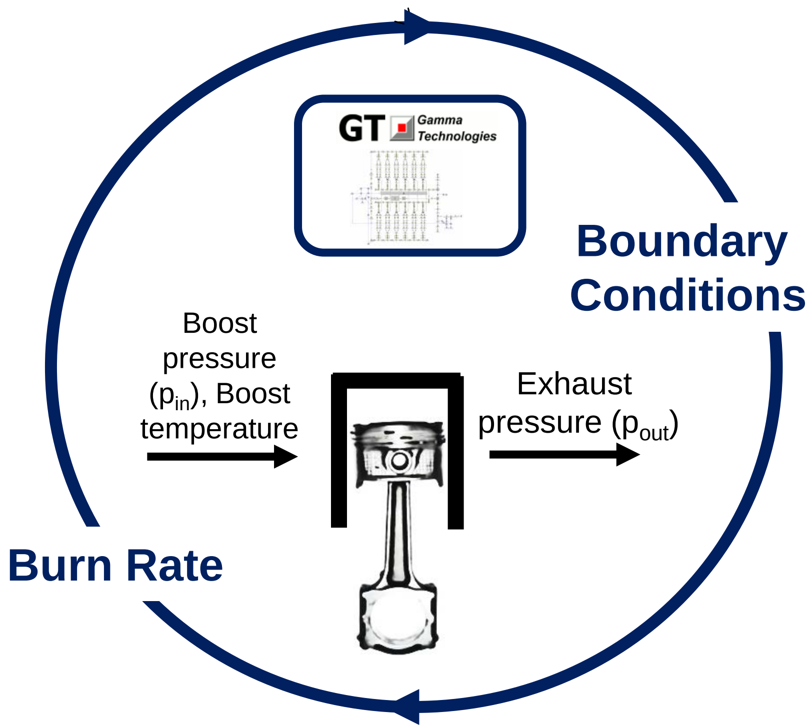


→ However: With a full-scale engine model this is when work starts

Single Cylinder Measurements Inter-Dependency

Inter-Dependency of pressure curve and single cylinder set-point

- Depending on the boost pressure the combustion changes, due to different thermodynamic conditions and different turbulence levels
- A different combustion leads to different cylinder-out temperatures
  - Affects the turbocharging
  - Boost pressure and exhaust pressure change

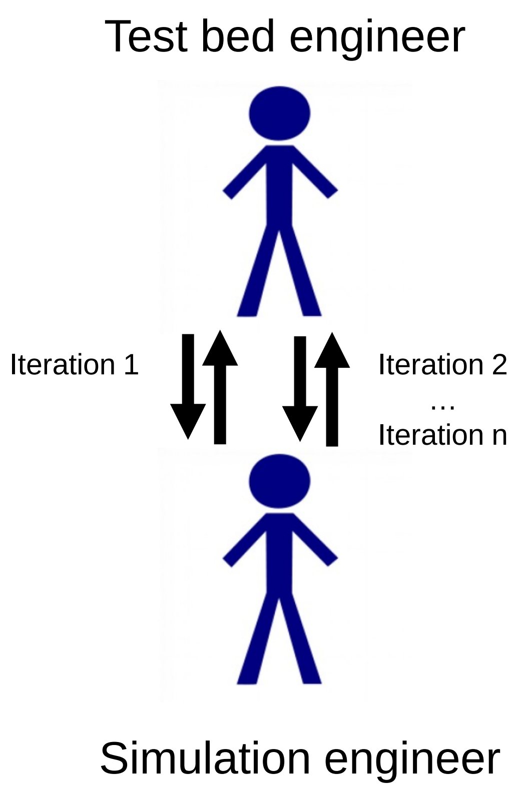


→ **Whole process has to be repeated until convergence is reached**

Single Cylinder Measurements
Traditional Process

Workflow to determine single cylinder set-point

- Test bed engineer informs simulation engineer that new measurements are available
- Simulation engineer extracts data from the measurements and begins simulation tool chain
- Simulation engineer informs test bed engineer that the new set-point data is available



Drawbacks:

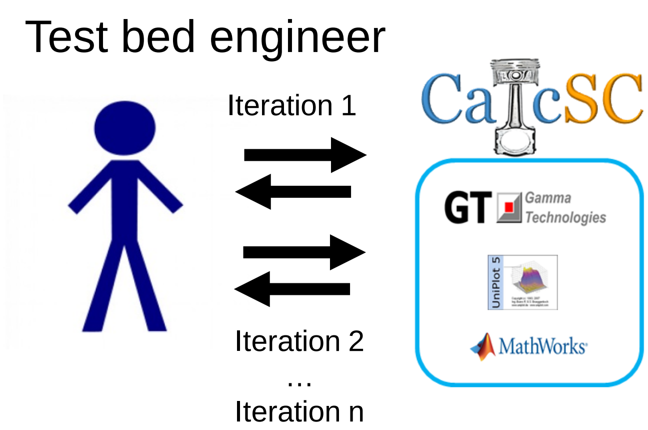
- High communicative effort which is time intensive
- Test bed engineer depends on availableness of simulation engineer
- High work-load of simulation engineer for the iterations without real gain in engine insight

→ **Room for improvement**

Automated Toolchain

Implementation of automated toolchain to simplify process

- Test bed engineer is provided with a concise GUI to enter measurement data
- Computation request is send via e-mail to workstation on which all relevant software is available
- Workstation performs simulation and generates results report which is send back via e-mail to the test bed engineer



Advantages:

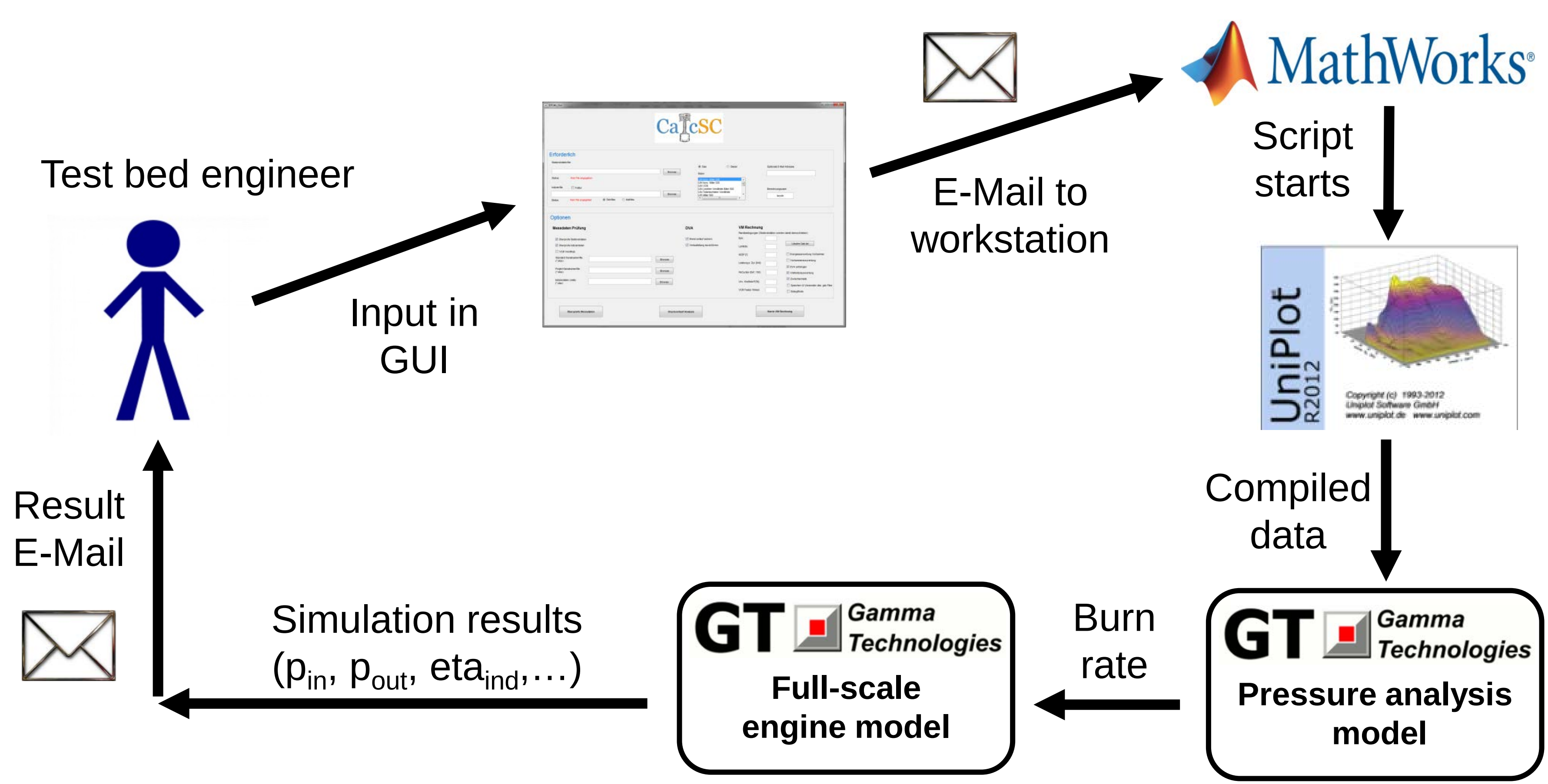
→ Time consumption due to high communicative effort significantly reduced

