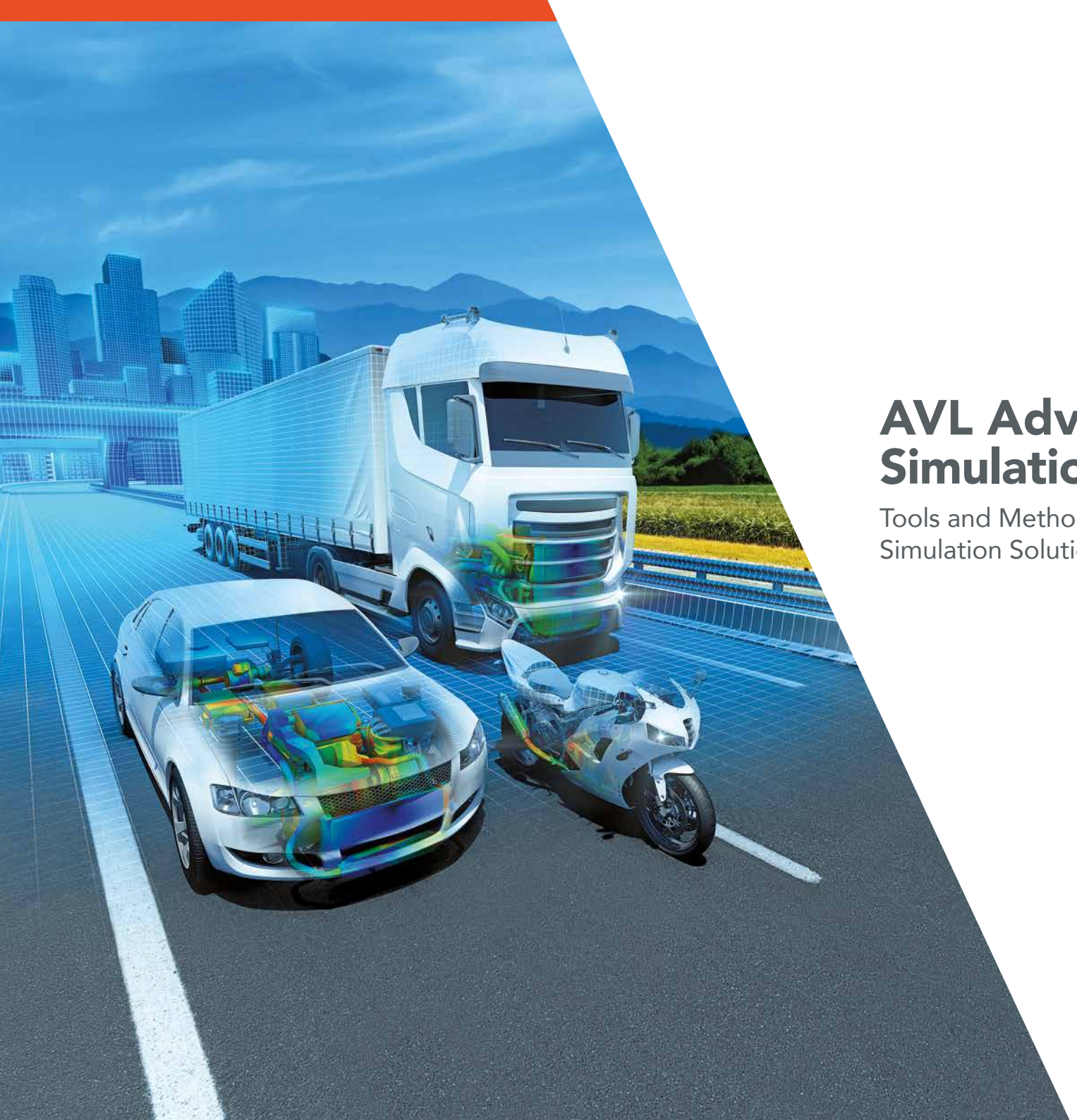

AVL Advanced Simulation Technologies

Tools and Methods for Next-Level Simulation Solutions

Real Driving Emissions (RDE) will be introduced as an additional requirement for type approval starting with autumn 2017, meaning that road profile, traffic situation, ambient conditions and driver behavior influence the vehicle emission characteristics. For mastering the RDE related challenges ahead, AVL Advanced Simulation Technologies offers a comprehensive toolset supporting the holistic engine and powertrain development including the integration into the vehicle from early concept to design to validation.

In the concept phase, AVL CRUISE™ M helps to configure all kinds of conventional and electrified powertrain systems, aiming at the minimization of fuel consumption and pollutant emissions, the transmission type selection or the development of gear shifting strategies for automatic transmissions. AVL CRUISE™ M also supports the development of engine and aftertreatment system thermal management strategies and enables the analysis of the emission reduction potential of electrified auxiliaries.

In the development phase, AVL FIRE™ and AVL CRUISE™ M Engine support combustion system optimization with respect to maximized efficiency and minimized NOx and particulate raw emissions. Coupled fluid-structure simulations based on AVL FIRE™ M provide quantitative information on thermal component loading of e.g. cylinder heads, exhaust valves, integrated water-cooled exhaust manifolds, etc. as input to engine thermo-mechanical analysis.

The development of low friction powertrains as well as the analysis of durability and NVH behavior of conventional and hybrid powertrain systems is delivered by AVL EXCITE™. With its versatile e-machine joints, AVL EXCITE™ enables the analysis and optimization of electrified transmissions with respect to NVH and gear engagement aspects.

In the validation phase, the physical and empirical based realtime capable AVL CRUISE™ M models, parameterized based on detailed component simulation results, support the control system development both in the office and in SiL and HiL test-environments or as plant models for validation of powertrain hardware functional behavior under virtual RDE conditions.

As your global partner, we look forward to working with you.

Dr. Gotthard Rainer
Vice President
AVL Advanced Simulation Technologies

All contents at a glance.

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Why Choose AVL as a Simulation Partner?

HIGH-FIDELITY SYSTEM SIMULATION MODELS

AVL provides fully interactive and integrated tool chains including AVL's own and third-party software tools. To obtain the best results throughout the development process, we created consistent simulation models for all of the development phases: fast simulation models together with DoE and optimization for the concept phase, very accurate simulation models for the design and development phase and real-time simulation models parameterized by highly accurate simulation models for engine and powertrain calibration.

POWERTRAIN ENGINEERING INSIDE

AVL's extensive engineering expertise is the strong basis for all of our software tools and methods. By analyzing the powertrain development processes, we have defined software application tasks which cover all of the aspects of powertrain development. Due to the complexity of these tasks, we place the emphasis on application-focused workflows which guide the user through to practical engineering solutions. Simulation results are displayed in the same easy-to-interpret way as test results.

CLOSE LINK TO TESTING

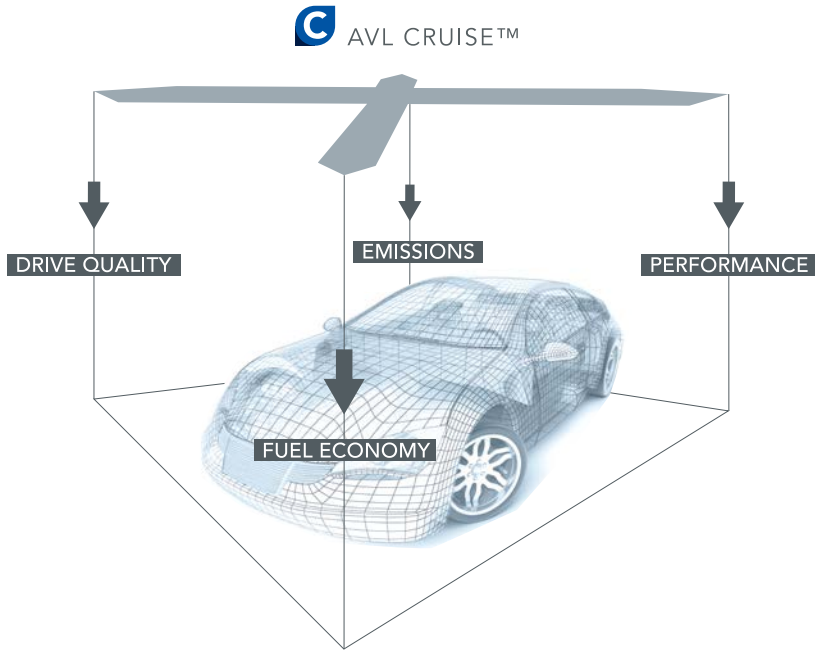
AVL's software tools are closely linked to and compatible with AVL's instrumentation and measurement tools. It is becoming more and more important to provide the development engineer with simulation results directly on the testbed based on test results. This leads to more insight into the powertrain, and subsequently a shorter test cycle.

A KALEIDOSCOPE OF SIMULATION POSSIBILITIES

AVL's simulation software development is based on the unique environment available from AVL. Powertrain Engineering, Instrumentation and Test Systems and Advanced Simulation Technologies are the three pillars of the company which provide a huge reservoir of synergies. AVL's simulation software development is driven by five core values that position AVL Advanced Simulation Technologies as a strong partner for all of your calculation tasks.

- High-fidelity system simulation models
- Seamless simulation workflows
- Powertrain engineering inside
- Close link to testing
- Simulation support worldwide

HIGH-FIDELITY SYSTEM SIMULATION MODELS
SEAMLESS SIMULATION WORKFLOWS



Vehicle System

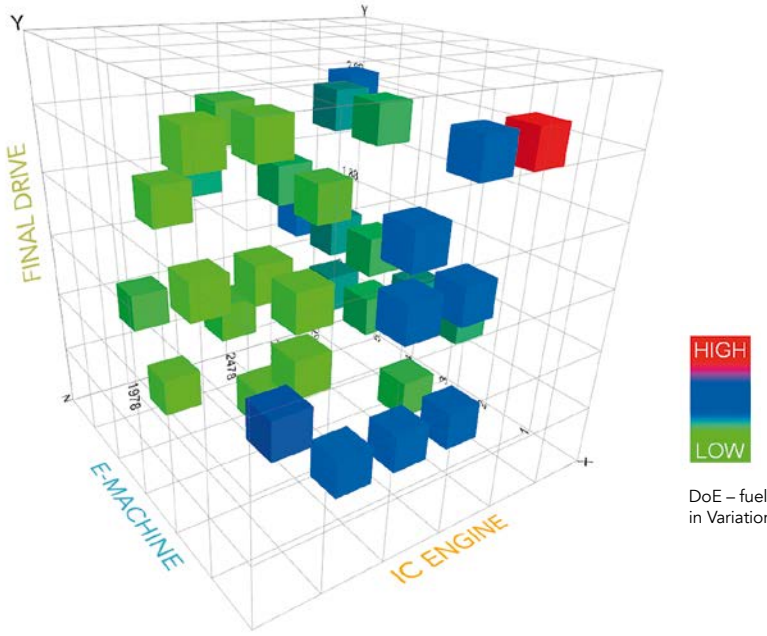
AVL CRUISE™ is featured industry-wide as the most mature and advanced system-level vehicle powertrain simulation package. It is able to handle the current and future complexity of powertrain structures with an extremely flexible but nevertheless user-friendly and easy-to-use concept.

FROM CONCEPT STUDIES TO CALIBRATION AND TESTING

AVL CRUISE™ offers all of the flexibility needed to build up a system model, which can be easily adjusted to all application requirements through the entire powertrain development cycle. It supports everyday tasks in vehicle system and driveline analysis throughout all of the development phases, from concept planning and design in the office to calibration and verification on hardware test systems. Starting with only a few input parameters in the early stages, the maturity of the model grows during the development process according to the continuously increasing simulation needs in calibration. Model re-use in consecutive or iterative development approaches ensures consistent decision processes and saves valuable engineering time by keeping the focus on the targets:

- Optimizing vehicle fuel efficiency
- Reducing emissions
- Improving vehicle performance and driveability

Range Extender Vehicle Simulation Model



DoE – fuel consumption results in Variation Cube

MANAGING CHANGES WITH EFFORTLESS EASE

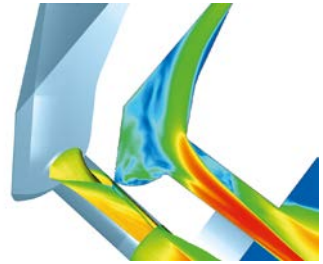
Today's multi-system vehicle powertrain concepts are pushing the complexity of system simulation models to the extreme. The highly adaptable system/subsystem structure of AVL CRUISE™ allows drivetrain concepts to be changed by a mouse click. Vehicle hybridization and model configuration changes to fit application needs in different phases are carried out within minutes, allowing more time to be spent on the engineering, calibration and testing tasks, without having to deal with mathematical equations and coding.

SOLUTION ORIENTED OPEN CONCEPT IN ALL TASKS

AVL CRUISE™ is more than just a vehicle simulation model. Streamlined workflows are realized for all kinds of parameter optimization, component matching and subsystem integration. The modular structure –with its wide range of interfaces to other simulation tools, ready-to-use analysis tasks and data management capabilities – are only a few of the key reasons why a growing number of leading OEMs and their suppliers have chosen to establish AVL CRUISE™ as their powertrain integration platform on a system level.

Heavy Duty Long Haul Truck Model

Injection Nozzle Flow, Cavitation and Erosion

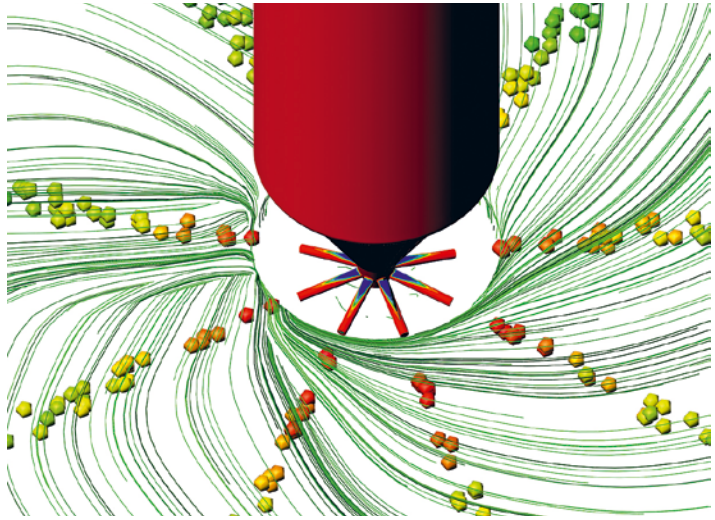


LES applied on a realistic diesel injector featuring three-phase flow and needle movement

AVL BOOST™ HYDSIM and AVL FIRE™ offer indispensable capabilities when it comes to the development and optimization of injection nozzles. While one-dimensional AVL BOOST™ HYDSIM models typically reflect the complete injection system from fuel tank to the injector, AVL FIRE™ focuses on the three-dimensional calculation of fluid flow in the injection nozzle.

