GT POWER
“IN THE LOOP”
GT Power "in the loop"
Usage of GT Power during the SW development process

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Introduction
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Introduction

Benefits:

- **development time**: decoupling of engine and software development cycles using GT Power for the first phases before “final confirmation” on engine.
- **development cost**: GT Power less expensive than testbench ...
- **the risks**: wrong initial assumptions have less impact on project schedule

In the other hand: time and cost to build up the GT model!
Introduction

Simulation with GT Power can be used instead of engine testbench for:

1. **System investigation**: analyze the system behaviour and physical tendencies
2. **SW development**:
   - Concept phase: evaluate the system modelling / tools: MAPFIT or MOCA
   - Implementation phase: SW validation via co-simulation / tools: Ascet and INTECRIO
3. **SW calibration**:
   - Get unmeasurable data at the testbench (residual gas fraction, air speed ...) / TPA
   - Reduce the testbench measurement points (DoE – Design Of Experiment)

**Tradeoff** GT model development **cost / benefits**

- From investigation phase to SW calibration, the use of simulation tools depends on the **model accuracy**!
- For one single project, expensive / For many projects (reuse), high potential
Proceeding
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Step 1: System investigation

- **System**: Air Path
- **Topic**: Charge determination

Bosch develops a model based engine charge determination. This model covers the usual range of engine operation. However, with new technologies, the air path variability increases, and the model implemented in ECU software has to be extended to these new degrees of freedom and operation area.

- **Step 1**: System investigation

How does the system behave?

GT Power is used to get a better feeling of the charge behaviour and give some input for the concept development phase.
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Step 1: System investigation

► What is a charge determination model?

- Exhaust VVT position
- Intake VVT position
- Intake manifold pressure (*Throttle and Wastegate*)
- Exhaust manifold pressure
- VVL, VCR, swirl flaps, etc.

► Bosch ECU software implements a charge determination physical model

- Calculation of the fuel quantity to be injected
- Estimation of the engine torque
- Control of the charge and the boost pressure
- Transitions between injection modes, and to CDA (Cylinder DeActivation)

**Question:** How do new technologies impact the engine charge?
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Step 1: System investigation

- The **GT Power simulations** help to understand the system behaviour. This knowledge is necessary to define a new concept, a new model.

GT Power simulations with variation of the intake valve timing and other parameters.

- Analysis of the valves behaviour
- Variation of the cylinder air filling
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Step 2: Concept validation

- **Objective:** to check whether the new SW model of the charge determination is good or not, a Design of Experiments (DoE) has been simulated on GT Power to collect some points.

- **DoE:** >2000 operating points, >4 degrees of freedom
  - Engine speed
  - Intake manifold pressure
  - Intake and exhaust valve timing
  - *Valve lift, variable compression ratio, swirl flaps, etc.*

**Question:** How to compare the charge model from the ECU software to the measured one in GT simulations?
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Step 2: Concept validation

- A first design of the charge determination model is made in Ascet. The model algorithm is used by an optimization tool to calibrate the maps and curves based on the simulation results from GT Power.

- The correlation results, and the analysis of the shape of curves and maps, inform whether the concept is representative enough of the system or not.

- After some recursion, the model is improved, ready for implementation.
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**Step 3: SW validation**

- After the concept validation, the SW functions are implemented in Ascet to generate embedded code.

- In order to save some time at the testbench, it is suitable to test the generated code and detect implementation bugs → GT Power can be coupled to the SW functions in a **co-simulation environment**.

- **Step by step** validation of model physical values.
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Step 3: SW validation

- With co-simulation, **stationary and transient** phases are analyzed

- **Combination of two co-simulation environments**
  - Coupling Ascet / Simulink via Intecrio (master)
  - Coupling Simulink / GT Power (slave)

- **Simulink used as interface** between the ECU functions (Ascet) and the engine (GT Power)
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Step 4: Three Pressure Analysis (TPA)

- **Target**: Use testbench measurements to validate the simulation model and calculate **unmeasurable values** with the GT Power engine model.

Intake manifold pressure  
(*testbench measure*)

Cylinder pressure  
(*testbench measure*)

Exhaust manifold pressure  
(*testbench measure*)
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Step 4: TPA Results

► TPA has been done for over 2000 operating points

► Accuracy of most points has been good enough to use the results

► New data like residual gas portion, better cylinder pressure indication, etc., are used for the engine calibration
Conclusion and Perspectives
Conclusion

- GT Power can be used all along the software development cycle. This proceeding allows to decouple the software development milestones from the hardware (engine) development ones.

- The two questions helping to decide to use GT Power or not:
  - How accurate does the GT model need to be?
  - What is the related development cost compared to the benefits?

- In the perspective of the study, GT Power helped to work on different topics, improving the SW maturity before the testbench sessions:
  - The charge determination model
  - The charge control using innovative technologies like VVL, VCR, etc.
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Perspectives

- Enhanced ECU software maximizes the potential of new engine technologies: CO₂ reduction, performance, dynamic
  - GT Power is a relevant tool to develop such enhanced features

- Reducing project cost by investing in system modelling
  - Hardware test facilities are expensive
  - No engine failure risks in simulation
  - The more accurate the model is, the more development steps it could support
    - For the ECU charge determination evaluation, the engine geometry is enough
    - For BSFC optimization, a good combustion model is necessary
  - In the end, the real system is the final judge... but could be less and less necessary for the software development purposes!