→ More independency of test bed engineer and simulation engineer

→ Simulation engineer is released from iteration computation

→ Error susceptibility when transferring the measurement data minimized

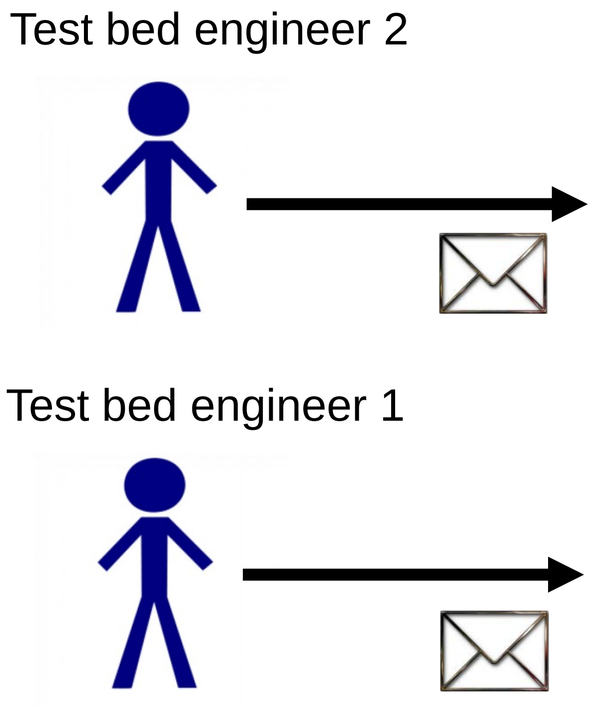
Automated Toolchain Scheme



Automated Toolchain
Additional Features

Multiple Users:

- Toolchain versioned with subversion → Changes in the models are automatically adopted for the next runs
- Allows several parallel-running computations
- Allows several users running simulations parallel