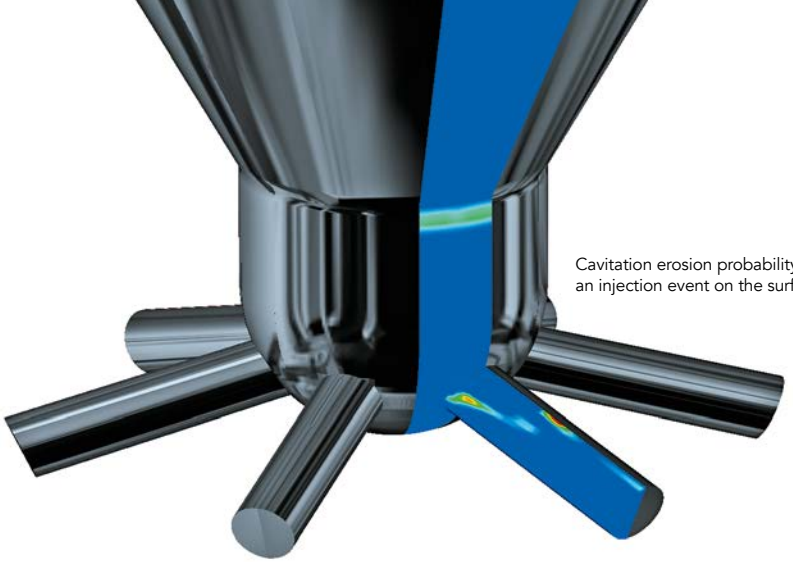
In an early engine design stage, fuel injection details, such as needle lift and inlet pressure level are not known. In a virtual prototyping environment, coupled 1D/3D fuel injection simulations are extremely valuable. While AVL BOOST™ HYDSIM provides the information about longitudinal and radial needle displacements as well as pressure levels, AVL FIRE™ improves the accuracy of the 1D solution by providing pressure forces acting on the needle and local flow rates.

Cavitating internal nozzle flow applied as input for combusting in-cylinder flow



THE TRUTH IS MULTI-PHASE

Modern injection systems make use of high pump pressures to enhance droplet break-up and mixture formation in the combustion chamber, targeting high performance, high efficiency and low engine-out emissions. The resulting huge pressure differences between the fuel supply line and the combustion chamber lead to a phase change from liquid fuel to fuel vapor. While the vapor reduces the effective orifice outlet area and, therefore, the amount of liquid fuel transported into the combustion chamber during a single injection event, it also affects the conditions that determine the release of the fuel droplets furtherdown the nozzle orifices. To accurately account for the effect of cavitation on fuel penetration and propagation in the combustion chamber, AVL FIRE™ offers advanced cavitation modeling. This capability enables accurate prediction of transient discharge rates and detailed insight into the instationary flow conditions in the nozzle orifice exit areas.



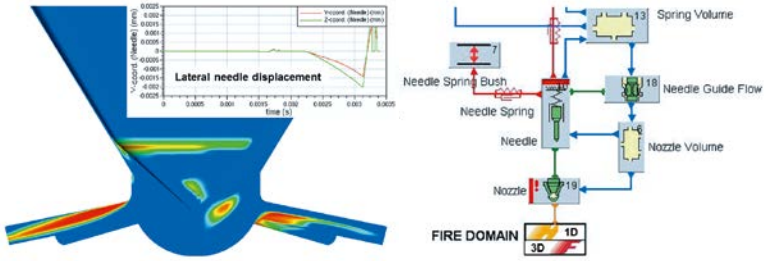
Cavitation erosion probability averaged over an injection event on the surface of the spray hole

NOZZLE INTERFACE

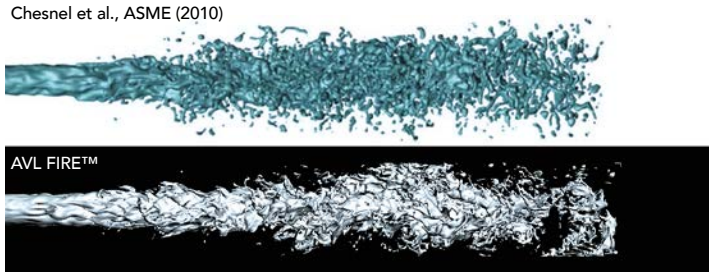
The flow conditions predicted at the nozzle orifice exit plane are recorded during the AVL FIRE™ injector flow simulation and serve as input for AVL FIRE™ in-cylinder mixture formation and combustion simulations. That way, a perfect correlation can be established between the flow conditions inside the nozzle and the conditions under which fuel enters the combustion chamber. This correaltion also takes into account the non-uniform flow out of the injector.

EROSION MODELING

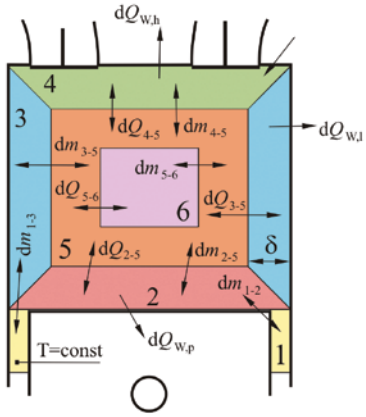
Cavitation in injection nozzles often causes material erosion and is strongly related to the durability of injection components. Prediction of erosion probability helps to define the design parameters of the nozzle in order to decrease the flow aggressiveness in critical areas and assure the best possible break-up of the fuel discharged into the combustion chamber or into the port.



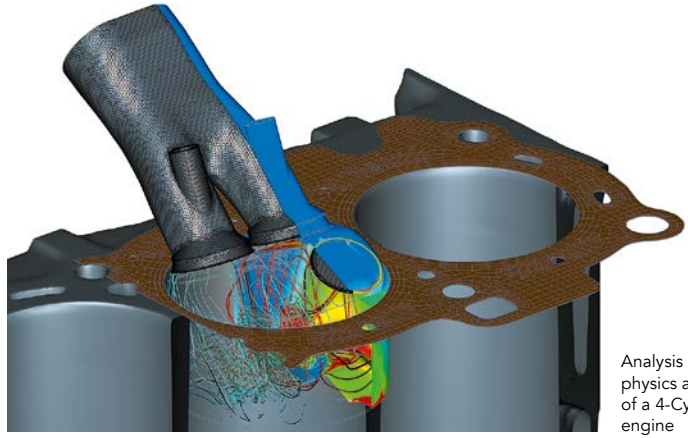
Coupling of AVL BOOST™ HYDSIM and AVL FIRE™ allowing for prediction of lateral needle forces and displacements



Application of LES together with the Volume-of-Fluid surface tracking method to capture spray propagation details



Multi zone combustion modeling in AVL BOOST™



Analysis of in-cylinder physics and chemistry of a 4-Cylinder gasoline engine

Combustion and Emissions

AVL BOOST™ and AVL FIRE™ are the industry's prime choice when reliable results are needed for engine thermodynamics and combustion/emission development. The intelligent integration of the two software tools facilitates solutions for complex tasks early in the development phase and unsurpassable accuracy during the detailed design phase.

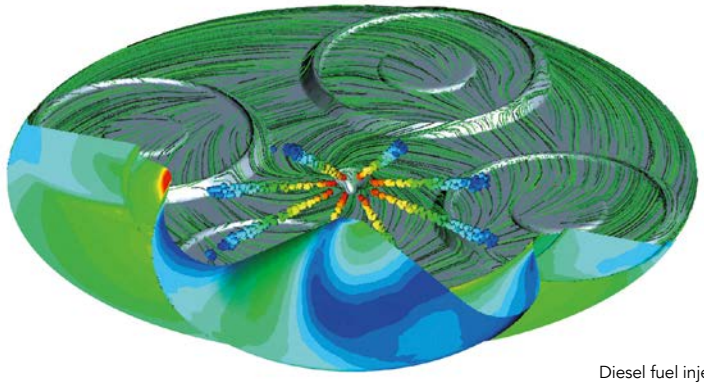
SPEEDING UP YOUR PROCESSES

The time required to create moving meshes for complex geometries of modern IC engines is reduced to merely hours with AVL FIRE™'s highly specialized, automated and parallelized pre-processing tool FAME™ Engine Plus. Key features include hexahedron dominated grids, local grid refinements and user-controlled constant grid boundary layer supporting accurate heat transfer calculation.

REFLECTING REALITY

AVL FIRE™ offers validated in-depth modeling of fuel sprays, ignition, combustion and emission modeling. Spray modeling includes primary and secondary break-up, droplet/droplet as well as droplet/wall interaction. Both spray and wall film models are capable of handling multi-component fuels, surrogate fuels and fuel blends. Combustion modeling is performed by deploying either intrinsic multi-zone models or by solving detailed reaction schemes using the chemistry solver integrated into AVL FIRE™. A very exciting new approach for predictive combustion simulation is offered by AVL TABKIN™. AVL TABKIN™ pre-calculates combustion chemistry and stores the result in reference tables. These tables are accessed and evaluated during the AVL FIRE™ in-cylinder flow simulation. In comparison to conventional approaches, using AVL TABKIN™ results in extremely short simulation times, even when using extremely large reaction mechanisms. Additionally, the results' accuracy is improved.

The AVL FIRE™ main program supports the accurate simulation of IC Engine in-cylinder phenomena by offering advanced modeling capabilities for turbulence (k-z-ζ, PANS, LES), wall treatment and heat transfer.



Diesel fuel injection

FEWER EXPERIMENTS, MORE CREATIVITY

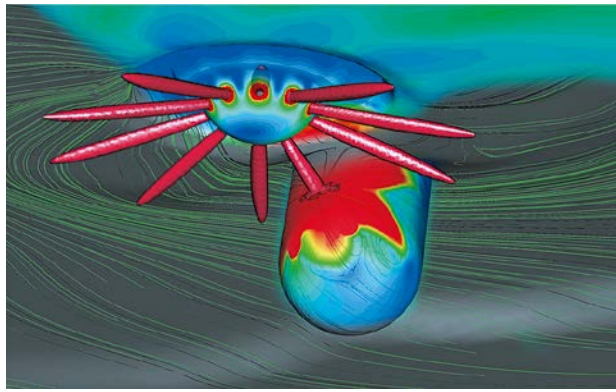
The capabilities offered by AVL BOOST™ and AVL FIRE™ enable accurate simulation of all relevant physics and chemistry in internal combustion engines and engine components, thus allowing the virtual testing of a large number of design possibilities while reducing the need for costly and time-consuming experiments.

1D/3D COUPLED SOLUTIONS

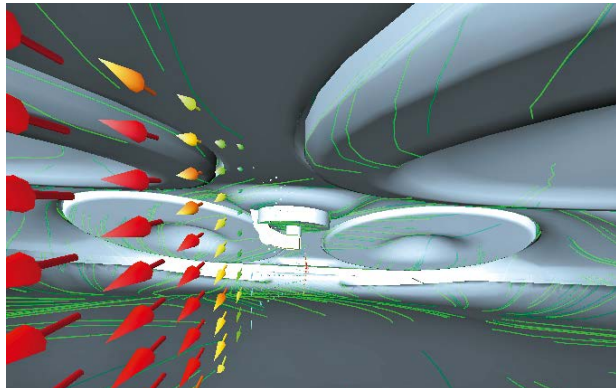
For highest accuracy and highest performance AVL BOOST™ and AVL FIRE™ can be executed as co-simulations exchanging pressure, temperature and species concentrations at the interface boundaries. That way it is possible to consider 3D geometrical effects in an otherwise 1D Model and to immediately see the impact of design changes on the overall system performance. Common 1D/3D applications include intake and exhaust manifold development, optimization of exhaust gas return and combustion/ emission prediction.

SYNERGIES BETWEEN SIMULATION AND TESTING

The direct integration of AVL BOOST™ in the testing environment allows you to calculate additional results online during the engine test – a tremendous timesaving benefit valued especially when being engaged in the most complex projects.



Gas injection onto a glow plug



Flow pattern in a gasoline engine

Turbocharging

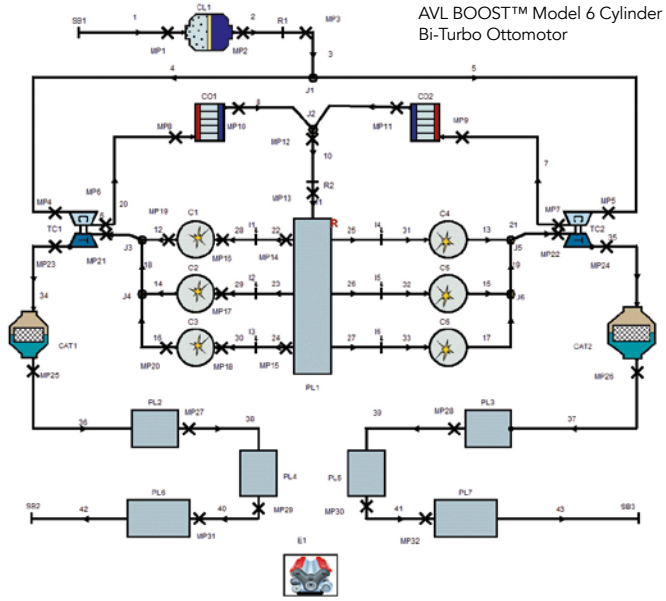
AVL BOOST™, AVL EXCITE™ and AVL FIRE™ allow advanced compressor and turbine component design and turbocharger matching as part of an overall engine system. This integrated approach accommodates the complex interaction between the system components to create the most effective low emission engines possible.

ENGINE PERFORMANCE AND EMISSIONS

CO_2 reduction and energy efficiency are the main technology drivers for pressure-charged engines. Turbocharging allows car manufacturers to reduce their engine sizes and emissions while continuing to deliver the power and performance customers demand.

PRESSURE WAVE SUPERCHARGER

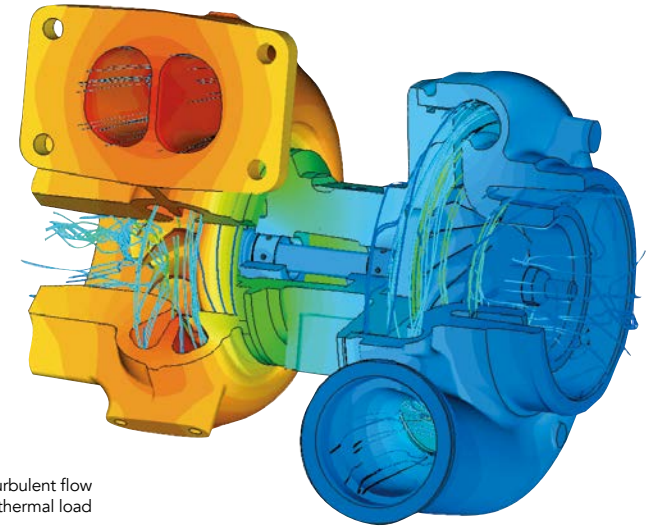
In contrast to standard pressure charging devices, the pressure wave supercharger process is a direct gas-dynamic transfer of exhaust gas energy to the fresh charge in the channels of the rotor via traveling shock and expansion waves. The underlying physics allow highly predictive 1D modeling where the performance is a simulation result. No maps for mass-flow or efficiency characteristics are necessary.



