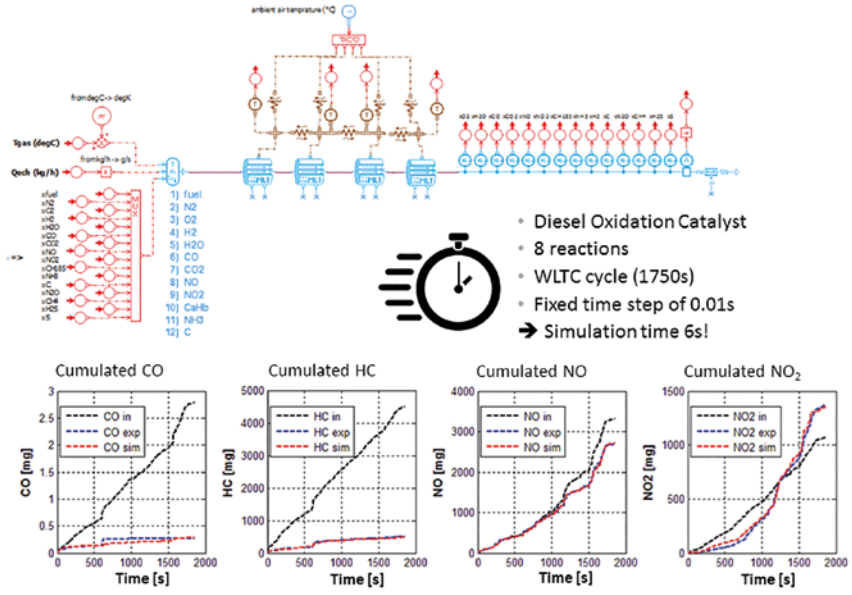
Optimizing After-Treatment Systems Performance.

Using a model-based system design approach to support the engineering of exhaust systems in an RDE context



The growing adoption of new regulations for the vehicle tail-pipe emissions has caused significant changes in the product development cycle of automotive OEMs. Rules have changed quite radically within a short timeframe, shifting from regular but smooth evolution of the emissions legal constraints we used to have year after year. The application of Real Driving Emissions (RDE) strongly impacts the way manufacturers engineer vehicles, and this also affects suppliers who can promote new features, tools and methodologies.

The new RDE regulations – whose objective is to evaluate vehicles in real life conditions – generated a more critical need to access efficient modeling and simulation tools supporting the analysis of vehicle emissions at any stage of the design cycle. System simulation used to be only deployed for R&D activities and (pre)design purpose. The new regulation context raises additional requirements, and emphasizes the need to work not only on sub-systems, but also to assess the performance of the system as a whole - i.e. to study the pollutant emissions conversion efficiency at vehicle level, with realistic mission profiles.

When working on the concept phase, engineering departments have a large number of technical options available, and need to make the appropriate decisions when it comes to selecting technologies combined within the optimal architectures. This requires fast simulations to quickly assess the potential of after-treatment devices in their vehicles architectures and variants, always trying to cover the wide range of driving cycles and conditions.

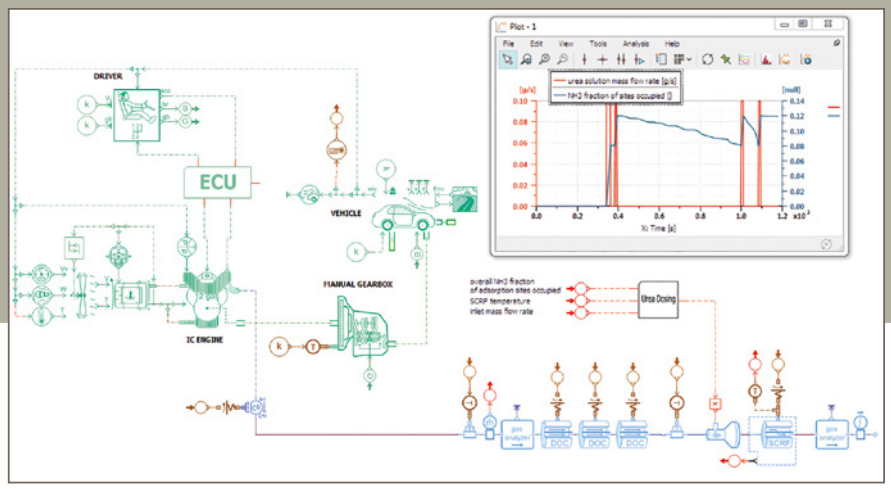
During the design stage, a special focus on the after-treatment control strategies is required, in parallel to hardware detailed analysis at component level. As the exhaust system integrates more and more sensors, actuators and connections with the ECU, plant models are necessary for the development and validation of control strategies using Hardware in the Loop (HiL) environments - which requires models running with fixed step solvers on real time hardware.