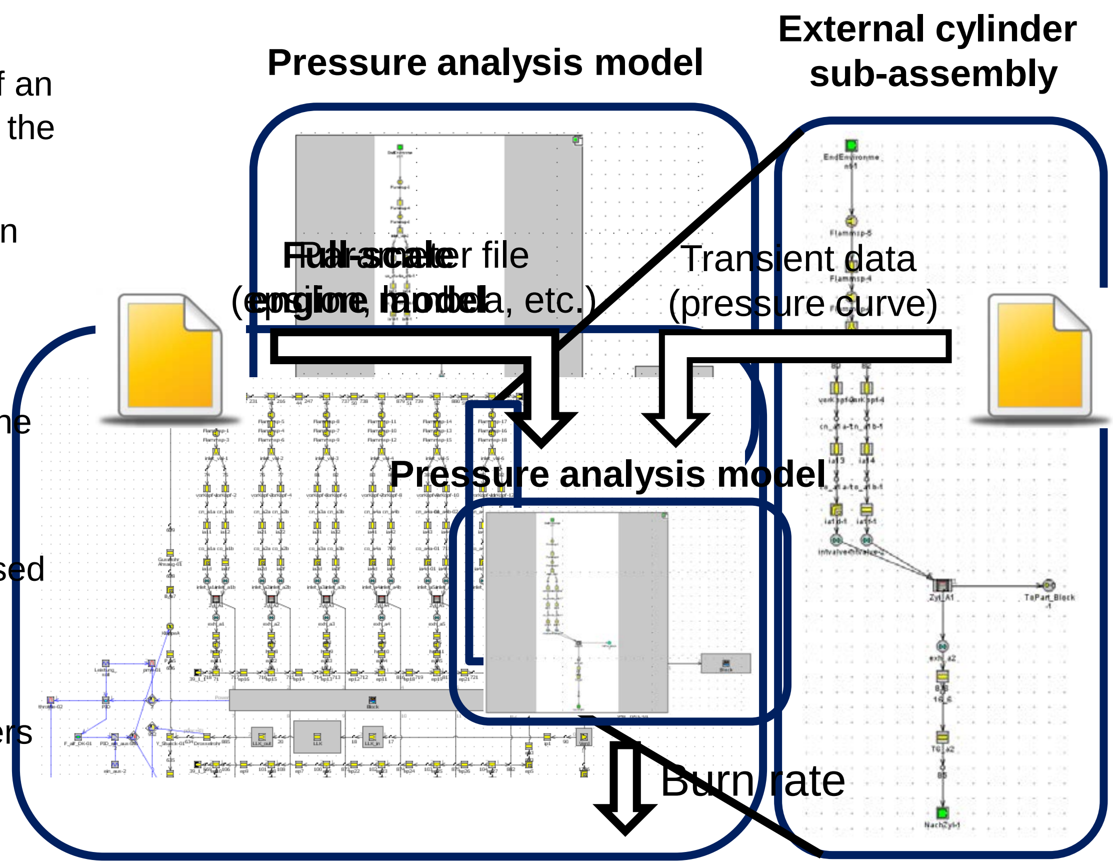
Automated Toolchain
Pressure Analysis Model

Model characteristics:

- Pressure analysis model consists of an external cylinder sub-assembly and the crank train block
- Cylinder configuration for the chosen engine type is loaded through the external cylinder sub-assembly
- Parameter file containing the configuration specific settings and the transient data file are generated in advance
- Three-pressure analysis (TPA) is used to allow detailed pressure analysis

Advantages:

- Easy implementation of new cylinders
- Main model file and front end can remain unchanged



Automated Toolchain
Full-scale engine model

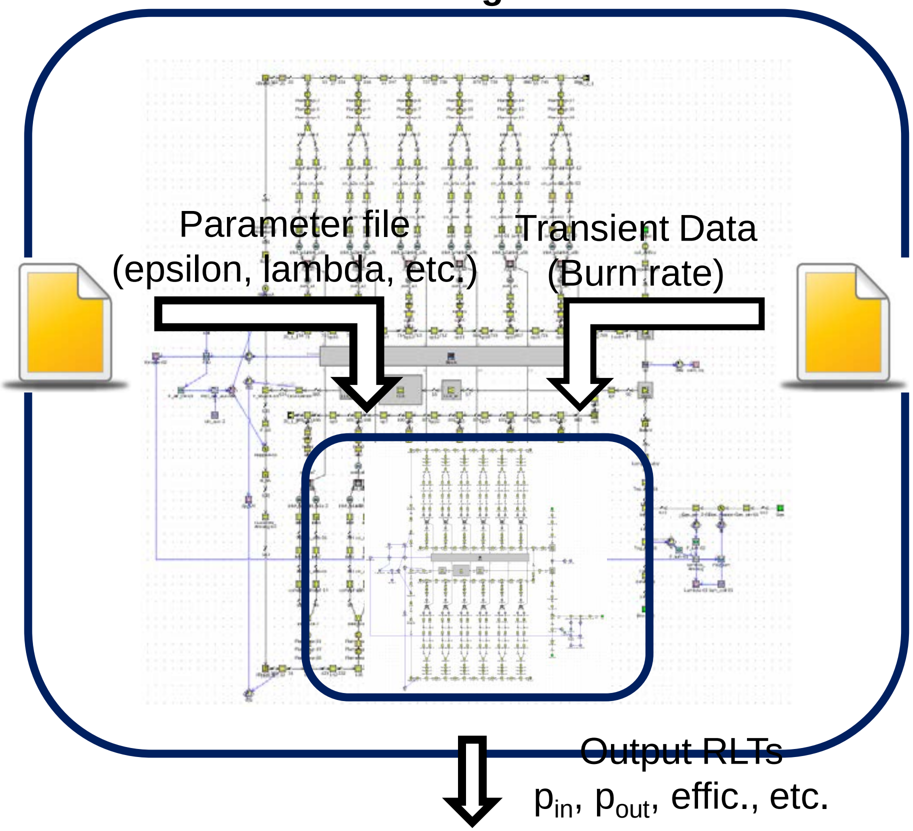
Model characteristics:

