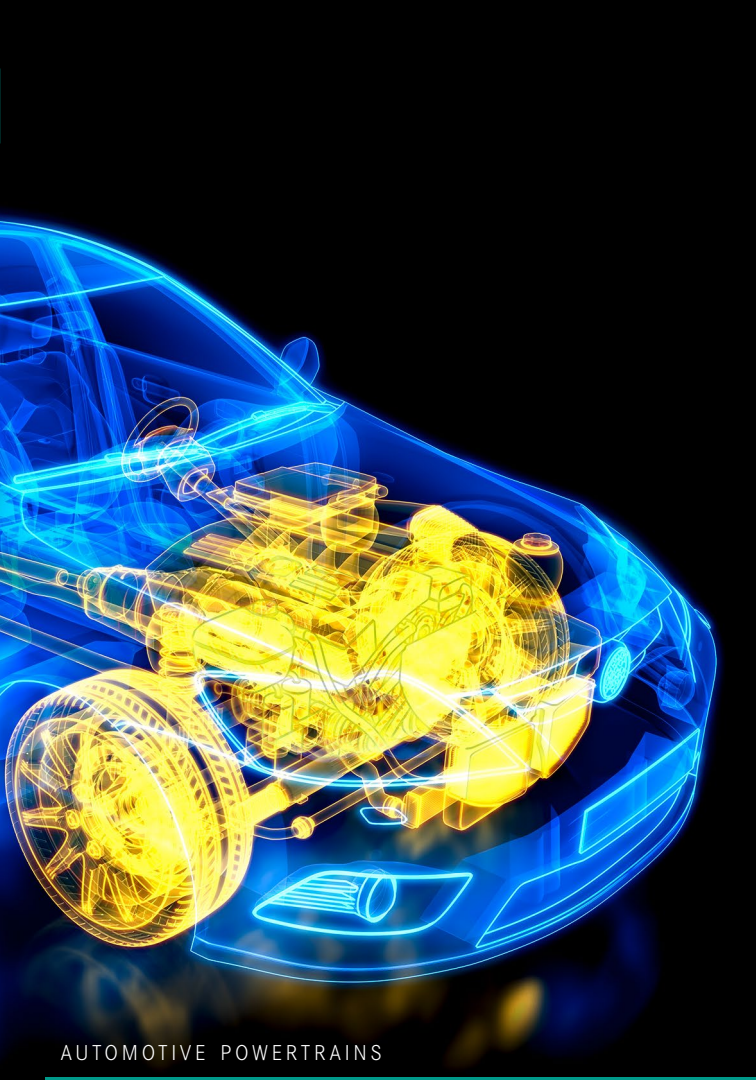


AUTOMOTIVE POWERTRAINS

THE FKFS
0D/1D-SIMULATION

Concepts studies, engineering services and consulting

RESEARCH IN MOTION.

FKFS

THE FKFS **0D/1D-SIMULATION**

VEHICLE IN MOTION ...

On the basis of constant engine speeds and loads, the combustion engine cannot be evaluated for critical situation. Real driving behavior, RDE measurements or high load driving cycles are always characterized by transient states and thus by fast changes in speed and load. At the same time, through numerous ECU controllers, actuators can have an effect on the engine and on the powertrain during transient states.

The objective must be to take real transient operations into account when making concept decisions at early development stages. Key areas of efficiency potentials are to be found in dynamic operations of the complex overall system “powertrain”.

In comparison to other simulation methods, 0D/1D-simulations offer a high predictability with a short time of computation. This allows not only performing transient simulations but as well executing extensive concept studies. Further, this model class enables simulations of the complex overall system (powertrain and vehicle) with the necessary resolution of detail. With these features, the 0D/1D-simulation is a powerful tool for the examination of both stationary and particularly transient system behavior.

MODULAR ENGINE TOOLBOX

Our modular engine toolbox provides virtual test engines with various piston displacements that can be equipped with different charging systems, combustion concepts and technology packages. Especially for suppliers it is interesting to virtually test new ideas in combination with different test engines of our modular engine toolbox.