AVL BOOST™ Model 6 Cylinder Bi-Turbo Ottomotor

MULTILEVEL SIMULATION DEPTH

Basic thermodynamic matching of the turbocharger is performed for steady-state operation, continued by the optimization of the transient response. The matching calculation is iterative, based on compressor and turbine maps, as well as the most important engine data. Engines equipped with the charging system can be integrated into the vehicle simulation tool AVL CRUISE™, to analyse the overall system of the engine and vehicle within a driving cycle.



Complex turbulent flow and thermal load

REDUCING CO_2-EMISSIONS

AVL BOOST™ and AVL FIRE™ offer an advanced pressure charging simulation system. Users benefit from the ability to:

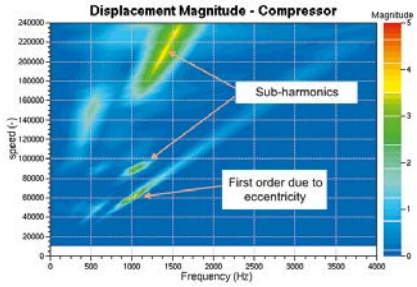
- Select a turbocharger to match a given engine
- Design new turbochargers with engine matching at every design stage
- Readily change compressor and turbine sizes and predict the effect
- Rapidly improve the turbocharging system, and determine the impact of wastegates, variable geometry, exhaust gas recirculation and component losses

ROTOR DYNAMICS AND BEARING ANALYSIS OF TURBOCHARGING SYSTEMS

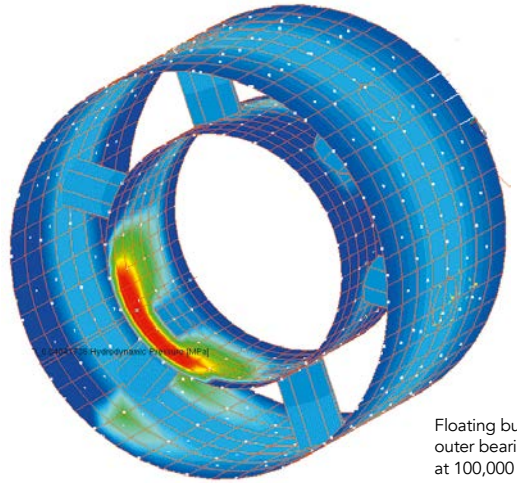
The investigation of the dynamic stability of the rotor bearing system is an important analysis target for the design of automotive and industrial turbochargers. This requires a multi-body dynamic solution including non-linear models for slider bearings with floating bushings capable of calculating the dynamic system behavior for rotor speeds up to 250,000 rpm.

AVL EXCITE™ considers all these effects with different levels of detail. The run-up calculation approach supports the detection of critical speeds caused by torsional and bending resonances. The elasto-hydrodynamic bearing model is applied to include the influence of full or semi floating bushing configurations including bores in the bushing to connect the inner and outer oil film of the bearings.

The results obtained with AVL EXCITE™ allow engineers to find an optimal matching of design parameters for damping the rotor system, oil mass flow and sensitivity for resonances.



Rotor dynamics – first order excitation and sub-harmonics



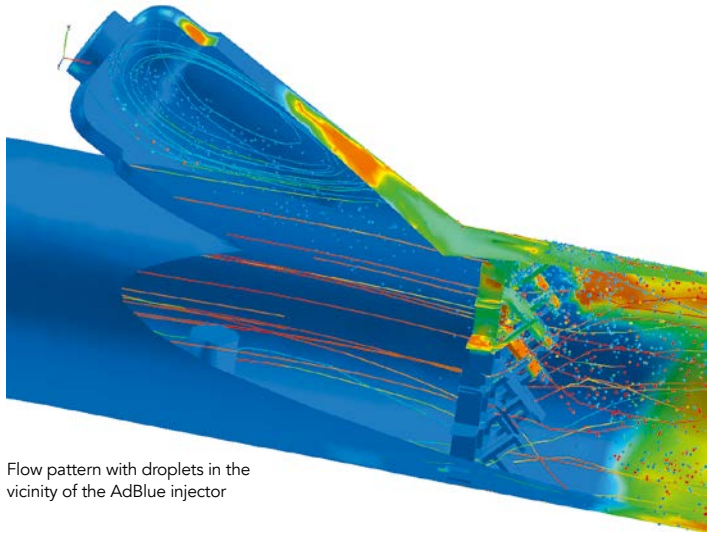
Floating bushing – inner and outer bearing oil film pressure at 100,000 rpm

Exhaust Gas Aftertreatment

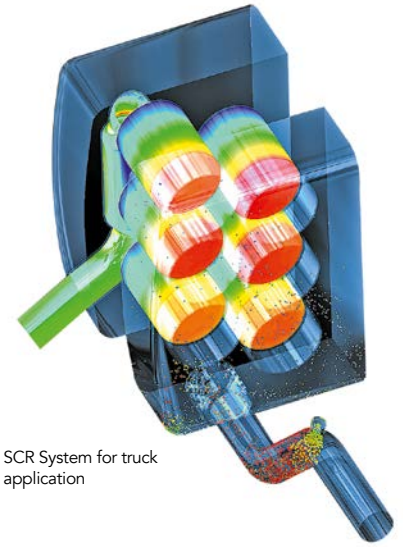
The AVL Aftertreatment simulation suite, consisting of the tools AVL BOOST™, AVL CRUISE™ and AVL FIRE™, is a unique open and scalable solution. It enables consistent modeling of all physics and chemistry relevant to exhaust gas aftertreatment systems during all stages of the development process.

UNMATCHED PERFORMANCE

AVL BOOST™ is in the vast majority of projects the starting point for development and optimization of aftertreatment systems and offers absolutely simple model setup and extremely short simulation times, close to or even faster than real time. This as well as the ability to model all common aftertreatment systems made the tool the undisputed market leader among 1D aftertreatment simulation software. It masters kinetics parameter identification, large parameter variations and system optimization with sovereign performance delivering the highest quality results.



Flow pattern with droplets in the vicinity of the AdBlue injector



SCR System for truck application

SEAMLESS INTEGRATION

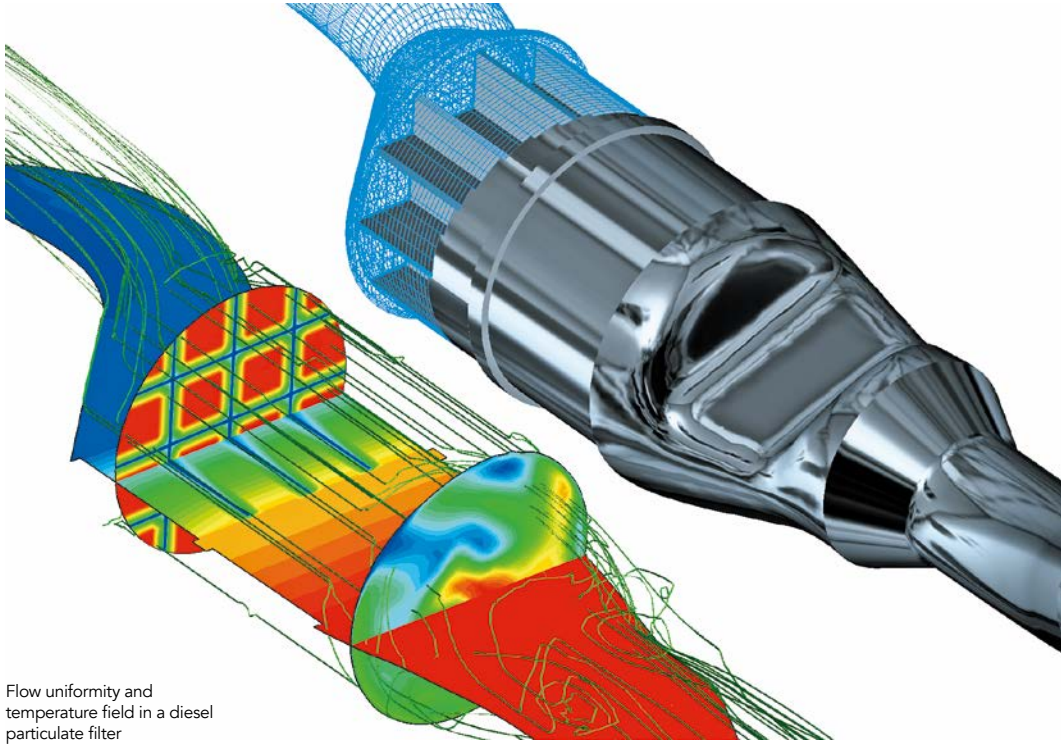
AVL BOOST™ and AVL FIRE™ feature the industry's only seamless integration of 1D, 2D and 3D exhaust gas aftertreatment system simulation tools. Both tools offer perfectly identical mathematical, physical and chemical models. The development engineer, hence, can select at any time in the development process the tool that matches best his needs for performance and accuracy. Switching from 1D AVL BOOST™ Aftertreatment to 3D AVL FIRE™ Aftertreatment or even in the other direction is possible without loss of consistency. Simulation setups can be directly imported from one tool to the other by just being applied to models that differ in respect to their dimension in space. Aftertreatment system performance data calculated using AVL BOOST™ and assembled to maps can also be integrated in AVL CRUISE™ models to predict drive cycle tailpipe emissions.

EASY HANDLING

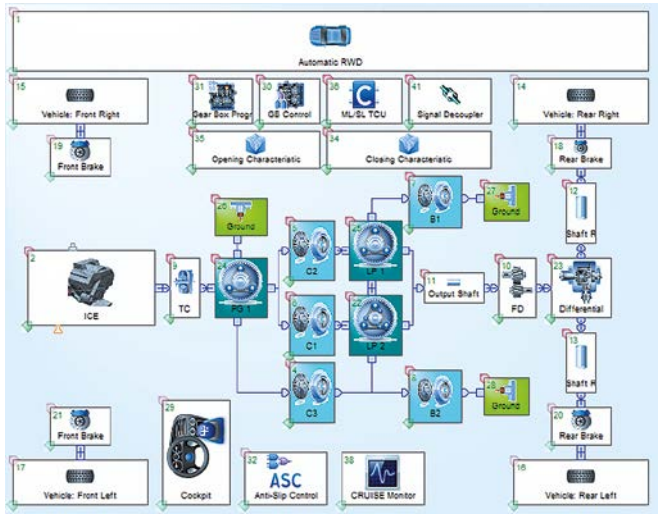
Pre-defined reaction schemes for all common aftertreatment systems are offered in both AVL BOOST™ and AVL FIRE™. The user also has the freedom to modify or to replace the offered schemes. AVL BOOST™ model set-up files can be imported in the AVL FIRE™ Solver GUI. This saves users from the time consuming and error-prone re-entering of model data when switching from 1D to 2D/3D CFD.

OPENNESS AS KEY TO SUCCESS

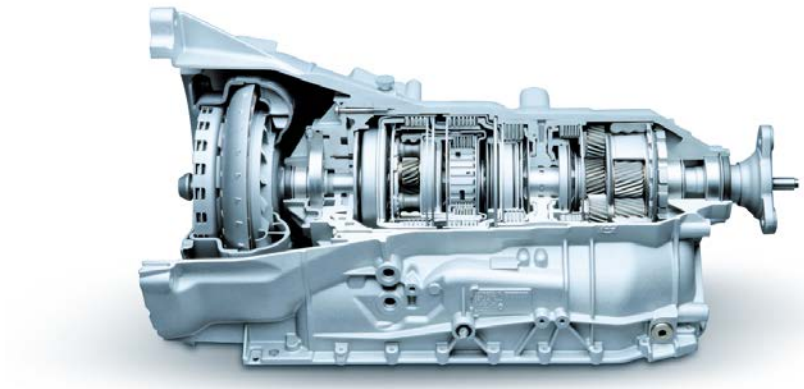
Both AVL BOOST™ and AVL FIRE™ support deploying user defined code extensions in the simulation procedure. For this purpose, both products offer the conventional possibility of linking user-defined functions to either tool. Recently AVL released the standardized AVL User Coding Interface AUCI. This enables an engineer to deploy any reaction mechanism of choice without having to program a single line of source code. Saving the input C-Code is generated automatically and the compiled object can be used with AVL BOOST™ and AVL FIRE™ equally without any further effort. AUCI also supports the exchange of the code between different parties involved in the development of an aftertreatment system. Before saving the input, the engineer can decide which part of the content shall be hidden/disclosed to the person that will actually use the compiled code. Thus, proprietary information remains protected while it is ensured that everyone involved can produce the same results.



Flow uniformity and temperature field in a diesel particulate filter



AVL CRUISE™ model with detail gearbox



Transmission and Driveline

Scalability and consistency is a central philosophy of AVL's simulation tool chain. The program portfolio offers transmission and entire driveline modeling capabilities on all the required levels. It answers the needs of diverse applications in component and control development and vehicle integration, from general system behavior to detailed analysis of losses to NVH and durability of single components.

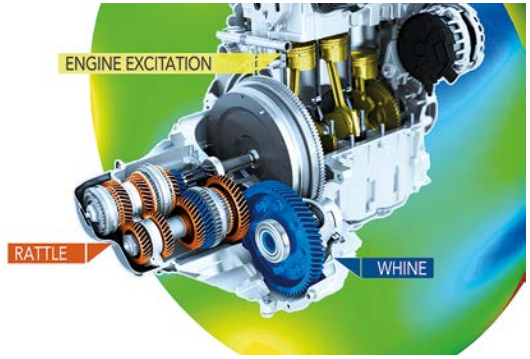
EFFICIENCY ENHANCEMENT – UNDERSTANDING COMPONENTS AND SYSTEMS

When searching for energy saving potential in already extensively optimized drivelines, a primarily component-focused approach, which was standard and normally sufficient in the past, is no longer appropriate. The entire energy flow from drive power generation to the power at the wheel needs to be investigated, taking into account the loss contribution of each component to vehicle CO_2 emissions.

This requires a comprehensive systematic approach with an integrated subsystem and detailed component investigation.

Using AVL EXCITE™, component and subsystem analyses are performed in order to derive friction maps for each of the loss-contributing parts. These maps are then used in AVL CRUISE™ for vehicle system investigation, such as the power flow and loss distribution analysis during drive cycle tests. This type of tool interaction makes it possible to understand the impact of each component as well as its modifications on vehicle fuel efficiency which in turn allows one to invest in component improvements with the highest cost/benefit ratio.