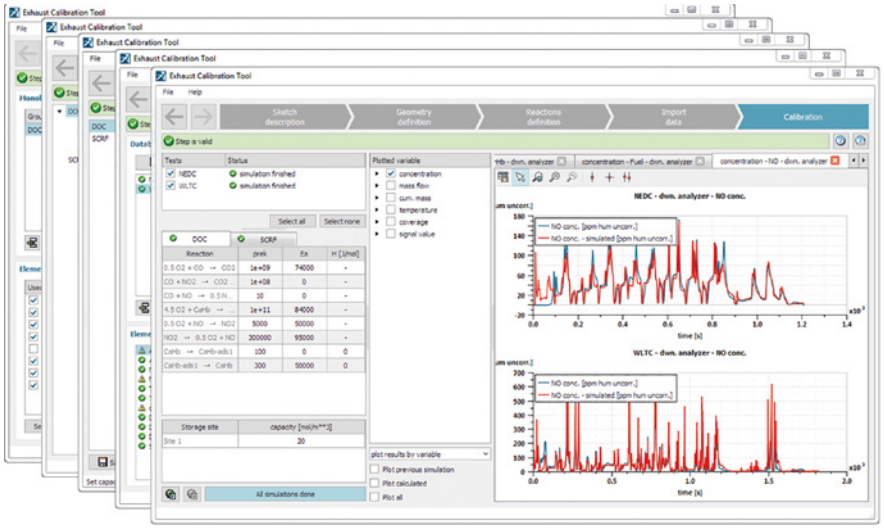
In the later phases of the V-cycle, control calibration tasks are also impacted by the RDE regulations. The calibration tests must migrate from engine dyno and in-vehicle to virtual environments using simulation tools, and cover the new complexity coming with the exploding number of systems and the variety of cycles to be addressed. The change from a calibration workflow based on the optimization of a few engine operation points to a calibration robust enough to tackle real life scenario - i.e. any kind of operation - strongly affects the process with a leap forward in complexity.

Simcenter Amesim™ software answers this growing demand for system simulation involved with the RDE standards requirements.

The after-treatment device (monolith and/or filter) is modeled using a 0D flow approach and thermal components. They can be easily combined to represent a full 1D channel model, to simulate the gradient of temperature along the monolith. This is definitely a “must have” for a fine prediction of the chemistry and the regeneration of filters in particular.

Whereas energy and mass balance equations are used to compute the thermodynamic state of the gas and





wall, a Langmuir-Hinshelwood formalism is used to represent the reaction rate expressions.

Practically, users benefit from multi-level models embedding various physical content, and can enable or disable any sub-models or reaction paths to adapt the model to the physics of their application, including the full details and complexity for an accurate prediction of the reaction mechanism or simplifying the model content for an optimized CPU performance.

As an example, users can activate and model adsorption and desorption phenomena using one or several storage sites. A diffusion model can be added to get more precise results for high flow regimes.

After designing all the after-treatment component models to work with both variable and fixed time step solvers, it is easy to integrate the model later in the design process in real-time targets and drastically reduces simulation times when the step size is increased.

More concretely, common after-treatment modeling approaches find their limits with short fixed steps because of the high dynamics of the reactions to be represented. To answer this issue, we have implemented an advanced reaction rate saturation algorithm in Simcenter Amesim, which guarantees a robust simulation whatever the step size, and ensures a physical consistency to get accurate results. On the other hand, the physical content of the model preserves the consistency of the results and the capability to predict the system performance on extrapolated conditions and driving cycles.

In extreme cases, using a fixed time step solvers of 0.1s, we can execute the simulation of an exhaust after-treatment device over a complete driving cycle in seconds, making it possible to simulate thousands of cycles in a couple of hours.

As a result, Simcenter Amesim enables the engineer to cover the complete V-cycle and can be combined with 3D CAE software for detailed design of catalytic converters. Thanks to a broad range of components offering several modeling options and computational performance, engineers are empowered with a tool providing the right level of model for their application. In addition to its modeling capabilities, Simcenter Amesim also provides tools and methodologies to optimize parameter calibration, reducing the gap toward the adoption of simulation software for after-treatment analysis.

A step-by-step process supports engineers in the definition of their simulation project, thanks to an application-oriented GUI that enables an easy set-up of the monolith or filter geometry and the reaction scheme details, for the loading and pre-processing of the available test data and as a last step for the handling of the tuning parameters. This comprehensive, integrated workflow significantly reduces the effort required for the tuning of the model, and saves incomparable amount of time for the users to focus on their engineering discipline. Those reduced simulation times also allow for the creation of optimization algorithms to automate the definition of chemical scheme parameters. ■