THE FKFS **0D/1D-SIMULATION**

EXPERIENCE

A model always gives results, which however not always represent the reality. Important for a reliable simulation is always a deep understanding of all modeling assumptions and limits of the used sub models.

Due to our longstanding experience, we are able to answer questions to nearly all aspects of the 0D/1D-simulation in a fast, reliable and competent manner. We carry out concepts studies, undertake daily tasks for our customers and are available as a research partner regarding any scientifical questions.

We maintain an open dialogue with our customers and partners especially when it comes to the robustness of results: Sometimes a narrow ridge lies between a reliable prediction and a theoretical simulation.

SUPPORT

We consider 0D/1D-simulations as an inevitable tool during the development of modern combustion engines.

A classic target endeavored during an engine development process is the optimization of the following main criteria:

» Performance

» Emission

» Fuel Consumption

By means of predictable simulation models, engine concepts can be compared at an early stage of development. Available information about main characteristics of the system behavior helps to focus on particular problems among the development work.

EXCEEDING LIMITS

In many cases of the development process, subsystems such as air path, combustion concept and oil circuit etc. are being separately designed and optimized. In real engines, however, all subsystems have a wide variety of interactions. The main target, therefore, has to be the optimization of the overall system. The 0D/1D-simulation provides many tools that are able to take interactions of all subsystems particularly for transient operating modes into account by using virtual test engines.

THE FKFS **0D/1D-SIMULATION**

ANALYSIS

For the model calibration, it is important to carry out a plausibility check of the measurement data at first. Calibrating a model based on erroneous data might be fatal. To prevent that from happening, we go through checklists and detailed analysis of the measurement data. Upon a longstanding experience in thermodynamical analysis (pressure trace analysis), gas exchange analysis and heat balance measurements, we from FKFS provide our expertise for our customers.

TRUST

The 0D/1D-simulation is a tool that delivers predictions. It is important to understand and validate results regarding all possible interactions. Only this way we can trust our simulation results and detect simulation limits in time.

APPLICATION AREAS OF 0D/1D-SIMULATIONS

The application of 0D/1D-simulations can be useful at different stages of an engine development. Here are some examples:

During conceptual phase:

- Comparison of different combustion and charging concepts with respect to fuel consumption and transient behavior
- Determination of an advantageous displacement volume/ turbocharging level for new engines
- Finding the optimal compression ratio and camshaft design for the conflict between partial load and full load
- Selection and arrangement of exhaust treatment components