AVL EXCITE™ – influence of gearbox rattle and whine on the radiated noise



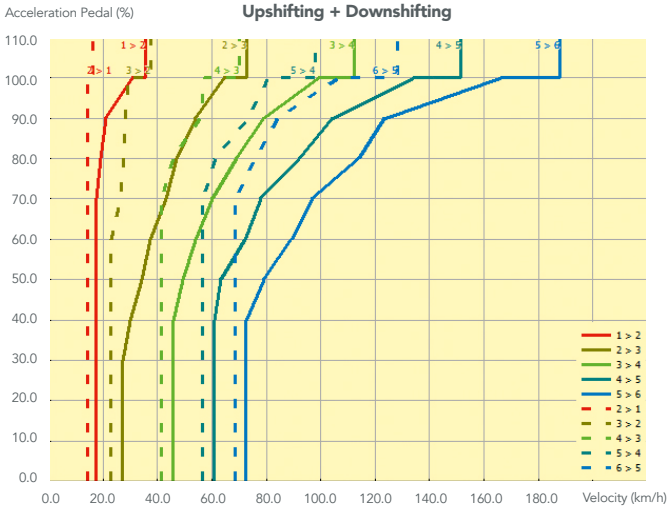
VIBRATION, STRENGTH AND ACOUSTIC OPTIMIZATION

With different modeling levels based on a rigid/flexible multi-body dynamics solution, AVL EXCITE™ supports the transient vibro-acoustic analysis of conventional and hybrid automotive and non-automotive drivelines up to 3 kHz. One simulation target is the investigation of the dynamic behavior and acoustic noise phenomena in drivelines under stationary and non-stationary operating conditions (e.g. tip-in/back-out, start-stop) such as boom, clonk, rattle, whine, chatter, whoop or shudder. For the analysis of vehicle chassis vibrations, the excitation forces from driveline dynamics are applied to the car body at mounting points such as the power unit mounts.

EFFORT REDUCTION IN GEAR SHIFTING PROGRAM DEVELOPMENT

To achieve CO_2 targets while still providing a competitive balance in terms of vehicle performance and driveability, automated transmission technologies such as AMT, DCT, AT and CVT are appearing more and more frequently on the market. Finding the right gear shifting program for the combination of vehicle type, powertrain technology and component limitations is creating new challenges in the vehicle development process.

AVL CRUISE™ GSP (Gear Shifting Program) represents the most efficient way to optimize the development of gear shifting programs. In early concept phases, AVL CRUISE™ GSP enables engineers to automatically generate gear shifting maps for different vehicle powertrain variants within seconds, improving the accuracy of simulated fuel consumption and vehicle performance results. Later on, calibration engineers can start with a gear shifting program which is near-optimized for fuel efficiency, performance and drive quality before having put the real vehicle on the road or testbed. This significantly reduces the development time and in-vehicle testing costs.



AVL CRUISE™ GSP – Generate & Optimize Gear Shifting Strategy towards given targets

Durability and NVH

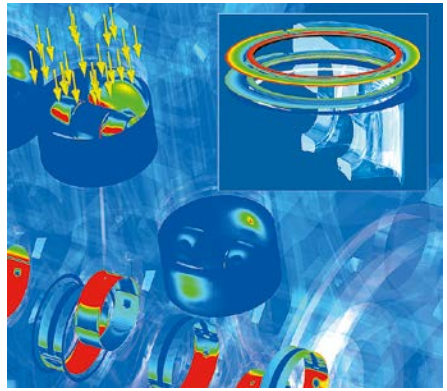
AVL EXCITE™ has been chosen by the majority of engine manufacturers worldwide as their main platform for strength, durability and NVH simulations of power units. This makes it the leading software on the market for durability analyses of engine components, valve train and timing drive dynamics, tribological analyses of lubricated engine contact points, cylinder kit design and NVH optimization.

REAL LIFE CONDITIONS FOR PRECISE RESULTS

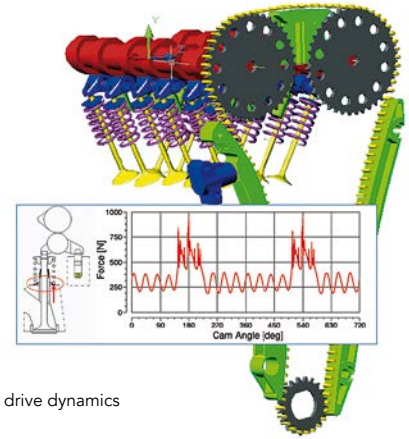
AVL EXCITE™ calculates complex dynamic models considerably faster than multipurpose tools. Short turnaround times are achieved by robust and optimized solvers even with complex models. The accurate consideration of non-linearities in lubricated engine contact points provides results which are similar to real life. Outstanding elastohydrodynamic (EHD) contact models for slider bearings and piston/piston ring liner contact facilitate detailed investigations of contact behavior, including the calculation of friction and wear. In this way the simulation assists the engineer in making the right design decisions efficiently and facilitates a significant reduction costly testing.

POWERTRAIN ORIENTED SOLUTION

Powertrain-analysis-specific workflows and automated model generation as well as result evaluation capabilities help the engineer to achieve short project lead times. For example, AVL EXCITE™ AutoSHAFT is a significant time saver for crankshaft model generation. Based on files from CAD, a dynamic crankshaft model can be generated within hours. AVL EXCITE™ calculates transient engine run-up and in-stationary conditions without relying on unrealistic speed steps. In this way, critical operating conditions can be detected reliably without the time-consuming interpretation of incomplete results.



Four cylinder inline engine – friction in lubricated crank-train contacts



Valve train and timing drive dynamics

MULTI-LEVEL SIMULATION MODELS

Different modeling levels for single components as well as for the entire system help the engineer to use an optimum balance of model depth in terms of required accuracy for the application target and the modeling and simulation time. The simulation models can be extended as needed during the development process, saving costs by eliminating the need to rebuild models for each step.

INTEGRATION AND CUSTOMIZATION

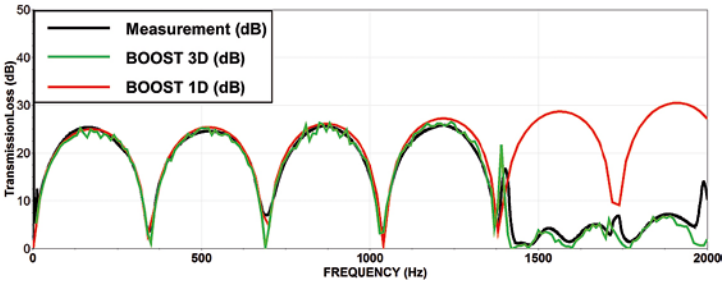
Interfaces for third-party FE and fatigue software enable the seamless integration of AVL EXCITE™ in the customer CAE environment. With the integrated finite element solver of Abaqus™ and the fe-safe™ based fatigue strength analysis tool AVL EXCITE™ Fatigue, the application workflows for fatigue and NVH analysis can be carried out optionally by AVL EXCITE™. For extensive design variation, parameter identification and optimization tasks, the integrated tool Design Explorer as well as interfaces to commercial optimization software are provided. Furthermore, AVL EXCITE™ offers customer-definable template models, plot and report generation, workflow descriptions and a customizable GUI.

DUCT ACOUSTICS IN TIME AND FREQUENCY DOMAIN

AVL BOOST™ offers linear and non-linear acoustics modules for the simulation of free field and in-duct acoustics in order to support

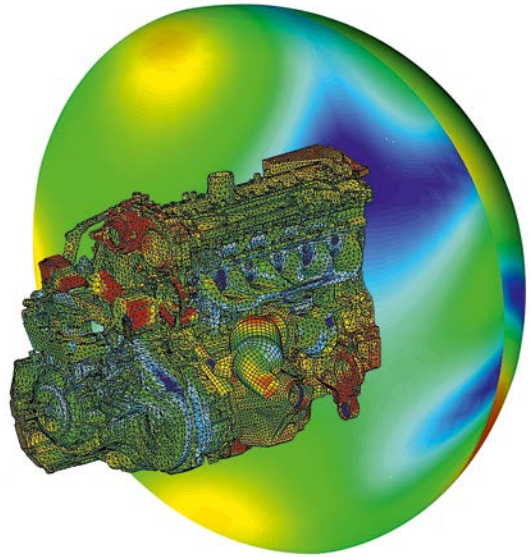
- Muffler design
- Intake and/or exhaust orifice noise reduction
- Sound engineering etc.

The resulting pressure waves can be used as excitation for shell noise simulation with AVL EXCITE™.



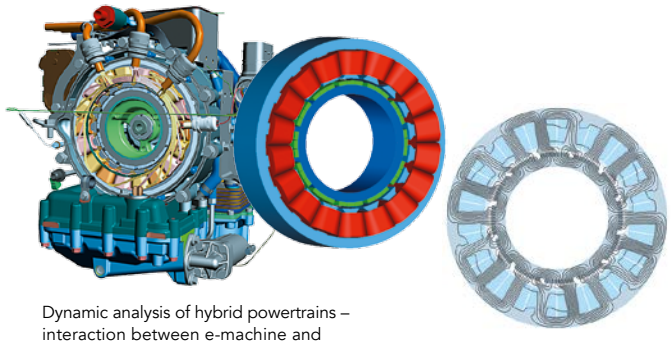
Higher Order Modes correctly predicted by AVL BOOST™ 3D

Acoustic of power units – structure borne noise and noise radiation (AVL EXCITE™ Acoustics)



Electrification

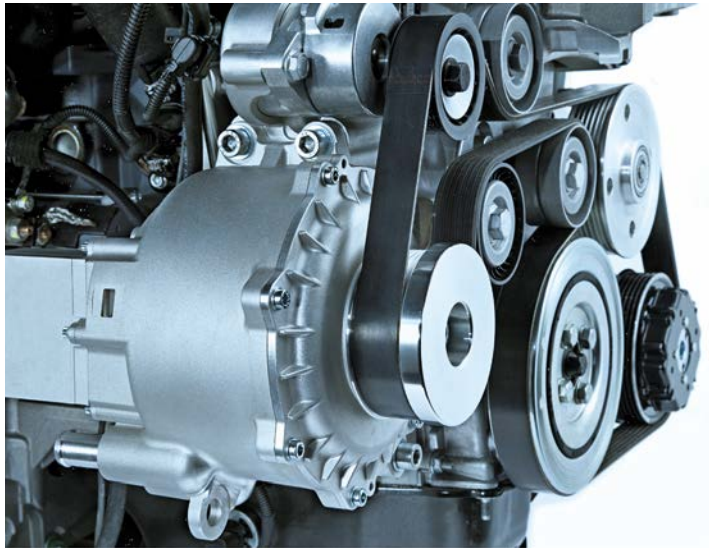
The simulation of vehicles with different levels of electrification (from HEV to PEV), the optimization of electrical systems and their components (such as electric drives, batteries and fuel cells) under completely new operating conditions and improvement in the performance of electrical turbochargers are just a few examples of AVL's innovative simulation capabilities in the huge field of new and challenging technology trends.



Dynamic analysis of hybrid powertrains – interaction between e-machine and IC engine (AVL EXCITE™)

HIGHLY DETAILED NVH ANALYSIS OF ELECTRIFIED POWERTRAINS

AVL EXCITE™'s domain is a detailed component and system analysis in terms of the dynamics, strength, durability and acoustics of hybrid powertrains and gen-set configurations. Analysis targets are e.g. the detailed investigation of the interaction between e-machine and the cranktrain of belt-driven starter-generator or mild hybrid systems, the dynamics and NVH of transmissions under combined non-stationary loading conditions or the influence of grid connection maneuvers on the dynamic behavior and load conditions of gen-sets.

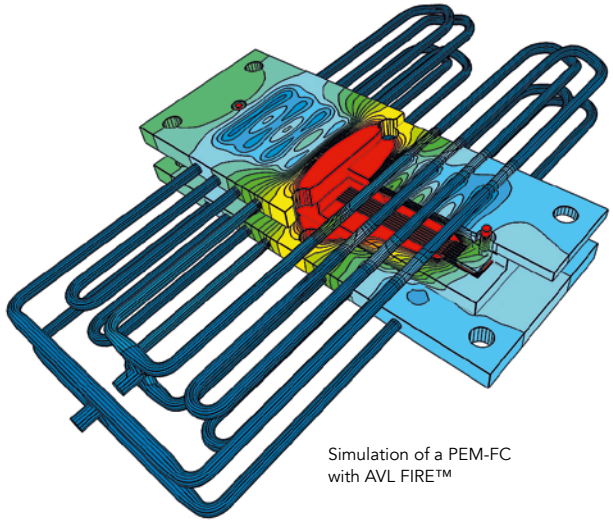


OPTIMIZING ENERGY STORAGE AND COOLING SYSTEMS

AVL FIRE™ makes it possible to predict the overall behavior of a Li-Ion battery cell, module or complete battery during transient charging and discharging processes. Critical conditions can be identified, thereby helping to optimize the system in terms of electro-chemistry, performance and thermal management. In order to accomplish these tasks, AVL FIRE™ offers thermo-electrical as well as predictive electro-chemical battery models which enable the simulation of electric charge transport in active layers and positive and negative collectors as well as heat conduction in thermal masses, while considering electric and thermal contact resistance.

UNDERSTANDING THE FUEL CELL

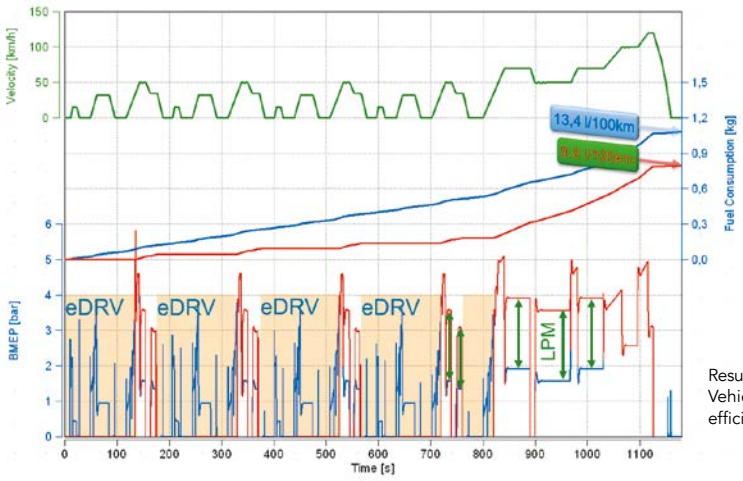
A comprehensive set of electro-chemical and physical models is offered by AVL FIRE™ in order to simulate the processes taking place in polymer electrolyte membrane fuel cells (PEM FC). AVL FIRE™ also solves the electro-chemical reactions in the catalyst layers. Water transport and the transport of hydrogen ions and gas species are calculated in the membrane. Phenomena handled in the gas diffusion layer include the capillary flow of liquid water and electron conduction. In addition, phase change due to evaporation and condensation, multi-phase momentum transfer, the multi-component diffusion of gas species and multiphase heat transfer are modelled. Heat and electron conduction are calculated in the bi-polar plates. Simulation of the cooling channels is also provided to measure convective heat transport.



Simulation of a PEM-FC with AVL FIRE™

ENERGY EFFICIENCY IS THE FINAL GOAL

Vehicle component and subsystem development cannot be done in isolation if the goal is to improve the fuel economy, performance and driveability. The acceptance and success of a new vehicle is determined by its strategic target definition, the choice of the powertrain configuration including the selection and sizing of the components in the early vehicle development phase. AVL CRUISE™ offers a wide range of implemented electric components on a system level, dynamic visualization of power flow and energy distribution analysis, as well as user specific model integration from other tools. These attributes provide an sustainable base for all hybrid concepts as well as control function development for all vehicle types from PEV to full HEV and other alternative powertrain solutions.



