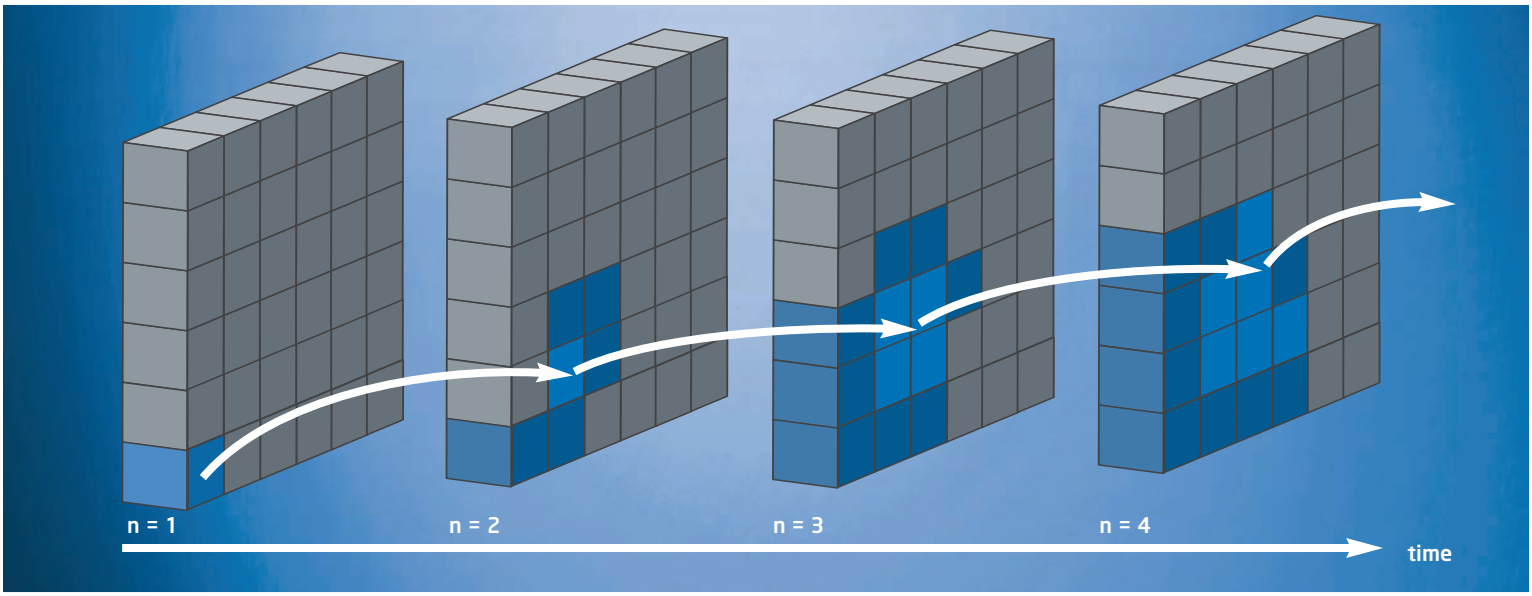
Dynamic Engine Modeling and Optimization

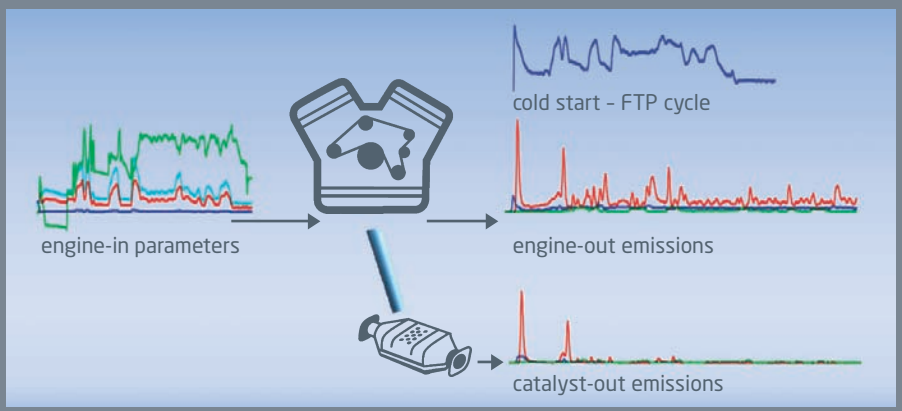
Model-Based Calibration and Algorithm Development



Meeting Future Requirements

The growing number of engine parameters necessitates the use of model-based approaches for calibrating and optimizing today's combustion engines. This is why steady-state design of experiment (DoE) methods are widely used for calibrating and optimizing engine responses, such as emissions, noise and fuel flow.

Recent advances in research and development have produced highly sophisticated methods that also take account of dynamic engine operation phases known to be a major cause of increasing fuel consumption and pollutant emissions. Tighter legislation and cost pressure are demanding the application of these intelligent modeling and optimization techniques as well as their rapid introduction into the production process.



