

LMS Imagine.Lab AMESim Internal Combustion Engine



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LMS Imagine.Lab Internal Combustion Engine helps users model and design comprehensive engine systems from air management and combustion up to engine control by providing accurate physical engine models and components. LMS Imagine.Lab Internal Combustion Engine has been developed in close collaboration with IFP. As a result, it offers a cutting-edge, flexible environment for designing and optimizing “virtual” engine and automotive subsystem concepts. Users have the ability to study couplings with fuel injection subsystems, vehicle thermal management, powertrain and any other components, and can adapt model definitions to a wide range of usage scenarios. Impact analyses of advanced technology choices can now be processed and analyzed on the spot.



- Engine Control
- Air Path Management
- Combustion
- Hybrid Vehicle
- Emissions

References

- Siemens VDO** - Gasoline engine ECU validation on HiL
- IFP** - Observer design for downsized gasoline engine control
- Delphi Diesel Systems** - Diesel engine ECU validation on HiL
- Toyota** - Test of new warm-up strategies for fuel consumption reduction
- Renault** - Development of VVA control strategies
- Fiat Powertrain Technologies** - New combustion concepts to satisfy future emission legislation

LMS Imagine.Lab Engine Control

LMS Imagine.Lab Engine Control is a complete and integrated solution to design and set up robust engine controls. From design to validation, it provides a relevant toolset to manage the growing complexity of engine control strategies and drive assistance technologies directly linked to the engine (speed regulation, gearbox). LMS Imagine.Lab Engine Control goes further than the classical “automatic” control approach, and provides a unique methodology for control design. The solution is mainly based on a strong modeling competence and a thorough understanding of the system physics.

OEMs and suppliers, engine manufacturers, engine control designers and testers (HiL test-benches) will be able to use state-of-the-art engine models, suitable for every stage from design to validation, as well as in real time. By using LMS Imagine.Lab AMESim throughout the development process, project engineers can implement and capitalize on their own modeling know-how, and share models to gain time and efficiency. Model accuracy and real-time analysis are no longer incompatible.

LMS Imagine.Lab Engine Control comes with a set of cutting-edge components:

- The LMS Imagine.Lab AMESim core platform
- Control-specific interfaces (Simulink and Real-Time)
- Links with market reference software : Simulink (Mathworks), Morphee2 (D2T), LabView RT (NI)
- Standard and specific libraries and components/models
- Analysis tools and methodologies for model reduction

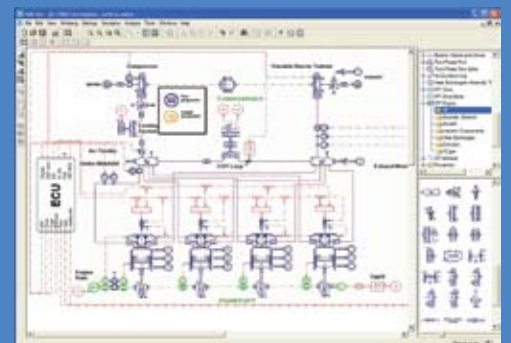
For more specific usage, detailed models of engine subsystems are available (injection, air loop, driveline, thermal, electrical actuators and motors) as well as analysis tools to study the combustion process in real time.

Implementing LMS Imagine.Lab Engine Control helps engineers reduce time to market (gain in efficiency) and design/validation costs (mainly reduce testing needs) while improving quality and robustness (better physical understanding, increase validation capacity). It offers unrivalled model-based, multi-domain system simulation within a single simulation platform, both in the design and validation process (Hardware-in-the-Loop and Software-in-the-Loop).

LMS Imagine.Lab Engine Control has been developed in close collaboration with IFP, ensuring delivery of cutting-edge, innovative and robust solutions.



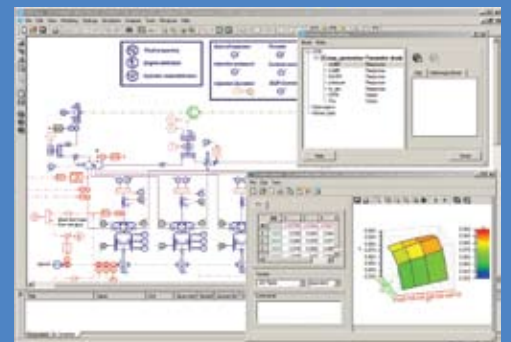
LMS Imagine.Lab Engine Control is a complete and integrated solution to design and set up robust engine controls.