Results from AVL CRUISE™: Vehicle electrification efficiency assessment

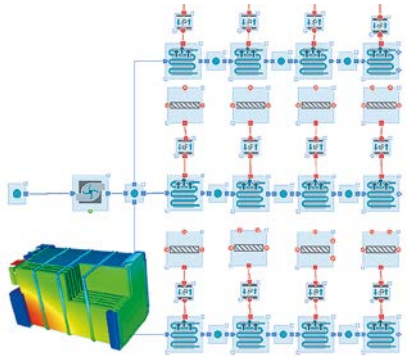
Thermal Management and Aerodynamics

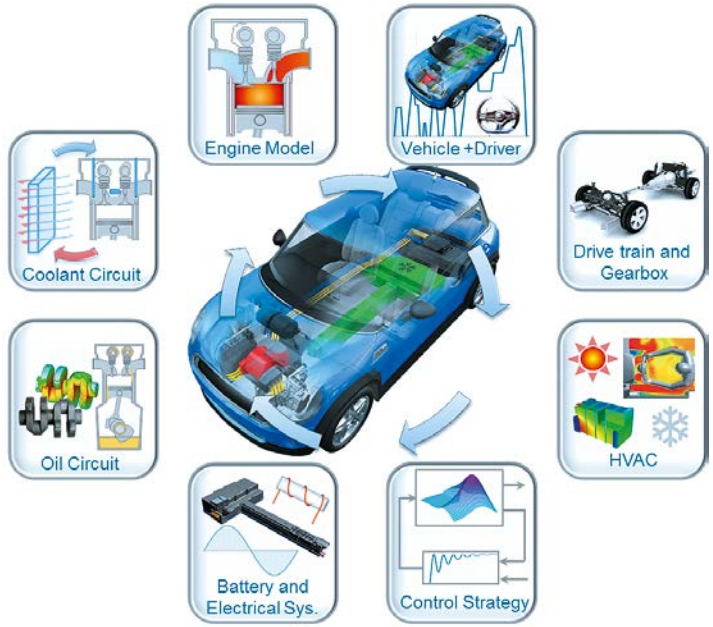
The component development tasks for the engine and vehicle are distributed over a number of departments. Using consistent simulation models delivers a virtual overall system simulation environment that is consistently detailed during the design process. This enables the sharing of relevant data across the various disciplines required for the study of vehicle thermal management systems (VTMS).

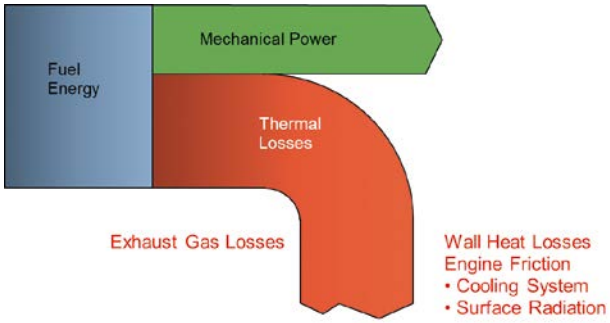
WHY THERMAL MANAGEMENT

A well designed engine cooling system enables fast engine warm-up

- To reduce friction losses
- To allow minimum time for aftertreatment system light-off
- To quickly clear the windshield of ice and condensation
- To ensure adequate cooling of all engine components under all operating and weather conditions
- To allow comfortable cooling or warming of the passenger compartment







SIMULATION ENABLES PERFORMANCE

To assist in the optimization of VTMS systems, AVL has established a comprehensive methodology for advanced vehicle simulation, including the simulation of:

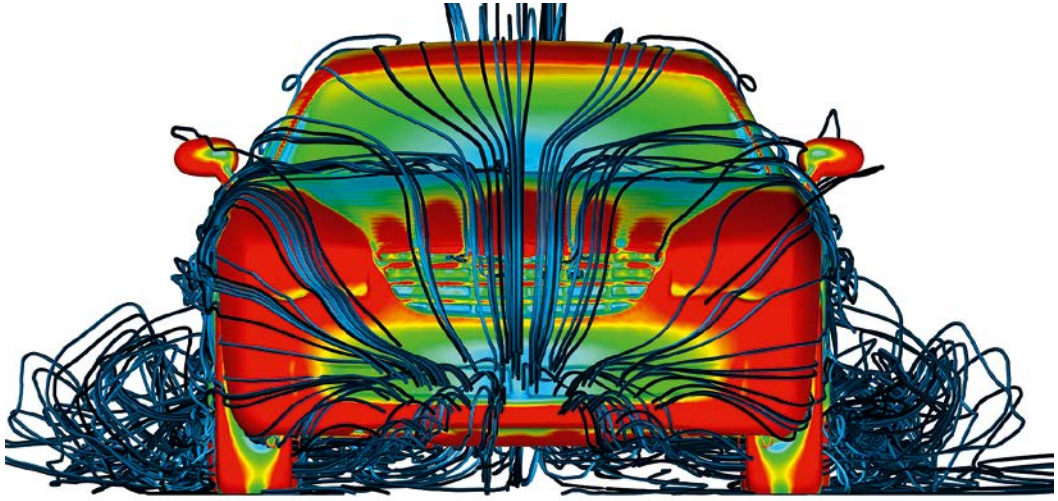
- Engine performance
- Exhaust gas aftertreatment
- Cooling and oil circuits
- Engine compartment flow
- Heat transfer between fluids and structure

SUPERIOR TOOLS FOR SUPERIOR SOLUTIONS

AVL offers an integrated set of tools consisting of:

- AVL BOOST™, for calculating 1D gas dynamics, performance, cooling and oil circuits and exhaust aftertreatment
- AVL CRUISE M, the industry standard for integrated vehicle simulation on system level
- and AVL FIRE™, 3D CFD for IC engine and vehicle development

These tools facilitate the seamless development and optimization of vehicle thermal management systems and control strategies.



External aerodynamic prediction with AVL FIRE™

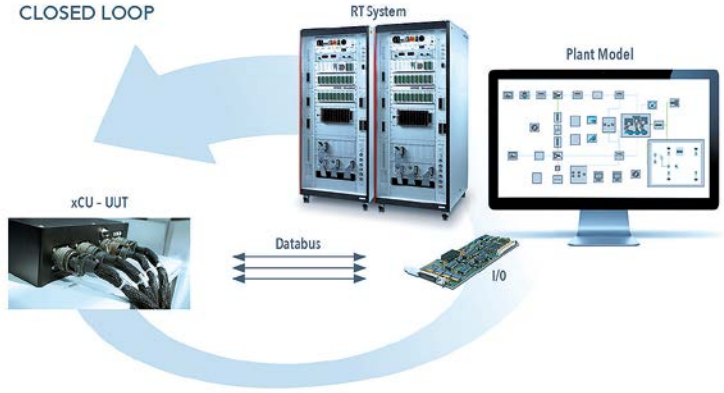
Calibration and Testing

The growing number of closely interacting components and control systems and the increasing complexity of control functions require the testing of an exhaustive number of new test case combinations. AVL CRUISE™ M MOBEO real-time models add more flexibility and productivity to HiL targets, such as AVL PUMA Open™ testbeds, dSPACE, ETAS, National Instruments and Opal RT.

CAE AND TEST WITH THE SAME PLANT MODEL

System models, set up in the office for solving powertrain analysis and optimization tasks using AVL CRUISE™ M MOBEO, can be used again in the field of components and control systems testing (engine testbed, Hardware-in-the-Loop). This is possible thanks to the use of the same system solver, which has been optimized for office as well as real-time applications. In this way, the effort required to exchange models in both directions between the office and test systems is kept to a minimum. This consistency between the model and solver forms the basis for achieving comparable high-quality results throughout the whole development cycle.

Model based component test

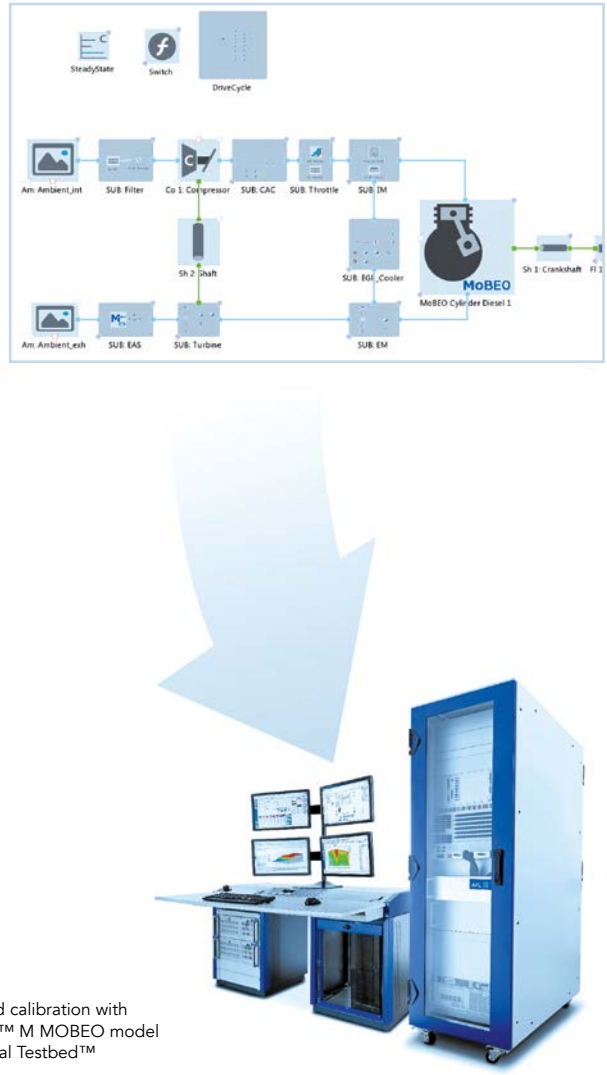


SEAMLESS CONTROL FUNCTION DEVELOPMENT AND CALIBRATION

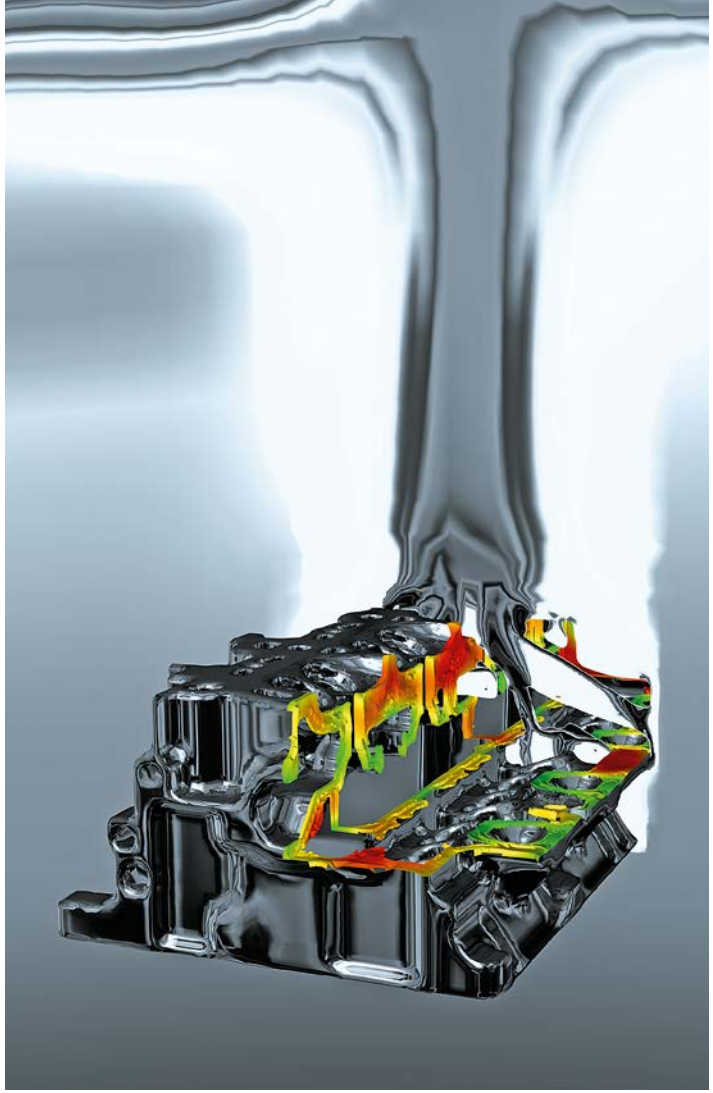
AVL CRUISE™ M MOBEO offers semi-physical modules for gasoline and diesel cylinder and exhaust gas aftertreatment system simulation, integrated into AVL CRUISE™ M. These modules with incorporated AVL engineering expertise combines the strengths of both physical and empirical modeling available for office and Hardware-in-the-Loop environments. AVL CRUISE™ M MOBEO enables an automated engine calibration backed up by powertrain engineering know-how.

AVL CRUISE™ M is a real-time capable simulation environment dedicated to the investigation of transient offline operating conditions in office and testing environment. AVL CRUISE™ M supports engine performance, fuel consumption, combustion, emissions, aftertreatment and cooling application.

The modular modeling concept of AVL CRUISE™ M MOBEO allows setting up of and switching between subsystems with various levels of detail within a single plant model. This significantly reduces the effort of parameter changes and model maintenance, and enables a quick adjustment to specific needs for different working environments. Interfaces to a wide range of modeling and programming tools and control test platforms provide engineers with the openness needed to expand model fidelity in well-defined areas, and to incorporate them into a seamless development workflow from MiL to SiL or HiL.



Model based calibration with AVL CRUISE™ M MOBEO model on AVL Virtual Testbed™

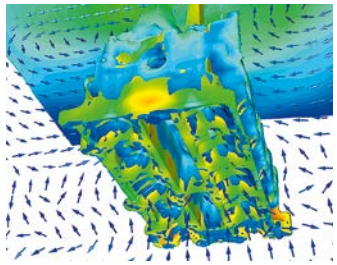


Aluminum cylinder head quenched in water

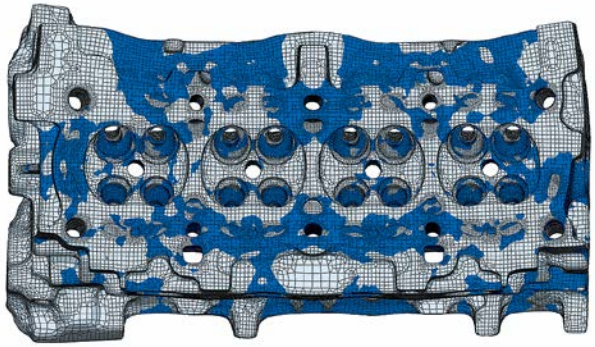
Quenching

Quenching is a common heat treatment technique used in production of cast parts or otherwise produced metal components. In particular, immersion or direct quenching processes are widely adopted procedures in automotive and aerospace industries to minimize the formation of undesirable thermal and transformational gradients, which may lead to increased distortion and cracking.