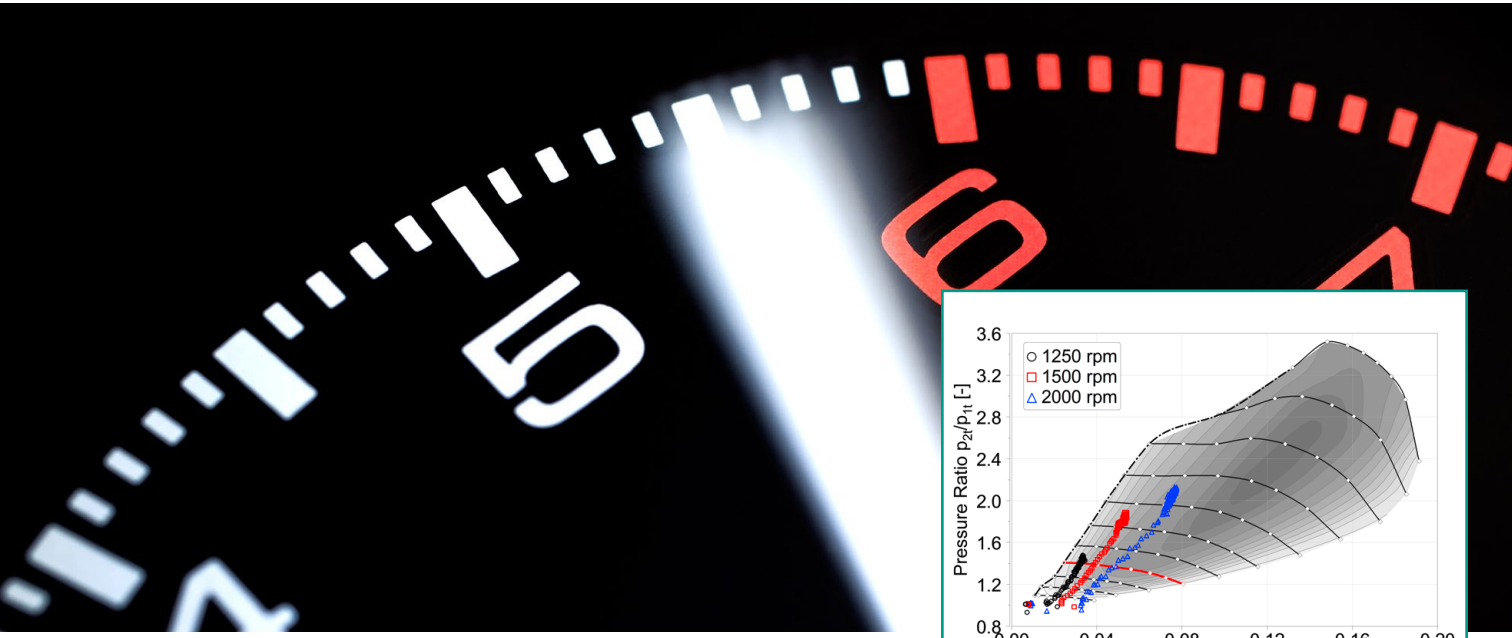
During design phase:

- Oil supply for individual bearings
- Comparison of different air path and exhaust path designs
- Designing cooler components

Function development, application and test phase of control units:

- Estimation of system limits and knock limit
- Optimizing transient operating conditions for diesel- and gasoline engines
- Evaluating heat-, warm-up- and regeneration strategies
- Testing ECU functions

THE FKFS **0D/1D-SIMULATION**



Evaluation of load steps in the compressor map

EXAMPLE: ACCELERATION PROCESS WITH CHANGING VALVE TIMING AND LIFT

The following will illustrate the interaction between the subsystems combustion/gas exchange and oil circuit using a downsizing gasoline engine.

Optimal valve timing and valve lifts with respect to performance and fuel consumption depend on engine speed and load and so on values that are variable during a transient process. The engine acceleration capacity at low speeds is also influenced by the actuation speed of the valve timing initiated by the hydraulic cam shaft actuator.

On the side of the oil circuit, a power reduction of the oil pump (reduced oil pressure) leads to a lower fuel consumption.

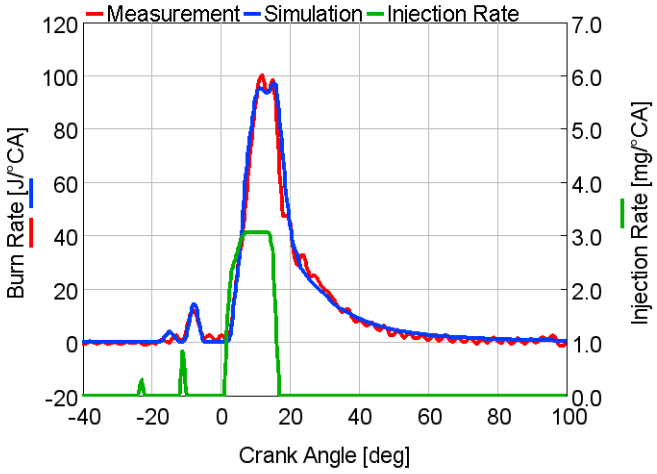
Gas exchange and oil circuit can be optimized independently. An important examination lies in the coupling of both systems for transient behavior.

