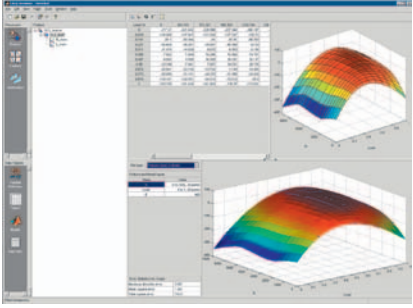


Ford Motor Company Accelerates the Calibration of Onboard Engine Diagnostics with MathWorks Tools

European onboard diagnostics (EOBD) systems monitor and store emission information from a number of sensors and actuators throughout a vehicle and compare results with predetermined fault thresholds. The systems must operate accurately in a variety of climatic conditions and throughout the life of the vehicle. As a result, developing these systems requires precise calibration, a potentially costly and time-consuming process.

By using MathWorks tools to enable most of the calibration process to be performed on a desktop computer, Ford Motor Company Limited UK saved development time and reduced reliance on physical testing and prototype vehicles.



Populating tables with models from the Calibration Generation tool to support a diagnostic strategy.

tion parameter required changing, the process had to be started again from the beginning.

Ford needed a process that would streamline development, produce reusable test data, and reduce repetitive testing on physical prototypes without impairing calibration accuracy.

THE SOLUTION

By using MATLAB®, Simulink®, the Model-Based Calibration Toolbox, and custom-built data analysis tools, Ford engineers completed development in just four steps: collecting, processing, and modeling engine performance data; generating calibrations; testing the calibrations using Simulink models of the misfire-detection strategies; and validating the final invehicle calibration.

They began by recording data on engine speed, load, torque, ignition timing, and crankshaft motion timing from chassis rolls, track, and road tests, and importing the test data into MATLAB. Using a custom data processor built with MATLAB, Ford batch-processed, filtered, and analyzed more than 100 files a minute.

Ford's previous calibration methods required precise measured data at all operating points

THE CHALLENGE

Ford's primary goal was to streamline EOBD calibration with a new development process. One of the areas selected for the new process included misfire calibration development, a task involving repetitive testing, manual data postprocessing, and system characterization over a wide range of conditions.

Engine misfire reduces engine torque, increases roughness and emissions, and can cause damage to the catalytic converter. The misfire detection algorithm identifies specific irregularities in crankshaft motion that indicate when cylinders are not firing correctly. It must also detect true misfire events while ignoring other fluctuations in normal running conditions.

Traditionally, calibration development was a laborious, multistep procedure involving iterative test cell and invehicle testing combined with Excel-based data analysis. If a key calibra-

THE CHALLENGE

To streamline onboard diagnostics calibration by adopting a model-based calibration approach

THE SOLUTION

Use MathWorks tools to enable most of the calibration to be conducted on a desktop computer by collecting and processing data and generating, testing, and validating calibrations

THE RESULTS

- Reusable models of engine control unit behavior
- Shorter analysis time
- Reduced usage of prototype vehicles

to fill calibration maps. Using the Model-Based Calibration Toolbox, engineers accelerated the process of testing and characterizing the behavior of the engine. They used design of experiments (DOE) tools in the Model-Based Calibration Toolbox to develop test plans that take the most critical test points of the engine's operating range, substantially reducing testing requirements. They then used the statistical modeling capabilities of the toolbox to create accurate and robust multidimensional models of the system throughout the operating range.

"The ease of use and statistical analysis within the Model-Based Calibration Toolbox enables us to accurately evaluate many model inputs quickly," notes Nick Wright, engineer at Ford.

Using these models with the Calibration Generation tool in the Model-Based Calibration Toolbox, engineers generated and optimized calibration maps of the misfire-detection thresholds and populated calibration tables.

Rather than evaluate and refine the calibration with physical testing, Ford imported the calibration and test data into a Simulink model of the misfire-detection algorithms. They simulated the model using input signals acquired while collecting the original test data. Engineers can optimize and re-evaluate calibrations on the desktop, comparing results from different simulations to see the effect of calibration changes.

Ford engineers also worked with MathWorks Consulting to build complex Simulink models with a flexible front-end GUI for the validation phase. "MathWorks Consulting enabled Ford to turn our ideas into a working toolset more quickly and cost-effectively than if we had attempted all the tasks in-house," explains Wright.

APPLICATION AREAS

- Algorithm development
- Automotive
- Data analysis
- Model-based calibration
- Modeling and simulation

PRODUCTS USED

- MATLAB
- Simulink
- Model-Based Calibration Toolbox
- Statistics Toolbox
- Optimization Toolbox

“*MathWorks tools have enabled our engineers to gain a greater understanding of the algorithm function and interactions and to explore the effects of calibration changes without using vehicles.*”

Robin Drane, Ford Motor Company Limited UK

Ford is applying their new calibration process to electronic throttle control safety and diesel calibration. They are also using MathWorks tools to develop and validate calibrations for exhaust gas temperature models, calibrations for coolant temperature, and manifold absolute pressure and mass air flow sensors.

THE RESULTS

- **Reusable models of engine control unit behavior.** With the new process, when key calibration parameters require modifications, Ford uses the accurate models of engine control algorithms to develop a new calibration rather than acquire new test data.
- **Shorter analysis time.** MATLAB helped Ford reduce calibration analysis time by a factor of 10 over previous Excel-based methods. They now test different strategies side by side and compare their performance on the same desktop.
- **Reduced usage of prototype vehicles.** The new process based on MathWorks products enabled Ford to reduce its reliance on prototype vehicles, saving weeks of testing and analysis time and facility costs.

For more information on Ford, visit www.ford.com

www.mathworks.com