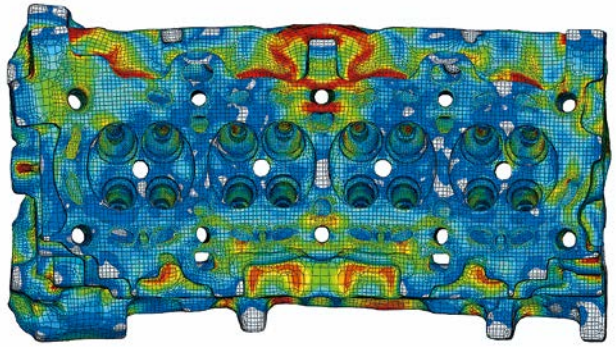
AVL FIRE™ offers state-of-the art modeling functionality in the field of quenching. Various quenching approaches can be simulated; air quenching followed by spraying and finally direct quenching. Different numerical models cover physical specifics of the thermal treatment process, which significantly influences the properties of cast materials. Commonly investigated components are cylinder heads or engine blocks made of aluminum, which can, under certain circumstances, undergo exceedingly high operational loads leading to material failure. Cracks commonly appear as a consequence of downsizing and weight reduction. An everyday application thereof would be the weight reduction of passenger cars to minimize tailpipe emissions. Despite the complexity of the investigated problem and long physical times, short turnaround times offer a great platform for virtual prototyping.



Submerged cylinder head during quenching; water flow disintegrating the vapor film during transition boiling



Von Mises stresses during quenching simulated by AVL FIRE™; five seconds after submerging



Von Mises stresses during quenching simulated by AVL FIRE™; 30 seconds after submerging

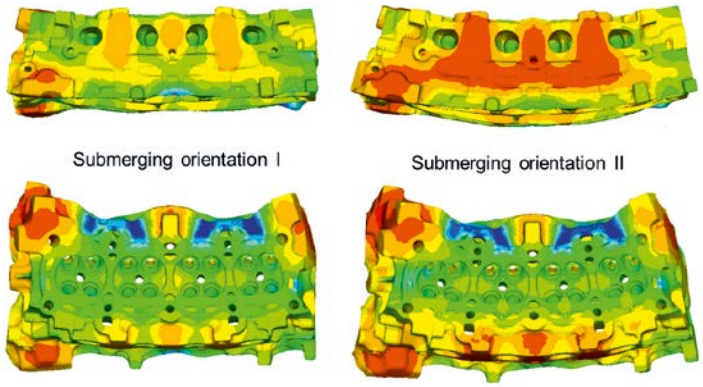
BOILING REGIMES DURING DIRECT QUENCHING

Physically, the most challenging quenching approach is submersion (or direct) quenching where reheated components are submerged in the water pool. Initially, film boiling slows down the heat removal, followed by nucleate boiling and finally single phase cooling after the solid has cooled down beneath the saturation temperature of the quenchant. Predicting different boiling modes and the transition is the key. AVL FIRE™ has proven to be an accurate and reliable numerical tool in numerous test configurations and full complexity cases, such as cylinder heads. The quenching process is affected by solid piece orientation, initial solid temperature, water temperature and more, therefore accurate prediction of local temperature histories within the structure is crucial for final prediction of residual stresses resulting from the production process.

THERMAL STRESS PREDICTION

Solid temperature results obtained with AVL FIRE™ serve as input for Finite Element Analysis of thermal loads and deformations. A simple GUI-based mapping step is performed to produce input data for Finite Element Analyses. Finally, predicted residual stress levels are compared with operational loads. If residual stresses superimpose the operational loads, the thermal treatment is to be changed. A different submerging direction or quenchant temperature may completely change the nature of residual stresses in critical areas and thereby improve the quality and safety of components in operation. When investigating quenching of steel components one needs to account for the release the latent heat during the martensitic phase transformation. In such case AVL FIRE™ is used to predict the boiling process on the fluid side, and is online coupled with a Finite Element simulation tool utilizing dante®, a coupled thermal, carbon diffusion, solid mechanics program. Needless to say, this extends the lifetime of the product and reduces the risk and warranty costs of OEMs in the market.

Cylinder head deforming in FEA simulations utilizing AVL FIRE™ quenching results as input



A Kaleidoscope of Simulation Possibilities

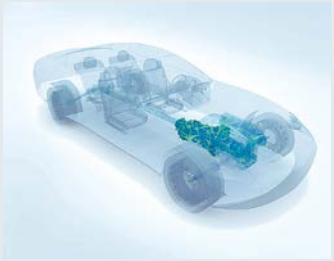
INCREASING SIMULATION DEMAND

The challenge of reducing time and costs along the product development cycle creates a growing demand to replace physical prototypes with virtual prototypes applying frontloading. The vast range of variables in modern powertrain systems and the increasingly considered interaction of all vehicle components need to be mastered in the most efficient manner. Engineers are facing a great number of challenging development and simulation tasks which need more than just 'good software'.

The unique power of AVL Advanced Simulation Technologies is derived from the systemic linking of single simulation results to integrated, multidimensional simulation platforms on the basis of AVL's sound knowledge of engineering. These simulation platforms address the key tasks of the powertrain development process. A closed measurement loop enables a very early verification of testing data and a significant reduction in test attempts.

OUR STRENGTHS HELP CUT DEVELOPMENT COSTS AND TIME

- Robustness, ease of use and the completeness of physical models enable simulation as a "frontloading" development tool
- Exceptionally reliable and practical simulation solutions which solve development problems with a high level of accuracy and confidence
- Simulation solutions focus on powertrain engineering and therefore provide problem-tailored capabilities for model set-up and result presentation to the powertrain development teams
- Experienced local support and powertrain simulation teams support global development activities



POWERTRAIN ENGINEERING INSIDE / CLOSE LINK TO TESTING

AVL SIMULATION WORK FLOWS THROUGHOUT...

AVL's unique simulation power is the combination and integration of AVL software tools, third-party tools, testing and analysis methods with seamless simulation workflows which guide the user to practical solutions.

...THE PRODUCT CREATION PROCESS

AVL's simulation workflows address application tasks which cover all aspects of the product creation process. The huge complexity of these tasks is bundled into multidimensional simulation platforms on the basis of AVL's sound engineering know-how.

AVL BOOST™

AVL BOOST™

MARKET DRIVERS

Automotive marketplace demands, such as fuel efficiency, passenger comfort and emissions, places limits on today's vehicle designs. The ability to meet the majority of these demands is highly influenced by the combustion engine.

These idealized targets often conflict, as shown by the constant trade-off between high performance and fuel efficiency, for example. To meet core specifications required by the vehicle team, engine designers must balance dozens, if not hundreds, of engine parameters. The use of simulation tools, whether pure simulation or a combination of hardware in testbed environments (hardware-in-the-loop), is essential.

AVL BOOST™ is an advanced and fully-integrated "Virtual Engine Simulation Tool" with advanced models for accurately predicting engine performance, acoustics, and the effectiveness of exhaust gas aftertreatment devices. It supports engine development in such a way that, for a given vehicle concept, the required torque and power can be delivered in combination with optimized emissions, fuel consumption and passenger comfort (acoustics and transient behavior).

AVL APPROACH

AVL BOOST™ – the well established "Virtual Engine Simulation Tool" with high fidelity simulation models for

- Combustion and pollutant formation in the cylinder
- Exhaust gas aftertreatment
- Acoustic analysis

AVL BOOST STRENGTHS

- Powertrain expertise drives software development
- Specialized user interface designed for engine engineers
- Consistent 1D and 3D aftertreatment simulation in AVL BOOST™, AVL FIRE™ and AVL CRUISE™
- Engineering, testing, and software under one roof
- Support provided by experienced engineers from local AVL offices around the world

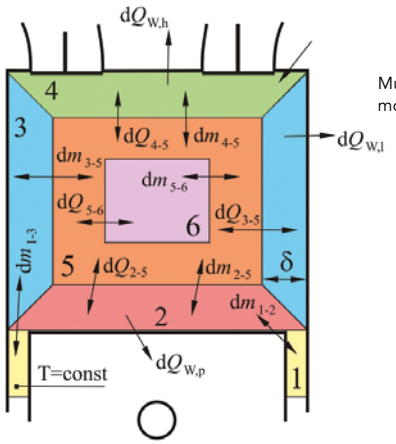
INTEGRATED SOLUTIONS WITH AVL BOOST™

AVL BOOST™ – AVL FIRE™

AVL BOOST allows to model any part of the intake or exhaust manifold in full 3D by coupling the 1D flow solution with the 3D CFD Software AVL FIRE™. This includes time as well as cost effective optimization of key elements such as the intake plenum (EGR mixing) or the close-coupled catalyst (uniformity, heat-up and conversion).

AVL BOOST™ – AVL CRUISE™

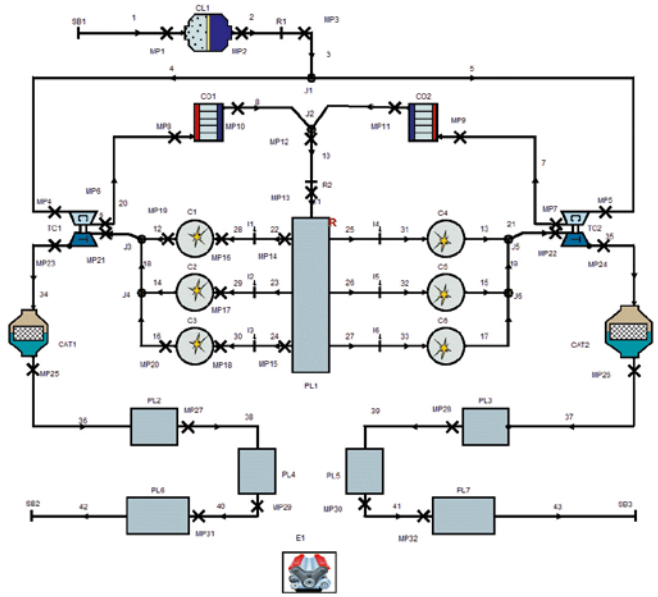
AVL CRUISE™ is a software package developed for vehicle simulation. Typically, AVL CRUISE™ uses engine maps for performance and emission data. However, a direct coupling to an AVL BOOST™ engine model can be selected for even greater accuracy, especially for transient analysis.



Multi-zone combustion modeling in AVL BOOST™

GCA – GAS EXCHANGE AND COMBUSTION ANALYSIS

Although today's engine testbeds are equipped with a variety of sensors, certain important performance and combustion parameters (for example residual gas concentration, volumetric efficiency, scavenging efficiency, and trapped mass) cannot be measured directly. This limitation is overcome by GCA, an integration of AVL BOOST™ into AVL's testbed environments AVL IndiCom™ and AVL CONCERTO™. This integration provides engine engineers with access to crucial results for their development tasks.



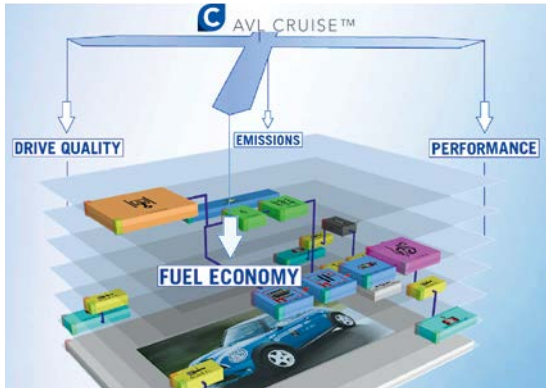
AVL BOOST™ model: 6 cylinder bi-turbo Ottomotor

AVL CRUISE™

AVL CRUISE™

MARKET DRIVERS

Cost reduction and time pressure in vehicle development demand highly flexible simulation systems. The models produced by these tools need to be able to fulfill their functions throughout the product development workflow to prevent the initial concept from being lost under the weight of conflicting engineering demands and compromises regardless of driveline topologies. The increased complexity of advanced vehicle concepts requires interdisciplinary cooperation of teams, because vehicle-level simulation tools need to be able to leverage the communication between different teams and ensure consistency in model and data management. Resources for the time- and cost-intensive development are hard to justify as are validation and maintenance of vehicle-level simulation tools. But comprehensive tools are required to create product-defining attributes such as fuel economy, emissions, performance and drivability with an optimized costbenefit ratio.



Finding the perfect trade-off to achieve given targets

CONSISTENT SIMULATION MODELS AND APPLICATION-FOCUSED WORKFLOWS

AVL CRUISE™ supports everyday tasks in vehicle system and driveline analysis throughout all development phases from concept planning to launch and beyond. Its area of application spans from conventional vehicle powertrains to highly-advanced HEV systems.

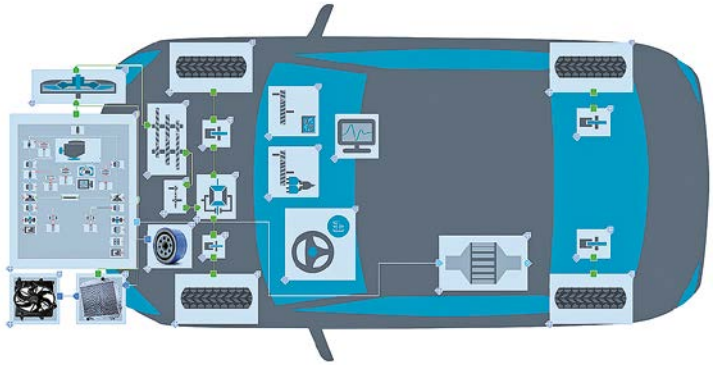
AVL CRUISE™ offers a streamlined workflow for all kinds of parameter optimization and component matching – guiding the user along the way to practical and attainable solutions. Due to its structured interfaces and advanced data management AVL CRUISE™ has established itself as a data communication and integration tool for various teams within world-leading OEMs and their suppliers. This facilitates consistent target definition and traceability of decisions made in reaching the best overall results for the developed product.

AVL CRUISE™ STRENGTHS

- Realistic vehicle system modeling of any topology with complete vehicle component models and scaleable fidelity
- Inclusion of all simulation vehicle system analysis tasks and workflows
- Intelligent and consistent management of data throughout teams, applications and workflows
- Developed with OEMs engaged in leading-edge vehicle and powertrain design – AVL CRUISE™ incorporates the expertise of these companies

YOUR BENEFITS

- Simulate driveline structures efficiently, from standard to the most complex
- Perform all fuel economy, emissions and performance tests in a single run with the same vehicle model
- Hybridize conventional vehicles with only a few mouse clicks
- Explore new transmission concepts such as automated manual transmissions and dual clutch transmissions
- Execute very large parameter optimization and component matching tasks with DoE functions
- View the energy and power flows graphically in the entire powertrain



Multi-disciplinary vehicle system model

AVL CRUISE™ M

AVL CRUISE™ M

INTRODUCTION

The multi-disciplinary vehicle system simulation platform AVL CRUISE™ M is designed for model-based system development, seamlessly integrating high-quality, realtime-capable subsystem models of engine, driveline, 1d fluid flow, aftertreatment, electrical and control system domains.

The numerical solver, tailored for efficient multi-physics vehicle system simulation is combined with a highly flexible, multi-detail level modeling approach, open to third-party tools and interface standards (FMI).