For example, the actuation speed of the hydraulic systems such as phase shifter or valve lift switch may not be sufficient when a sudden acceleration from part load to high load is initiated. The potential of the individually optimized subsystems can thus not be utilized. This could result in an unacceptable deterioration of the engine acceleration behavior.

The 0D/1D-simulation allows considering a transient response of both combined systems and is able to show possible conflicts at an early development stage.

Likewise, a thermal modeling of the warm-up behavior can be integrated, since the available oil pressure for the actuators is strongly temperature-sensitive.

THE FKFS **0D/1D-SIMULATION**



High model accuracy in prediction of combustion processes with the UserCylinder

THE FKFS USERCYLINDER: HIGHEST COMBUSTION PREDICTABILITY

The combustion chamber is the heart of the combustion engine. Here the conversion of the chemically bound energy into heat and pressure and thereby into mechanical work takes place.

The UserCylinder is a plug-in object for the 1D-flow simulation software GT-Power which replaces the regular cylinder object. During a GT-Power simulation, the complete high pressure cycle (compression and work cycle) is being calculated by the FKFS code. Within an overall engine simulation, this enables more detailed and faster predictions of the combustion processes. As examples, important cylinder results such as heat release rate, fuel consumption, cylinder pressure rate, emission and knock are to be mentioned.

By using the UserCylinder, we can make predictions especially when only few or no measurement data is available.

For customers who want to use the UserCylinder for their simulation work in the GT-Power environment we offer licenses with a detailed documentation-manual, work-shops and support.

Overview:

- Phenomenological burn rate for gasoline and gas combustion
- FKFS knock model
- Cyclic variation model
- Quasidimensional charge motion and turbulence model
- Phenomenological burn rate model for diesel combustion
- FKFS injector modell
- Phenomenological nitrogen oxide (NO) and soot model
- Simple handling due to its full integrity into GT-Suite and GT-Post
- Possibility of an automated model calibration with measured cylinder pressure rates
- User manual available in German and English language
- FKFS provides fast and founded support for all combustion simulation aspects (support@fkfsusercylinder.de)

THE FKFS **0D/1D-SIMULATION**

OUR EMPLOYEES

The 0D/1D-simulation department has 15 employees, including the head of department, Dr. Michael Grill, and three highly experienced project managers taking the responsibility for the topics “gas dynamics & longitudinal dynamics”, „hydraulics & thermal behavior” and “combustion”.

Our employees are well experienced in various simulation topics, engine design and development. For us, it is a matter of course to provide a detailed documentation of our work and maintain a close exchange with our customers.

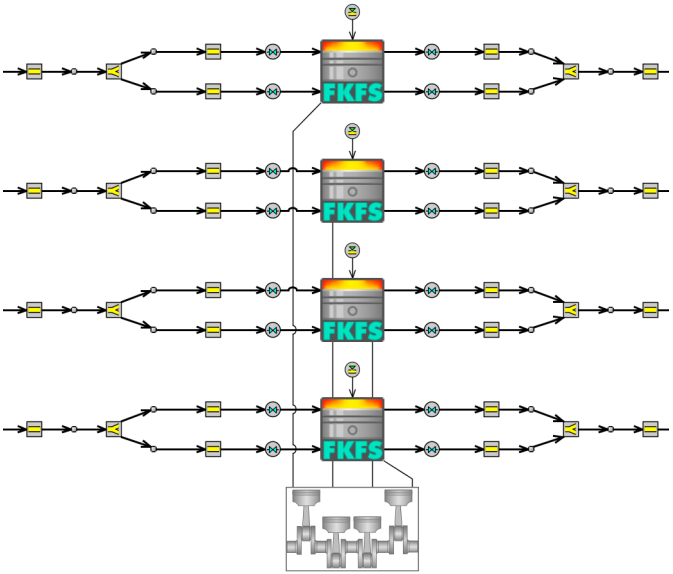
OUR RESEARCH

Combustion methods, engines and automotive technologies are rapidly developing. Keywords to be mentioned by way of example are RDE, water injection, alternative fuels or the RCCI-combustion method. Therefore, models and simulation methods are continuously to be developed, model conceptions adjusted and new mechanisms understood.