The co-simulation between LMS Imagine.Lab AMESim and Simulink is used to design engine control strategies with the help of an engine-to-pilot model.



A complete vehicle model including a mean value engine model as the core of an engine HiL test bench.



A methodology has been set up to simplify high fidelity models into a mean value engine model, using the DOE tool embedded within LMS Imagine.Lab AMESim.

Features

- Engine models running offline/online (real time)
- A chain of models with associated methodology, suitable for every stage of the design process
- Non-linear engine models based on physics (including phenomenological combustion models)
- Several model levels available for most components (to find the best compromise between detailed description and CPU time)
- Engine model can be linked to other AMESim model libraries (cooling system, transmission) to obtain a comprehensive model
- Compatibility with major hardware manufacturers for real-time simulation (Mathworks, NI, D2T...)

Benefits

- Process more virtual adjustments and tuning
- Improve test quality and perform in-depth control validation thanks to more accurate and faster models
- Develop more sophisticated and easy to calibrate control strategies
- Take advantage of a single environment for engine and control design/validation
- Gain in efficiency with easy-to-share models
- Quickly adapt to new projects with easy-to-modify models
- Reduce need for testing on account of real-time combustion models based on geometrical parameters, improved test specification and better insight
- Comprehensive engine actuators modeling

LMS Imagine.Lab Air Path Management

LMS Imagine.Lab Air Path Management helps users to design all kinds of air path architectures - including exhaust systems - for any kind of technical choice. The solution provides a quick analysis of the impact of selected technical architectures (variable valve timing, turbo charging, exhaust gas recirculation, diesel particle filter). It accurately manages the air mass and burned gas ratio in the combustion chamber.

Engine technology focuses on how to maintain performance while reducing both emissions and fuel consumption. The main concern for cutting-edge engine design relates to NOx and CO2 emissions. Some of the major challenges that engineers are faced with today are accurately analyzing combustion by mastering injection and in-cylinder gas composition as well as managing optimized downsizing associated with turbo charging.

LMS Imagine.Lab Air Path Management is based on the AMESim multi-domain system simulation approach and on a set of libraries and component models, which provide the necessary tools to design advanced air path management strategies: mechanical, IFP-engine and thermal libraries, powerful analysis tools, turbo map pre-processing, linear analysis, Simulink interface, generic co-simulation to allow coupling with CFD tools.

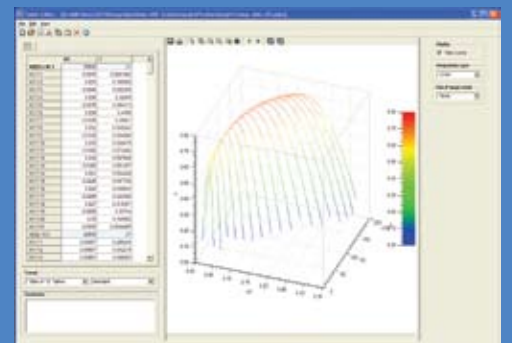
LMS Imagine.Lab Air Path Management helps to design all kinds of configurations and provides detailed modeling of air path actuators like valves, VVT, and VVA. Moreover, with the phenomenological combustion model the impact on torque, emissions and consumption can be analyzed. Furthermore, the interaction between air path and other engine subsystems can be detailed and examined.

With LMS Imagine.Lab Air Path Management, engineers can efficiently test new technologies and designs, and take advantage of a balanced compromise between required simulation accuracy and calculation times. Finally, LMS Imagine.Lab Air Path Management directly evaluates the system's behavior and helps to define associated control strategies when coupled to the LMS Imagine.Lab Engine Control solution. Engineers can focus on real issues rather than on the development and maintenance of engine models. The solution's flexibility and modularity makes it possible to implement and integrate the latest technological innovations.

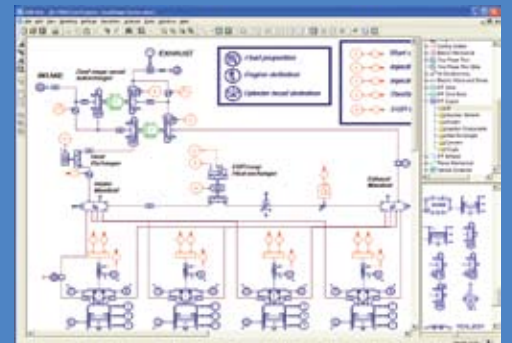
LMS Imagine.Lab Air Path Management has been developed in close collaboration with IFP, ensuring the delivery of cutting-edge, innovative solutions.