This allows for AVL CRUISE™ M subsystem and overall vehicle models to be re-used in the powertrain development process anywhere from traditional fuel efficiency, emissions and performance analysis to entire vehicle thermal and energy management assessment in the office as well as validation and calibration on realtime HiL and test systems.

FUNCTION DEVELOPMENT AND CALIBRATION

AVL CRUISE™ M Engine is one of the essential parts of the entire AVL CRUISE™ M multi-disciplinary model-based development solution, focusing on system level realtime engine simulation which can be used throughout vehicle development cycle. Scaleable engine modeling depths from empirical to semi-empirical, and then the physical level, using a crank-angle resolved cylinder and a gas path approach provide a unique solution to create and execute models which meet the requirements of model-based calibration.

This ensures consistent, comparable, and reproducible tests which can be performed even before the hardware is available to lower the risk

of missing critical operating conditions in early development phases and increase development efficiency. Integrating AVL CRUISE™ M MOBEO's semi-physical modules for the simulation of cylinder and exhaust aftertreatment system in AVL CRUISE™ M, enables an automated engine calibration process for all vehicle types, backed up by powertrain engineering know-how.

The open concept of AVL CRUISE™ M supports calibration and test tasks from MiL to SiL to HiL which can be applied to a wide range of globally leading RT platforms, achieving real-world conditions without any actual risk to the driver or equipment.

VEHICLE ENERGY MANAGEMENT SYSTEMS DEVELOPMENT

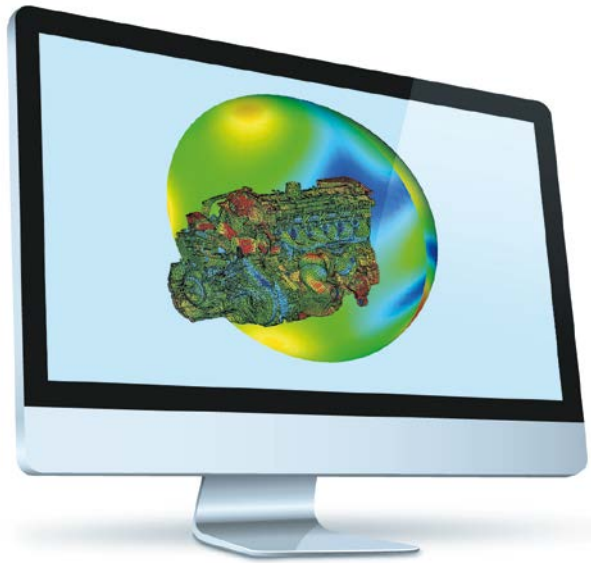
AVL CRUISE™ M provides a simulation environment for the development of an effective thermal management system and its control strategy which require a comprehensive consideration of the entire powertrain.
It works as the thermal link between the powertrain subsystems, covering integration tasks such as cooling and heating of all relevant components, reduction of thermal losses and optimization of the overall efficiency, detecting critical thermal conditions, so preventing damage to the vital parts of the engine and driveline. In addition to the subsystem components, there is a fully-integrated property database extendable by the user containing numerous solids, oils, and coolant media.

The modular system integration with other AVL CRUISE™ M domains extends capabilities for realistic interaction and development of complete vehicle energy management.

In the office…

…on HiL…

…on the testbed. Simulate Anywhere. AVL CRUISE™ M



AVL EXCITE™

AVL EXCITE™

MARKET DRIVERS

AVL EXCITE™'s family of products are the leading market simulation tools for powertrain NVH and durability assessment. The powertrain development process is increasingly subject to opposing pressures. As the requirements for strength, durability and noise reduction rise, so do associated time and cost pressures. This challenge can only be met through the use of efficient simulation and calculation tools.

These tools must be as realistic as possible during the concept phase with increasing precision throughout the later development stages. Math-based models assist engineers in producing higher quality products while achieving shorter development times and lower costs.

AVL APPROACH

AVL has developed complementing tools for simulating and calculating individual components, submodels and entire system.

HIGH FIDELITY SYSTEM SIMULATION

Complete systems and individual components with various modeling depth levels can be built or scaled for each stage of the development process. Models can be adapted to meet requirements ensuring the optimum balance between simulation effort and accuracy.

POWERTRAIN ENGINEERING INSIDE

With many years of experience in the field of engine development, AVL's software uses accurate and validated mathematical models to provide calculation results which are as realistic as possible. AVL simulation solutions are highly application-oriented.

CLOSE LINK TO TESTING

The AVL EXCITE™ Designer tool provides results in a format which enables an electric motor to reproduce the torsional vibrations of a combustion engine on the transmission testbed. In this way, AVL EXCITE™ enables customers to save time and costs during the testing phase of a project.

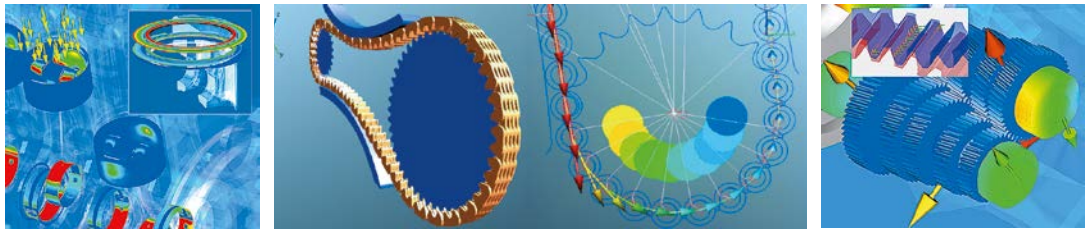
AVL TOOLS FOR STRENGTH, DURABILITY AND NVH SIMULATIONS

AVL EXCITE™ POWER UNIT

is the industry's leading tool for calculating the dynamics, strength and acoustics of combustion engines, transmissions and powertrains. It is also used for the detailed analysis of local hydrodynamic effects in oil-lubricated contacts (slider bearings, piston-liner contacts).

AVL EXCITE™ DESIGNER

uses analytical methods to enable the fast and realistic dimensioning of crankshafts and powertrains at an early stage in the development process.



AVL EXCITE™ – dynamics, durability and NVH of engines and powertrains

AVL EXCITE™ TIMING DRIVE

ensures reliable results for all kinds of valve trains and timing drives. It covers the entire work-flow, from the kinematic designing of cam profiles and the dynamic behavior of individual components, to entire timing drives driven by gears, chains or belts.

AVL EXCITE™ PISTON & RINGS

is an efficient tool for sizing piston assemblies. The piston ring module can be used to calculate absolute values for inter-ring pressures, piston ring movements and blow-by as well as the reliable trend prediction of lube oil consumption.

AVL EXCITE™ ACOUSTICS

is a new tool for calculating the noise radiation of vibrating structures such as power units. Using a unique automated procedure to generate the acoustic mesh within minutes, starting from the unmodified structural FE mesh and a wave-based technique solver, it enables the calculation of airborne noise results with significant short analysis lead time.

AVL EXCITE™ STRENGTHS

- Robust and optimized solver for short calculation times
- Parameter-based simulation models – easy variation of design parameters
- Hybrid modeling approach (2D workspace with a 3D view capability) for easy and fast model generation
- Customizable GUI – user definable for template definition
- Integrated standard workflows for crankshaft dynamics and NVH analysis, extendable by user-defined workflows
- Automated application-oriented and user-extendable 2D post-processing (standard reports)
- Design explorer – integrated tool for DoE and optimization
- Interfaces to third-party CAE software (FE, optimization) and application programming interface for smooth integration into the existing CAE environment

CUSTOMER BENEFITS

- One simulation environment for all phases of the engine development process and for all structural dynamics analysis
- Based on AVL's 60+ years of leadership in engine and powertrain engineering consultancy
- Dedicated user support and guidance teams around the world with AVL engineers who are highly experienced in engine analysis

AVL FIRE™

AVL FIRE™

MARKET DRIVERS

The automotive industry continues to focus on delivering products with improved quality, balancing driving comfort, performance and fuel consumption while continuously reducing tail pipe out emissions. To meet these requirements, automotive engineers demand development tools which provide accurate representations of complex systems in the virtual world. A rapidly growing number of design parameters for both traditional and alternative powertrain systems increases the importance of predictive simulations which can be deployed during all phases of the product development process. AVL FIRE™ 3D Computational Fluid Dynamics (CFD) Software, with a particular focus on accurate modeling of physics and chemistry related to IC Engines and powertrains, meets the demands of the development engineers during all stages of their work. AVL FIRE™ is used every day by hundreds of engineers to accurately predict results on a robust basis, quickly and reliably. AVL FIRE™ users optimize designs more quickly and with greater confidence.

AVL FIRE™ is primarily used by researchers and developers working in internal combustion engine and powertrain engineering. The software is integrated into their specific processes. This way the quality and performance of new concepts and products can be tested, well before the hardware is available. Development cycles are shortened and costs are reduced, even though the number and complexity of the tasks performed are significantly higher.

AVL APPROACH

As the leading simulation program in the field of combustion engine analysis, AVL FIRE™ specializes in the accurate prediction of engine gas exchange, fuel injection, mixture formation, combustion and emission as well as exhaust gas aftertreatment.

1. HIGH FIDELITY COMPONENT SIMULATION

The overall environment and individual components of AVL FIRE™ allow it to be applied in any phase of the development process. The wide range of available models allows users to properly balance simulation effort and accuracy.

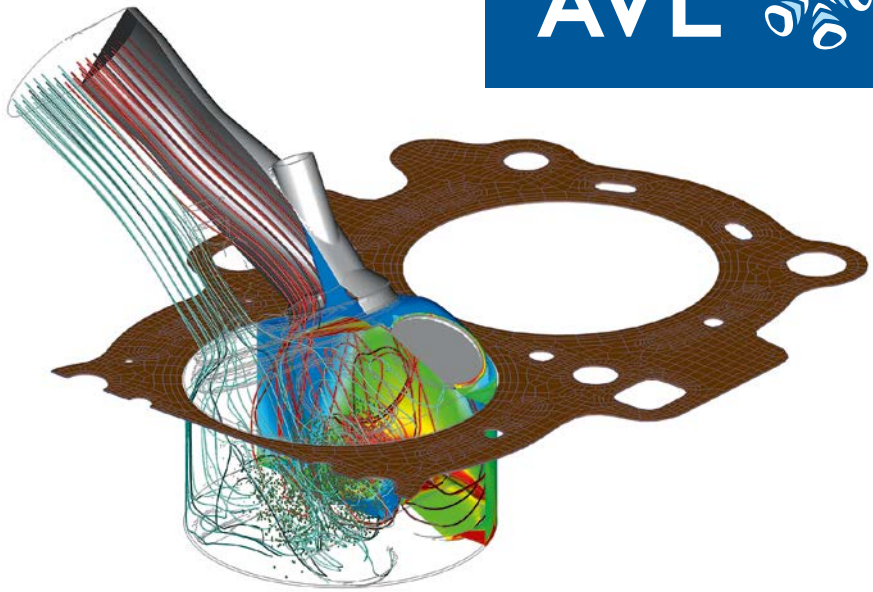
2. POWERTRAIN ENGINEERING INSIDE

The development of AVL's simulation tools is in a unique way supported by over six decades of engine engineering experience

collected in our powertrain engineering division. While our customers as well as our own consulting and service business can directly profit from this know-how, our software development team gains invaluable insight into current and future requirements.

3. CLOSE LINK TO TESTING

The virtual inspection of engine-related phenomena with AVL FIRE™ allows shorter development times and cost reductions. New techniques – such as coupling with optimization tools – allow for the investigation of more design variations. The results are: a more robust prototype on the testbed; shorter test periods; lower costs; higher product maturity and quality.



AVL FIRE™ STRENGTHS

- AVL FIRE™ is a full-scale 3D CFD Solution with an embedded chemistry solver, complemented by pre- and post-processing tools, all embedded in an intuitive graphical user interface; there is no need to purchase third-party tools, even for the most complex tasks
- AVL FIRE™ is based on tested state-of-the-art solver technology capable of handling general polyhedral computational elements and offering a robust platform for continuous enhancement
- AVL FIRE™ offers automated meshing technology for arbitrarily complex geometries, including multiple moving parts; this helps to drastically reduce setup times for complex models
- AVL FIRE™ offers a consistent set of physical and chemical models to cover various types of fluid flow simulation tasks – in particular those related to internal combustion engines – at different stages in the development process
- AVL FIRE™ development effort is complemented by AVL's internal R&D activities as well as by extensive industrial and academic partnerships
- AVL FIRE™ provides an open code structure enabling researchers to extend the software's capabilities to meet specific requirements
- AVL FIRE™ offers unique models and capabilities to simulate flow and chemistry in exhaust gas aftertreatment

CUSTOMER BENEFITS

- AVL FIRE™ is specifically tailored to meet the requirements of automotive research and development engineers
- AVL FIRE™ is flexible to allow users to adjust modeling complexity and integrate the software into their CAx framework
- AVL FIRE™ is a tested tool, used daily in AVL's engine development process and by hundreds of customers worldwide
- AVL FIRE™ is easy to use thanks to automated pre- and post-processing, integrated application-specific workflows and pre-defined solution control files
- AVL FIRE™ provides reliable and accurate simulation results. Its models are extensively validated
- AVL FIRE™ computational models are being continuously developed and enhanced via in-house research activities and partnerships with leading technology centers world-wide
- Customer support is provided by engineers who know powertrains and powertrain development

AVL FIRE™ M

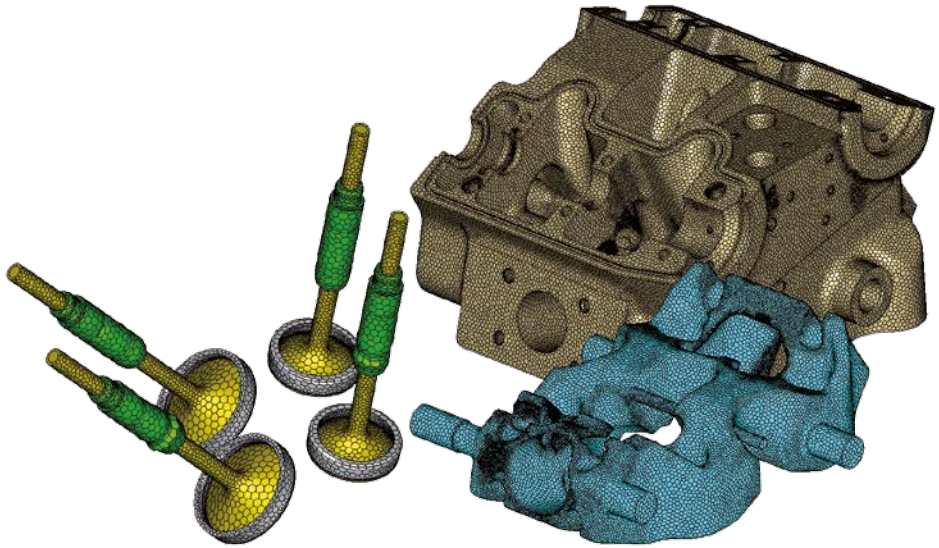
AVL FIRE™ M

TURNING PROBLEMS INTO SUCCESS STORIES

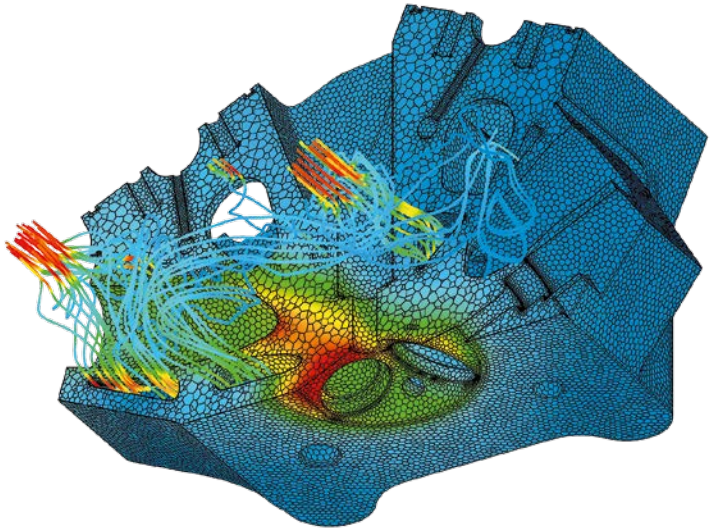
AVL FIRE™ M is a novel solution for generating, executing and analyzing standard CFD models. It offers a comprehensive set of new capabilities for pre-processing, main program and post-processing, and is the first FIRE™ version integrated in the AVL Simulation Desktop – a highly functional Graphical User Interface (GUI) also providing common project and data management for all CAE tools developed at AVL Advanced Simulation Technologies. This enables easy information sharing and supports inter-disciplinary simulation tasks.