In order to provide solid simulation tools for tomorrow’s questions, we maintain a close relation to the combustion engines and automotive engineering institute (IVK) of the University of Stuttgart and carry out our own research.

OUR TOOLS

- GT-Suite/GT-Power
- FKFS UserCylinder
- Converge
- EnginOS Tiger
- MATLAB/Simulink
- CarMaker
- Dymola
- Cantera

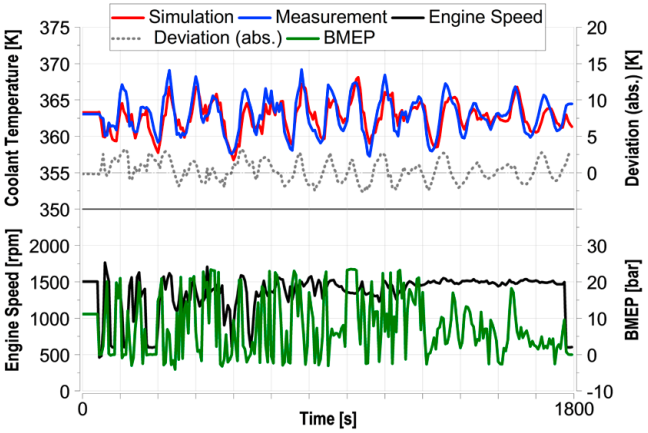


Air path model with FKFS UserCylinder in GT-Power

THE FKFS **0D/1D-SIMULATION**

OUR EXPERIENCE – YOUR ADVANTAGES AT A GLANCE

- Longstanding experience in 0D/1D-simulation
- With engines from 20 to 165 mm in bore diameter we are thoroughly familiar with (Otto/Diesel/Gas)
- Decisive for the efficiency of a combustion engine is the combustion chamber: Expertise and strong sub models with the FKFS UserCylinder
- The most difficult part of serious simulation projects is often the knowledge of simulation limits: With our extensive experience and our founded knowledge we can provide advice
- Virtual test engines of our modular engine toolbox help in testing various components and evaluating technologies in various future scenarios without the need of any engine hardware
- Highly qualified employees, a close connection to research fields, founded knowledge of our applied sub models
- Close exchange of information with our colleagues in the field of 3D-CFD and engine test bench



Prediction of the coolant temperature of a commercial vehicle in the "European Transient Cylce"

OVERVIEW: 0D/1D-SIMULATION AT FKFS

- Building GT-models based on CAD data or test bench setup
- Building fast running GT-models (FRM) and software in the loop (SiL)
- Calibration of GT-Power models with or without the FKFS UserCylinder
- Combustion process development and analysis including emission prognoses
- Combustion control
- Gas exchange analysis and optimization
- 1D/3D-CFD coupling
- Comparison of different turbocharger concepts
- Full vehicle and longitudinal dynamic simulation
- Hybrid strategy development
- Energy partition chart
- Friction modeling
- Exhaust emission aftertreatment
- Heat-up of the exhaust system (Cat-light-off)
- Thermomanagement & cooling circuit simulation, waste heat recovery
- Modeling and simulation of oil- and fuel circuits
- Mechanics of the crank- and valve drive

RESEARCH IN MOTION.

FKFS THE COMPANY

The Research Institute for Automotive Engineering and Vehicle Engines Stuttgart (FKFS) was founded in 1930.

Its highly qualified staff conducts research and development projects in the fields of powertrains, vehicles and automotive mechatronics. Highly specialized test benches as well as measurement, testing and simulation procedures developed internally at FKFS provide engineers with the means to solve complex and demanding problems.

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2016-10