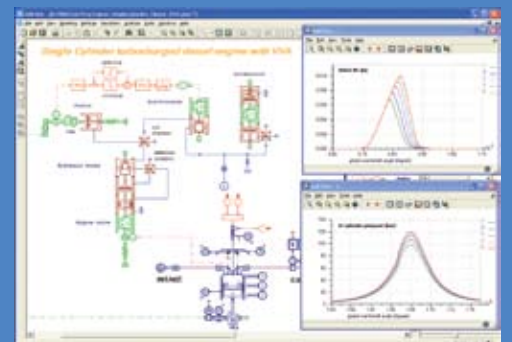
LMS Imagine.Lab Air Path Management provides a quick analysis of the impact of technical architecture such as VVA systems.



Users can obtain a graphical representation of the interpolations results with AMETable.



The modular approach of AMESim makes it possible to design all kinds of air paths like dual-stage turbochargers.



Detailed modeling of a Variable Valve Actuation system coupled with a single cylinder diesel engine.

Features

- Physical combustion models for compression ignition and spark ignition applications coming from 3D
- Modular & multi-domain approach to model all kinds of configurations (system approach)
- Detailed modeling of air path actuators and sensors (valves, VVT, VVA)
- Phenomenological combustion model to analyze impact on torque and emissions
- Steady-state and transient operations
- Several levels of detail depending on the simulation constraints
- Interface with Simulink for actuator/system control design

Benefits

- Efficiently test new technologies and designs
- Access a balanced compromise between required simulation accuracy and calculation times
- Improve data and model exchanges (collaborative work)
- Optimize the design at the system level taking into account interactions with thermal aspects, combustion and exhaust
- Predict the impact of the air path strategy on performance, noise, emissions and residual gas
- Directly evaluate associated control strategies

LMS Imagine.Lab Combustion

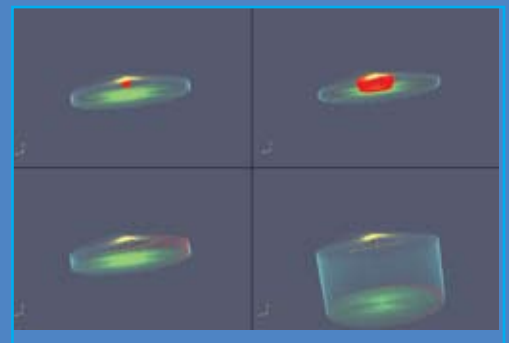
LMS Imagine.Lab Combustion supports the design and the optimization of new combustion processes and adaptation of engines to alternative fuels. It helps users to optimize the cylinder geometry (piston shape, head, location of injectors, plug), to optimize engine parameters (such as advance, turbulence: swirl/tumble/squish, lambda control or injection split...) for different fuel types, and study advanced combustion processes including HCCI and CAI. Combustion processes get increasingly complex in order to comply with conflicting demands. More stringent emission standards have to be met while customers desire higher engine response and lower noise levels. Engine designers are therefore looking for interesting alternatives beyond the continuously evolving conventional gasoline Spark Ignition (SI) and diesel Compression Ignition (CI) combustions.

LMS Imagine.Lab Combustion provides an efficient way to investigate the transient engine behavior by using an unparalleled numerical multi-domain system simulation approach. The IFP-Engine library provides dedicated components for combustion simulations and can be seamlessly coupled with 3D combustion codes and models (like IFP-C3D).

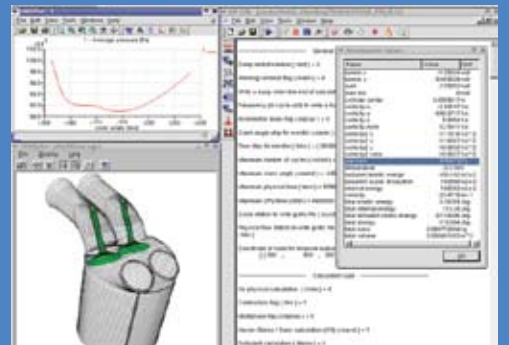
LMS Imagine.Lab Combustion provides the ideal toolset to analyze the dynamic behavior of any combustion process, and enables flawless 3D calculation integration in a system approach. Dedicated libraries come with state-of-the-art 1D and 3D models suitable for various applications from large diesel to high-rev gasoline engines.