- Separate full-scale engine model for each engine type
- Burn rate is read from file created by the pressure analysis model
- Parameter names in all models identical
- Converged init-file provided to accelerate start-up
- Names for e.g. turbine inlet piping for all models identical to simplify export of result RLTs

Advantages:

- Straight forward implementation of new engine types

Full-scale engine model



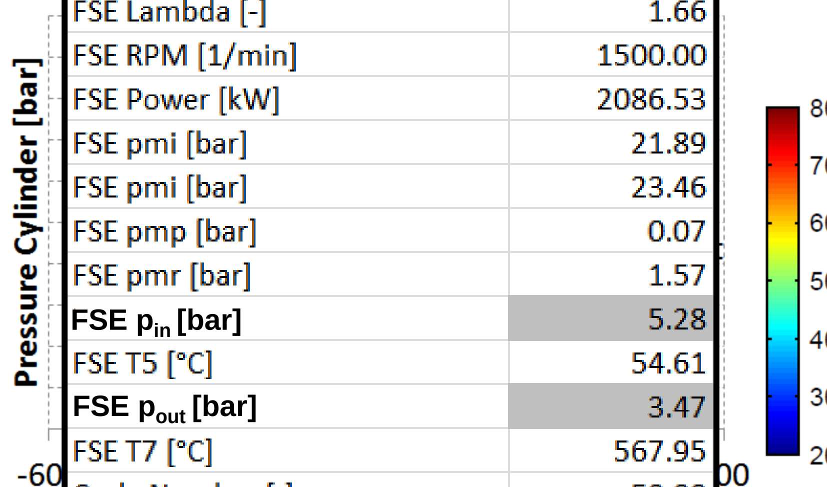
Results Content

Result E-Mail

Content:

- Stationary Engine Data
  - Measurement Data for comparison
  - Simulation Data
  - Combustion Data
- Transient Data
- Turbocharging Data
- Part of the analysis can be accomplished within the toolchain

Can be adopted to the relevant RLTs



Simulation Data	
Deviation Pressure Analysis [%]	1.86
Case	1.00
FSE Lst [-]	15.95
FSE Lambda [-]	1.66
FSE RPM [1/min]	1500.00
FSE Power [kW]	2086.53
FSE pmi [bar]	21.89
FSE pmi [bar]	23.46
FSE pmp [bar]	0.07
FSE pmr [bar]	1.57
FSE p_{in} [bar]	5.28
FSE T5 [°C]	54.61
FSE p_{out} [bar]	3.47
FSE T7 [°C]	567.95
Cycle Number [-]	59.00
FSE Eff. Power/Cylinder [kW]	130.41

Conclusion

- Full-scale engine model provides highest accuracy for generation of the boundary conditions for single cylinder measurements

- Automated toolchain facilitates the computation of the single cylinder boundary conditions
  - Computation on a separate workstation allows parallel computation of several users
  - GUI enables users without GT-Power background to also use the generated models
  - Allows the test bed engineer to work more independently
  - Reduces time needed for communication
  - Minimizes errors in data transfer
  - Enhances data analysis & data validation

Thank you for your attention.
Questions?