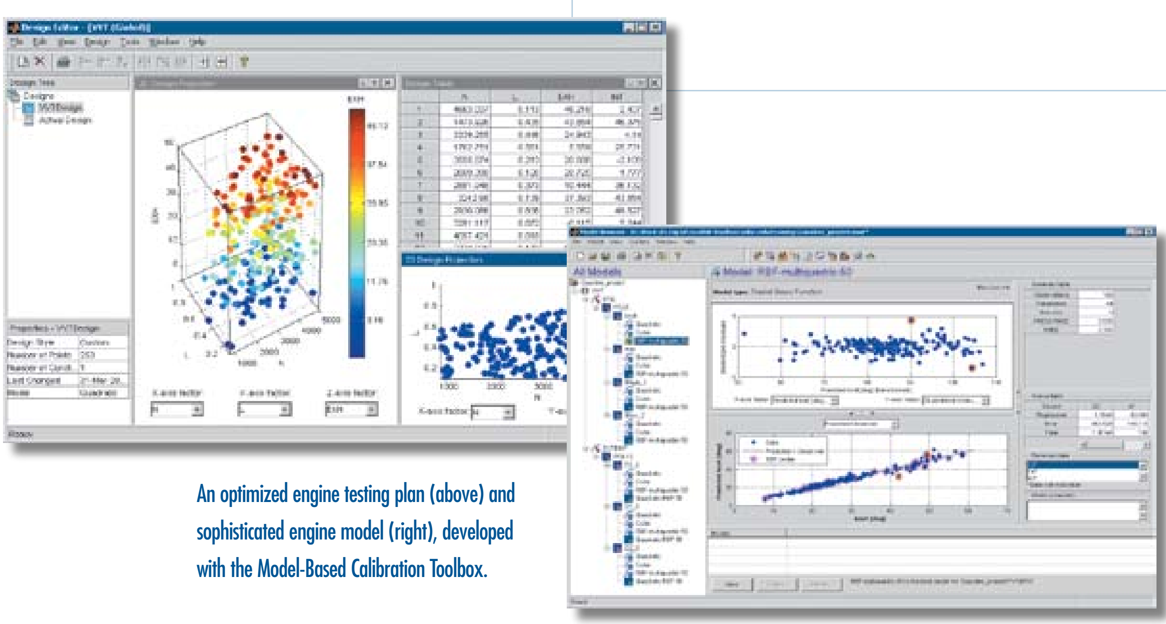
Model-Based Calibration Toolbox 3

Calibrate complex powertrain systems

The Model-Based Calibration Toolbox provides design tools for calibrating powertrain systems. The toolbox is built on the high-performance technical computing environment of MATLAB® and the modeling capabilities of Simulink®. The Model-Based Calibration Toolbox enables the development of optimized calibrations for complex high-degree-of-freedom engines that are difficult to calibrate using traditional methods. Using the toolbox, you can develop a process for systematically generating calibrations that find an optimal balance of engine performance, emissions, and fuel economy .

KEY FEATURES

- Classical, space-filling, and optimal designs, based on Design of Experiments methodology, for creating optimized test plans
- Techniques for developing high-fidelity, nonlinear statistical engine models from test data
- Linear regression and radial basis function modeling techniques for performing accurate fits to your data
- Built-in and user-definable libraries of empirical model forms
- Boundary modeling for keeping optimization results within the engine operating envelope
- Table manipulation, optimization, and trade-off tools for calibration problems
- Tools to fill lookup tables from models, optimization results, or test data
- Calibration import/export links to ETAS INCA and ATI Vision



An optimized engine testing plan (above) and sophisticated engine model (right), developed with the Model-Based Calibration Toolbox.

Working with the Model-Based Calibration Toolbox

The Model-Based Calibration Toolbox supports the three key steps of powertrain calibration:

- Designing an efficient test
- Processing data and producing engine response models
- Performing the calibration

Designing the Test

The Model-Based Calibration Toolbox enables you to design a test plan based on Design of Experiments, a methodology that saves test time by letting you perform only those tests that are needed to determine the shape of your engine response.

The toolbox offers a full range of proven experimental designs, including:

- Classical: Box-Behnken, Central-Composite, and Full Factorial
- Space-filling: Latin Hypercube and Lattice
- Optimal: V, D, and A optimality criteria

You can use the experimental design to define the test points to be run in an engine dynamometer. You can then bring the test data into the Model-Based Calibration Toolbox to develop engine models.