AVL FIRE™ M offers automated modeling of arbitrary complex geometries deploying polyhedral cells. Additionally, tools for interactive generation block-structured grids are provided.

Extended solver capabilities allow setting up multi-domain models. This is essential if classical fluid flow problems and heat transfer into adjacent structures need to be solved simultaneously.

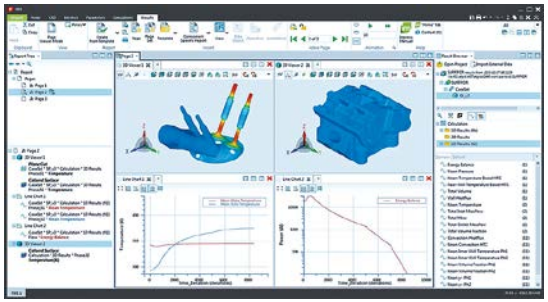


Multiple domains discretized in a single meshing step



Coolant flow through the thermally loaded cylinder head

Highly functional GUI



The easy and fast assignment of material properties to individual domains with the help of the extensive AST Property Database is another highlight of the new AVL FIRE™ version.

Simulation results are assessed in the new AST Post-Processor, supporting interactive and template-based visualization and analysis of two- and three-dimensional calculation data. The post-processor also allows the creation of animations, movies and 3D PDF, allowing engineers to easily recognize and interprete the causes and effects of transient fluid flow phenomena. An in-built report generator creates application-specific documentation.

This results in significantly shorter model turn-around times, helping to investigate more design variants more efficiently in the product development process.

TYPICAL APPLICATIONS

Typical simulations frequently executed by AVL FIRE™ M *standard* to support the development and optimization of powertrain components include:

- Intake and exhaust ports
- Manifolds and lines
- Ventilation and air conditioning equipment
- Internal and external aerodynamics
- Cooling systems
- Turbocharger
- Heat transfer and thermal load of structural parts

CUSTOMER BENEFITS

The software's user-friendliness and the high degree of automation provide easy access to CFD to a large number of people, enabling them to take advantage of a simulation-driven design process.

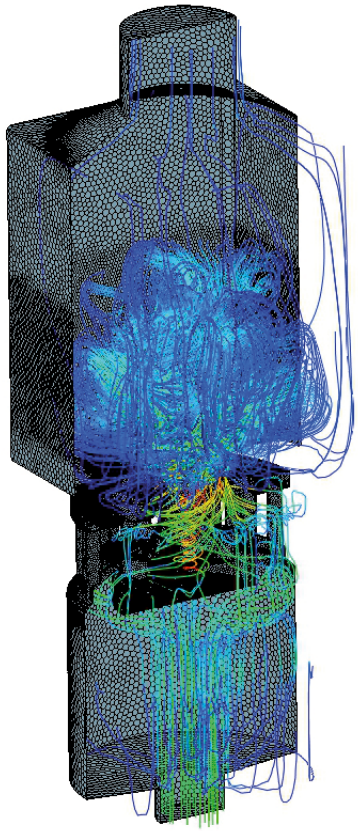
AVL TABKIN™

AVL TABKIN™

MARKET DRIVERS

For internal combustion engines, one of the major market challenges is to optimize engine-out emissions without sacrificing thermal efficiency. Higher predictivity from combustion CFD simulations, at reduced CPU time, will enable the industry to elaborate the best specification of engine soft- and hardware in a shorter time frame. A more detailed description of fuel and emissions chemistry is key to achieve improved CFD predictivity. However, with traditional approaches, the description process leads to a significant increase in CPU time, often exceeding project lead times.

Diesel combustion in the early phase

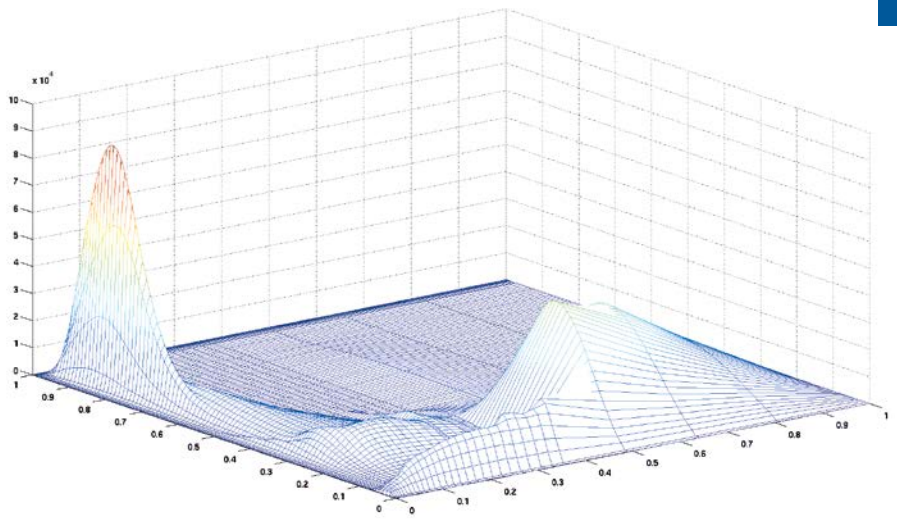


Swirling flow in gas turbine combustor

AVL APPROACH

AVL TABKIN™ pre-calculates combustion chemistry and efficiently maps the results to the flow field computed with CFD. This chemistry tabulation technology allows to include the most detailed fuel chemistry available today directly in CFD simulations, while still meeting engineering project lead times. AVL TABKIN™ is natively coupled to AVL FIRE™. Interfaces to AVL TABKIN™ exist for all common CFD codes.

Sample from AVL TABKIN™ look-up table



AVL TABKIN™ STRENGTHS

AVL TABKIN™ embodies more than a decade of experience with chemistry tabulation technology for combustion applications. The modeling approach has been successfully applied to diesel and gasoline engines. Advanced concepts such as Low Temperature Combustion (LTC) and Premixed Charge Compression Ignition (PCCI), as well as dual-fuel concepts such as Reactivity-Controlled Compression Ignition (RCCI) or diesel-ignited gas, which are all strongly driven by chemical kinetics, are accurately modeled with AVL TABKIN™:

- AVL TABKIN™ substantially reduces the computation time for CFD simulations with detailed reaction schemes.
- AVL TABKIN™ significantly enhances the predictivity of combustion CFD simulations through an improved physical description of the turbulent combustion process and the use of state-of-the art fuel chemistry.

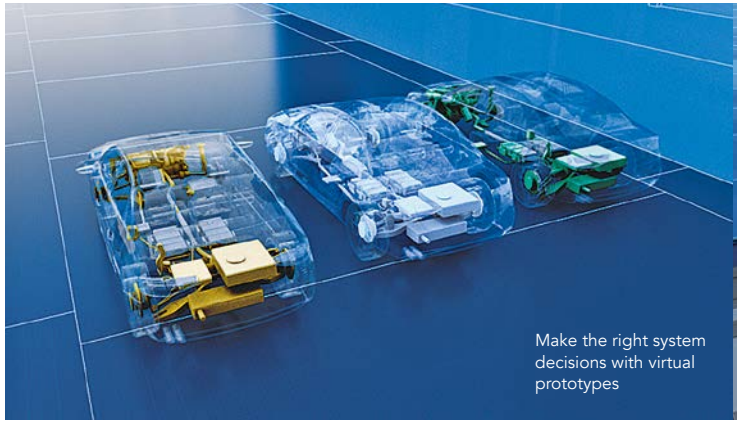
AVL TABKIN™ INTERFACES

AVL TABKIN™ Interfaces link the look-up table generated with TABKIN™ to the CFD code of the user's choice in two different ways:

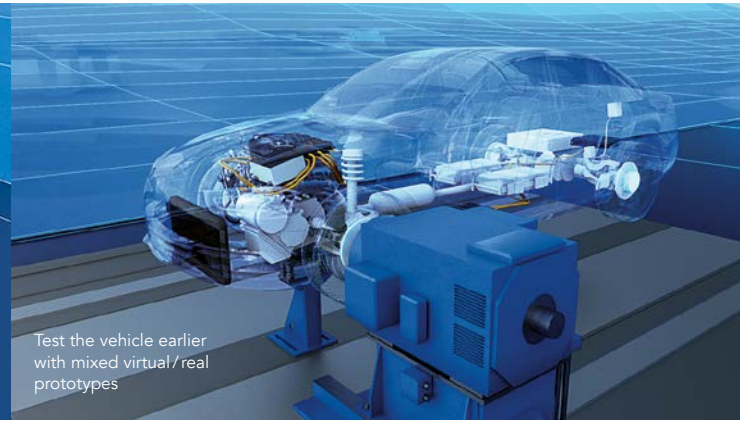
- Through the AVL TABKIN™ FGM combustion model, implemented in the latest AVL FIRE™ release and available through User-Defined Functions (UDFs) for other supported CFD codes.
- By using tabulated chemistry data, generated with AVL TABKIN™, for other combustion models in a native format of the CFD of the user's choice.

CUSTOMER BENEFITS

- Improved speed and predictivity of combustion CFD simulations
- 50 % reduction of cost-per-useful-answer (est.)
- Reduced number of hardware prototypes and shorter time-to-market



Make the right system decisions with virtual prototypes



Test the vehicle earlier with mixed virtual / real prototypes

Model.CONNECT™

Model.CONNECT™

INTEGRATION OF VIRTUAL AND REAL COMPONENTS

WHAT'S THE CHALLENGE?

Early evaluation and validation of the entire system within the vehicle development process is the key to efficiently master the challenge of developing high-tech vehicles.

- Complex mechatronic systems require the interoperability of a large number of components and functions from various domains
- A high number of models, which were developed with specific simulation tools from different tool vendors and which have established themselves in the organization, must be connected
- Simulation and testing will become highly integrated through a model-based development approach

ENRICH YOUR REALITY

Model.CONNECT™, an integration product out of the Integrated and Open Development Platform, allows the implementation of model-based development by closing the gap between virtual and real worlds. This results in increased cost benefits and efficiency across your development process.

Model.CONNECT™ creates vehicle prototypes built with virtual and real components that are well-established in your development landscape. Being available at every vehicle development step, it is suitable for a broad range of powertrain and vehicle applications, e.g. integrated safety, vehicle dynamics, energy management, real driving emissions, advanced driver assistance systems.

Model.CONNECT™ also interconnects all AVL products and solutions.

WHAT'S UNIQUE?

Model.CONNECT™ is AVL's integration platform for setting up and executing system simulation models consisting of subsystem and component models from multiple model-authoring environments. Models can be integrated based on standardized interfaces, such as the Functional Mockup Interface (FMI), or based on specific interfaces with a wide range of well-known simulation tools.

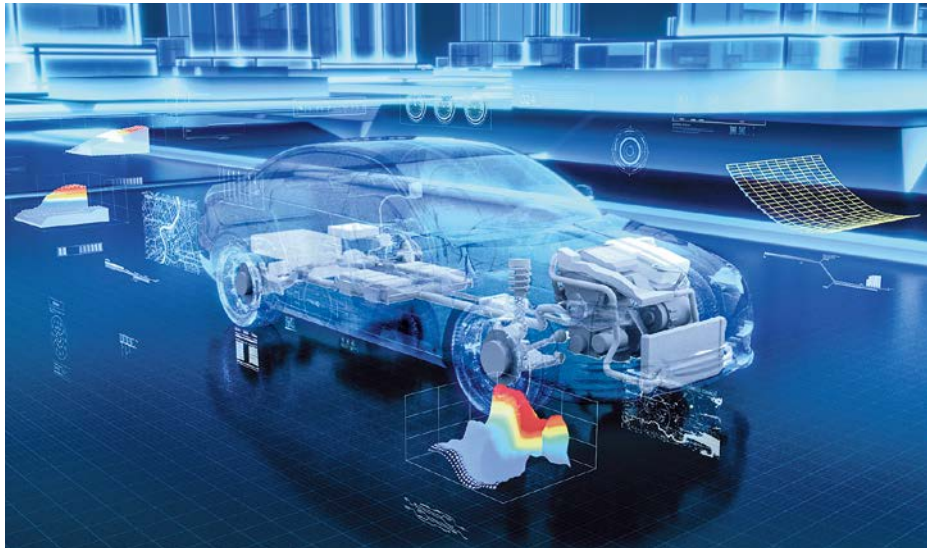
Model.CONNECT™ contains different "execution engines", which handle the complex communication between virtual and real components with highly sophisticated coupling algorithms. These coupling algorithms enable stable and energy-conserving coupling of simulation models and simulation models with and on real-time systems, consistently over the development process.

Furthermore, the user is supported in organizing simulation model variants. These variants may describe different configurations of systems as well as different testing scenarios and testing environments.

Model.CONNECT™ features powerful model parameterization and batch simulation capabilities, online monitoring, result analysis and reporting functionalities. Interfaces to various optimization tools enable design studies and optimizations.

AT A GLANCE

- Industry-leading co-simulation and coupling error compensation algorithms
- Connect on and with real-time systems to local and distributed co-simulation
- Support of more than 25 simulation tools for various domains (e.g. AVL CRUISE, MATLAB, ECS Kuli, Dymola, MSC Adams, LS-DYNA, AMESim, GT Power...)
- Supports Functional Mockup Units compliant with FMI standard 1.0 and 2.0 for co-simulation and model exchange
- Integration of models not supporting FMI
- Suitability for a broad range of powertrain and vehicle applications (e.g. integrated safety, vehicle dynamics, energy management…)
- Proven in customer projects for model integration – in the office, on HiLs and on testbeds



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