Determination of optimum engine-in parameters for minimizing tailpipe emissions

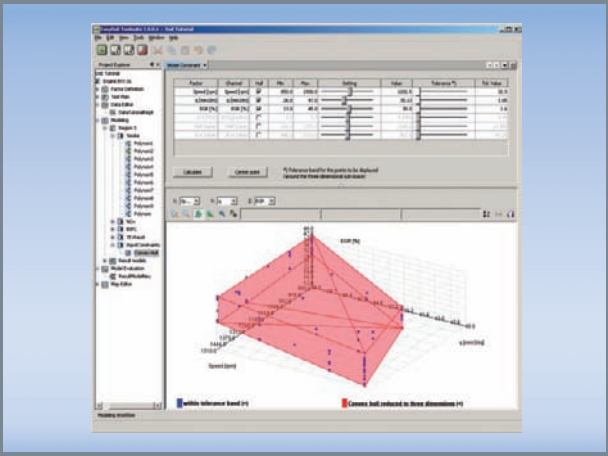
Above: engine multistate-time diagram with optimum path

IAV Modeling and Optimization Tools

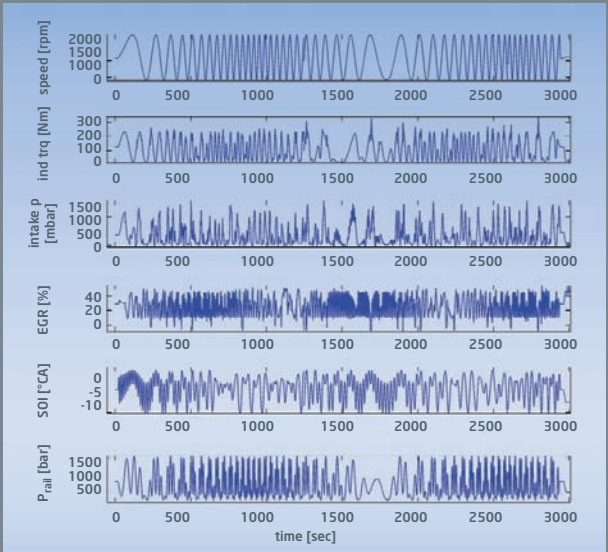
IAV provides a complete tool chain for steady-state and fully dynamic engine modeling and optimization. These tools have been applied successfully for

- *rapid measurement,*
- *modeling emission and optimizing cold-start and driving cycles,*
- *modeling and optimizing fuel consumption,*
- *protecting components and*
- *virtual engine simulation.*

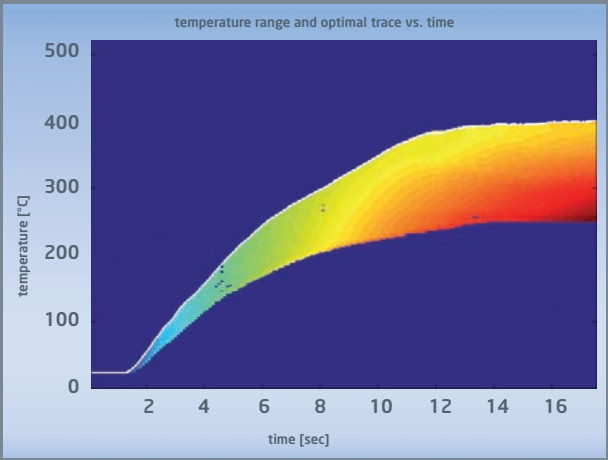
IAV gives customers support in integrating these tools into their process chain, provides documentation and training, and offers assistance in developing new fields of application.



Screenshot of EasyDoE Toolsuite



Dynamic engine excitation



Evolution of temperature and related emissions after cold start

Steady-State Optimization

Modern DoE tools, such as IAV's EasyDoE Toolsuite, help engineers to cope with the growing requirements in the field of engine calibration. The user interface is workflow-based and supports all the necessary steps in the DoE process:

- Test Design
- Modeling
- Optimization

Users can easily fit models from measured data and compare the different modeling approaches. The Toolsuite makes model fitting so easy that even less experienced engineers can create models quickly. Model responses are visualized and smooth engine maps can be generated for integration into control units.

Dynamic Engine Modeling

The simulation of transient engine behavior is based on nonlinear dynamic models. IAV provides methods to create data-driven models, such as

- Volterra Series,
- Neural Networks and
- Probabilistic Models

from measured data. To guarantee high model quality while keeping measurement costs as low as possible, IAV determines engine operation boundaries and generates multi-input chirp or APRBS (amplitude-modulated pseudo random binary sequence) test sequences. These fully dynamic experimental designs take into consideration

- amplitude distribution,
- frequency distribution,
- engine operating boundaries and maximum gradients.

IAV also offers services to accompany measurements, signal processing and data validation.

Dynamic Engine Optimization

Engine optimization based on dynamic models needs to consider the impact of current engine parameter values on future engine responses. Such dependencies can demand large processing horizons that involve an unacceptably high level of computational load.

IAV provides methods for overcoming this computational complexity, making optimization possible within a short time. IAV's techniques are based on well-established methods, such as Dynamic Programming, Particle Swarm Optimization and Evolutionary Algorithms. As a result, IAV's tools calculate optimum parameter time traces for engine operation – also in combination with a catalytic converter simulation. These time traces, for example, can be used for deriving new control strategies or for improving fuel consumption and emissions.

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