Managing Designs

The Design Editor in the Model-Based Calibration Toolbox lets you generate, augment, and visually compare designs without needing to know the detailed mathematics of Design of Experiments.

Fitting the Model

The Model-Based Calibration Toolbox draws on MATLAB functions for data analysis and visualization, statistics, and optimization to fit the models and generate a graphical representation of the engine's behavior. The toolbox helps you ensure that test points taken in the laboratory match the original experimental design. Using the Model Browser Tool you can then interactively fit different model types to the collected data.

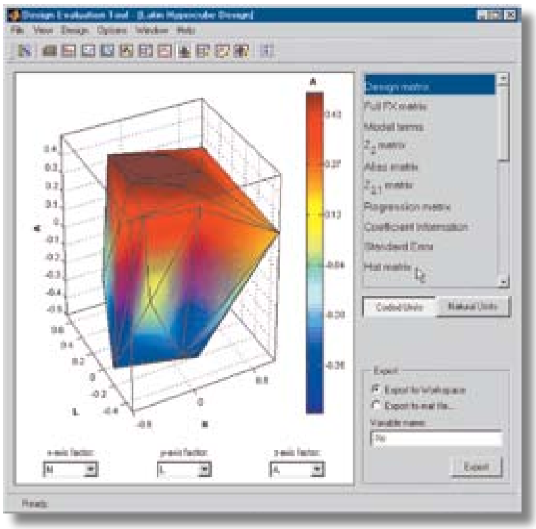
Selecting Models for Engines

The Model-Based Calibration Toolbox includes a library of empirical model types for modeling engine behavior, including torque, fuel consumption, and emissions. Available models include polynomials, splines, radial basis functions, growth models, user-defined M-files, and Simulink models.

Modeling Multiple Variables

Collecting engine data often involves sweeping a single control variable while holding other variables constant—for example, sweeping spark at a given engine speed, load, and air/fuel ratio. This approach introduces two sources of variation: local (variation within tests when the spark angle is changed), and global (variation between tests when the engine speed, load, and air/fuel ratio are changed).

The Model-Based Calibration Toolbox lets you estimate local and global variations separately by fitting local and global models in two stages. You can use two-stage modeling to map the complex relationships among all the variables that control the behavior of the engine.



Investigation of the properties of designs using the Design Evaluation Tool.

Calibrating the Powertrain

The CAGE (CAlibration GEneration) tool in the Model-Based Calibration Toolbox is a graphical user interface that lets you calibrate lookup tables for your electronic control unit (ECU). With CAGE, you can fill and optimize lookup tables in ECU software using Model Browser models.

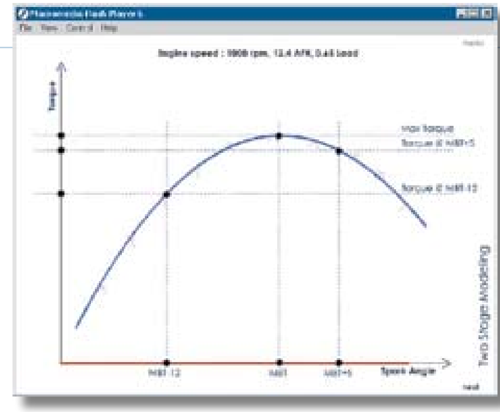
Calibrating Control Features

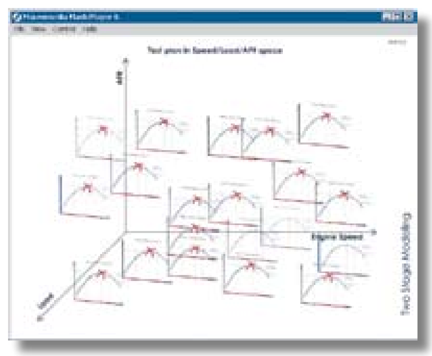
CAGE lets you generate optimal calibrations for lookup tables that control engine functions, such as spark ignition, fuel injection, and inlet and exhaust valve timing. Calibration of these features typically involves trade-offs between engine performance, economy, reliability and emissions. With CAGE you can:

- Make trade-offs between competing design objectives
- Deal with multiple constraints
- Perform weighted optimizations based on typical drive cycles
- Use built-in or custom optimization routines
- Manipulate table values with custom functions
- Export calibrations to ETAS INCA and ATI Vision

CAGE also lets you perform multiobjective optimizations, which are useful for illustrating trade-off possibilities.