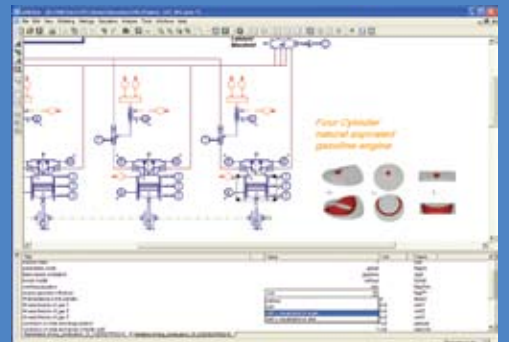
LMS Imagine.Lab Combustion supports the design and the optimization of new combustion processes and adaptation of engines to alternative fuels.



1D combustion models in LMS Imagine.Lab AMESim taking into account geometry allow 3D visualization within Paraview.



IFP-C3D is embedded in the LMS Imagine.Lab AMESim environment as the 3D tool dedicated to CFD Engine calculations.



IFP-Engine proposes advanced combustion models derived from 3D combustion models, like Coherent Flame Model for spark ignition engines.

Features

- Straightforward 3D calculation integration in a system approach
- State-of-the-art 3D and 1D models suitable for various applications from large diesel to high-rev gasoline engines
- State-of-the-art empirical models (Wiebe law) with automated fitting tool

Benefits

- Accurately predict boundary conditions for 3D calculations using 1D models
- Combine good prediction of combustion heat release in 1D by integrating models and methodologies developed for 3D approaches

LMS Imagine.Lab Hybrid Vehicle

With LMS Imagine.Lab Hybrid Vehicle, engineers can define, analyze and validate power management, electric systems and engine sizing/architecture for hybrid powertrain systems. It helps to define and specify the best powertrain architecture, taking vehicle thermal and power management into account.

The requirements regarding driving and comfort have become as stringent as fuel consumption and vehicle emission regulations. Hybridization is one of most effective measures to reach challenging emission and fuel consumption targets.

LMS Imagine.Lab Hybrid Vehicle is based on the AMESim multi-domain system simulation approach and provides dedicated tools that help to model and design hybrid engine architectures. With the AMESim models, a conventional propulsion system with an on-board rechargeable energy storage system can be designed through a set of specific multi-domain libraries (IFP-Drive, IFP-Engine, Electric Motors and Drives, Powertrain) and, subsequently, the behavior of the entire system and its individual components can be studied. The AMESim platform also takes into account control systems thanks to advanced real-time interfaces with most commonly used real-time targets.

Features

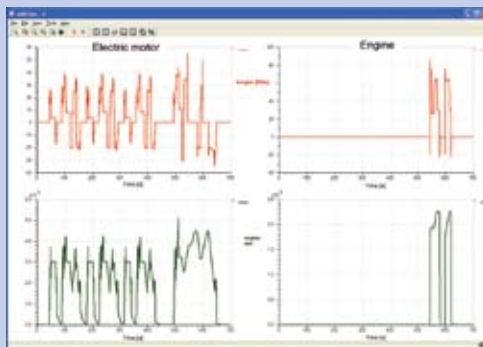
- All necessary components to model hybrid vehicles
- Possibility to detail any subsystem
- Several possibilities for the control design
 - Interface with Simulink (Mathworks)
 - Link with Morphee2 (D2T)
 - Link with LabView RT (NI)
- AMESet to modify existing submodels and/or create specific ones

Benefits

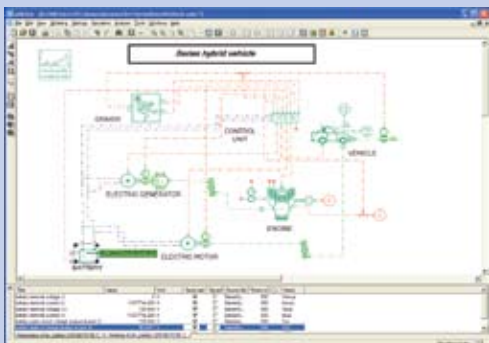
- Easily link powertrain subsystems
- Rapidly size hybrid powertrain architectures
- Study their effects on performance, emissions and fuel consumption



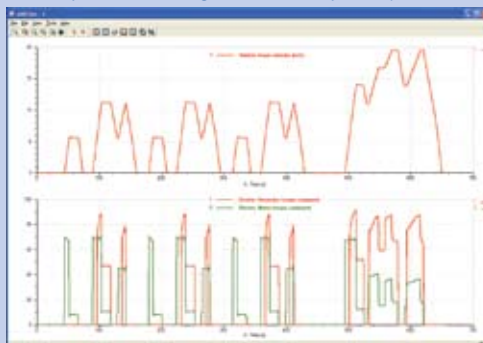
Engineers can analyze and validate the power management of hybrid powertrain systems.