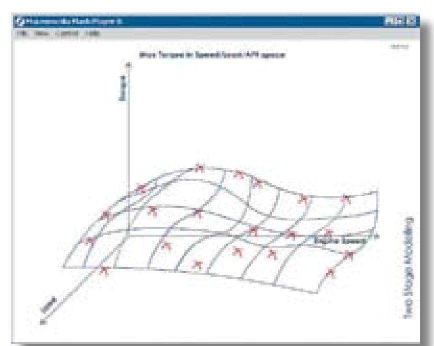
Engine data is collected for each test by sweeping spark while keeping speed, load, and air/fuel ratio constant.

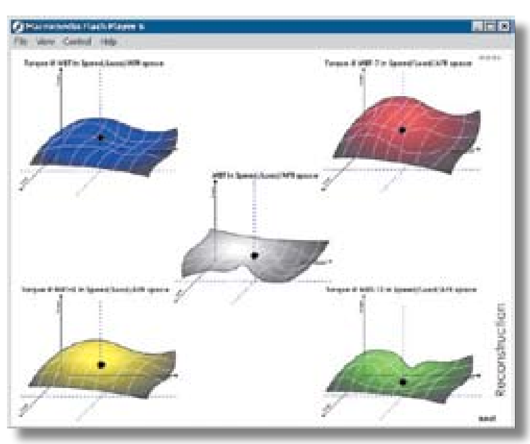




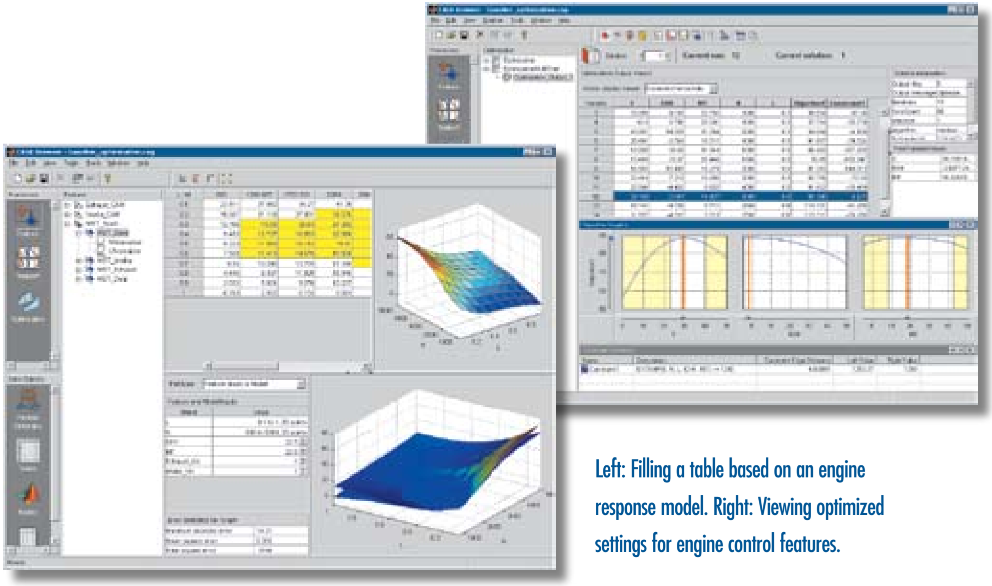
A series of these tests is conducted, each at a different value of speed, load, and air/fuel ratio. A model is then fitted to each test (local fitting).

The local models are used to calculate global models of the engine's behavior as speed and load vary (global fitting).





Global fitting is performed for several different aspects of engine behavior. (Images courtesy of Ford Motor Company).



Left: Filling a table based on an engine response model. Right: Viewing optimized settings for engine control features.

Calibrating Estimator Features

ECU software often includes features for estimating states that are too difficult or costly to measure in production vehicles, such as torque and borderline spark. Using CAGE, you can describe estimator features graphically using Simulink block diagrams, fill the lookup tables for these features, and then compare the estimators to empirical engine models made from measured engine data. CAGE lets you:

- Generate optimal calibrations directly from empirical engine models
- Compare calibrations to test data
- Export calibrations to ETAS INCA and ATI Vision

Required Products

MATLAB®
Simulink®
Extended Symbolic Math Toolbox
Optimization Toolbox
Statistics Toolbox

Related Products

Neural Network Toolbox. Design and simulate neural networks

For more information on related products, *visit www.mathworks.com/products/mbc*

Platform and System Requirements

For platform and system requirements, visit *www.mathworks.com/products/mbc* ■

For demos, application examples, tutorials, user stories, and pricing:

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