Results of a parallel hybrid vehicle model show that the internal combustion engine is used only in the final part of the cycle, when a higher car velocity is required.



Example of a hybrid vehicle series including the modeling of the battery.



Electrical motor and generator operating all along the vehicle cycle.

LMS Imagine.Lab Emissions

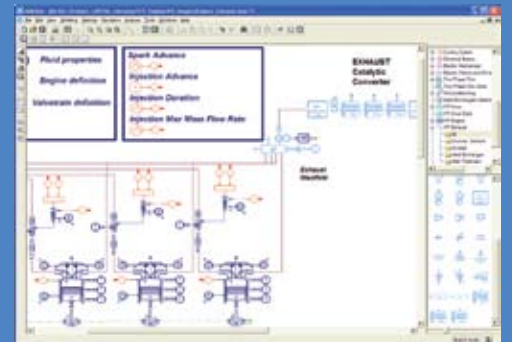
LMS Imagine.Lab Emissions focuses on overall engine optimization according to required emission standards. The ready-to-use models enable users to test engine configurations including the after-treatment components and control strategies, and consequently investigate strategies for emission reduction. LMS Imagine.Lab Emissions assists in meeting the most stringent emission standards (Euro IV and V, TierII) and helps accurately model and analyze NOx, CO, CO₂, particles emission levels depending on technological choices.

LMS Imagine.Lab Emissions is based on the AMESim multi-domain system simulation approach and comes with a set of advanced tools and libraries for modeling the engine architecture and its environment (injection system, exhaust, combustion chamber, cooling system). The IFP-Drive, IFP-Engine, IFP-Exhaust, Thermal, Cooling System libraries can model the whole engine system and easily couple multiple physical domains to accurately study interactions and cross-influences.

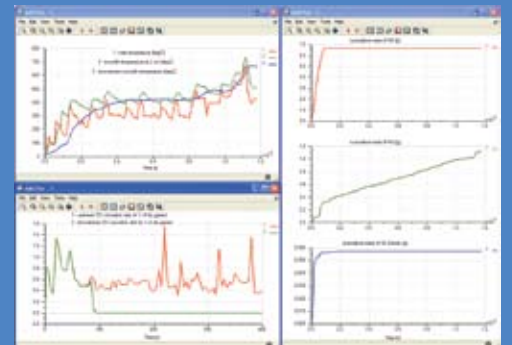
LMS Imagine.Lab Emissions is especially useful for engineers in charge of engine or exhaust development and calibration. It offers new opportunities in terms of system optimization and focuses on the possibility to couple the engine and exhaust system. It is strongly linked to other engine solutions, such as air path management, combustion, injection, control and thermal management. It helps to investigate the effect of engine design parameters and control strategies on the engine-out emissions taking into account the running conditions, the combustion process itself as well as the influence on the exhaust process and the tailpipe emissions. LMS Imagine.Lab Emissions presents a new method to explore and optimize engine emissions during cold start with engine warm-up and catalytic converter light-off.



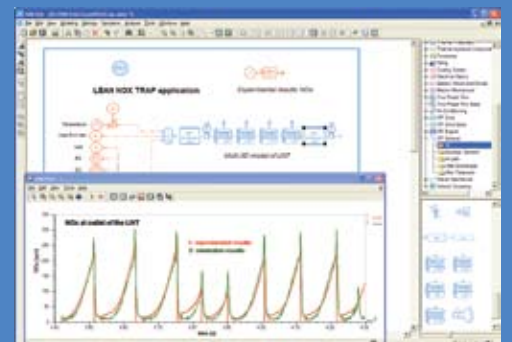
LMS Imagine.Lab Emissions facilitates global engine optimization according to required emission standards.



Model of an internal combustion engine with exhaust line, showing exhaust generation and pollutant post-treatment.



The previous model simulates the light-off and conversion efficiency of a 3-way catalytic converter.



LMS Imagine.Lab Emissions accurately predicts the NOx storage and release into a Lean NOx Trap.

Features

- Dedicated ready-to-use libraries for modeling pollutant formation in the combustion chamber, the exhaust system and the associated controls
- A direct coupling between the combustion process with engine-out emissions/injection/air path/engine thermal management/pollutant after-treatment
- Several levels of coupling available

Benefits

- Complete analysis of system cross-influences in a single platform
- Possibility to run steady-state and transient analysis
- Accurate description of engine warm-up and catalytic converter light-off



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