USING THE MATLAB TOOLSET TO IMPROVE EFFICIENCY IN THE EOBD CALIBRATION PROCESS

N. Wright and R. Drane
Ford Motor Company Limited, UK

Agenda

• Introductions and Agenda  N. Wright
• Background  N. Wright
• Historical Calibration Process  R. Drane
• New Calibration Process  R. Drane
• Simulink Simulation Tools  N. Wright
  – Generic Simulink GUI
  – HEGO Simulink GUI
• Data Processor Tool  R. Drane
• Summary  R. Drane
Agenda

• Introductions and Agenda  N. Wright
• Background  N. Wright
• Historical Calibration Process  R. Drane
• New Calibration Process  R. Drane
• Simulink Simulation Tools  N. Wright
  – Generic Simulink GUI
  – HEGO Simulink GUI
• Data Processor Tool  R. Drane
• Summary  R. Drane

Background

Ford has developed a number of CAE tools to improve efficiency in the EOBD calibration process. Benefits of this approach include:

• Reduced development cycle time
• Reduced usage of prototype vehicles
• Reduced testing costs
• Re-usability of test data
**Agenda**

- Introductions and Agenda  
  N. Wright
- Background  
  N. Wright
- **Historical Calibration Process**  
  R. Drane
- New Calibration Process  
  R. Drane
- Simulink Simulation Tools  
  N. Wright
  - Generic Simulink GUI
  - HEGO Simulink GUI
- Data Processor Tool  
  R. Drane
- Summary  
  R. Drane

---

**Historical Calibration Process**

1. Collect Mapping/Calibration Data
2. Post Process Mapping Data and Generate Initial Calibration
3. Individual task-specific programs and spreadsheets
4. Collect More Data
5. Run Calibration on Vehicles to Validate
6. Collect Sign-Off Evidence Data
7. Key Calibration Parameter Change
8. Release Process
**Agenda**

- Introductions and Agenda  
  N. Wright
- Background  
  N. Wright
- Historical Calibration Process  
  R. Drane
- **New Calibration Process**  
  R. Drane
- Simulink Simulation Tools  
  N. Wright
  - Generic Simulink GUI
  - HEGO Simulink GUI
- Data Processor Tool  
  R. Drane
- Summary  
  R. Drane

**New Calibration Process**

- Collect Data on Vehicles for Entire Calibration and Validation Input Signals for Simulink Simulation Tools
- Integrated Calibration and Validation Process Using Matlab Toolset:
  - Custom Data Processor Tool
  - MBD/Model
  - Simulink Simulation Tools
- Iterative Process
- Collect Sign-Off Evidence Data
- Key Calibration Parameter Change

Nick Wright and Robin Drane  
The MathWorks International Automotive Conference, June 2004
Matlab Toolset Integrated Calibration Process

Collected Data

Data Processor Tool
Process data collected for calibration generation

MBC Model
Model calibration surfaces

CAGE
Generate initial calibrations

Simulink Simulation Tools
Run simulation models with all collected data sets

Tweak Calibration

Not OK

OK

Spreadsheets
Generate initial calibrations

Data Processor Tool
Conduct validation analysis on output from simulink models

Collect Sign-Off Evidence Data

Agenda

• Introductions and Agenda
  N. Wright

• Background
  N. Wright

• Historical Calibration Process
  R. Drane

• New Calibration Process
  R. Drane

• Simulink Simulation Tools
  N. Wright
  – Generic Simulink GUI
  – HEGO Simulink GUI

• Data Processor Tool
  R. Drane

• Summary
  R. Drane
Simulink Simulation Tools

Ford in association with The MathWorks have developed a number of Simulink Powertrain Control System Strategy Models. Features of the tools:

- Desktop calibration and validation
- Data batch processing
- Auto calibration
- System robustness testing
- Standard controller allows connection to any correctly formatted Simulink Model
Agenda

• Introductions and Agenda N. Wright
• Background N. Wright
• Historical Calibration Process R. Drane
• New Calibration Process R. Drane
• Simulink Simulation Tools N. Wright
  – Generic Simulink GUI
  – HEGO Simulink GUI
• Data Processor Tool R. Drane
• Summary R. Drane

Generic Simulink GUI - Tool Format
Generic Simulink GUI - Tool Format

Controller Automatically Recognises Calibration Parameters, Inputs and Signals and configures GUI.

Generic Simulink GUI - Tool Format

Load Calibration Information and Data.
Generic Simulink GUI - Tool Format

- Edit Calibration Scalars
- Select Input Conditions Using Recorded Data or Constant
- Select Which Inputs and Signals to Display
Generic Simulink GUI - Tool Format

- Edit Table Function
- View Flags
- View Variables
- View Selected Point

Nick Wright and Robin Drane  The MathWorks International Automotive Conference, June 2004
Generic Simulink GUI - Tool Format

View Data in Standard units or Normalise Variables

Zoom Option on Display

Generic Simulink GUI - Tool Format

Activate History Option
Generic Simulink GUI - Tool Format

Select Up to 4 History Files

History Option Allows Viewing Effects of Calibration Changes

Review Calibration Differences Between Files

Generic Simulink GUI - Tool Format

Save Options
Agenda

- Introductions and Agenda  N. Wright
- Background  N. Wright
- Historical Calibration Process  R. Drane
- New Calibration Process  R. Drane
- Simulink Simulation Tools  N. Wright
  - Generic Simulink GUI
  - HEGO Simulink GUI
- Data Processor Tool  R. Drane
- Summary  R. Drane

HEGO Simulink GUI - Batch Processing
HEGO Simulink GUI - Batch Processing

View all Sweeps

Rotate Facility on Graphics

Distribution Data can be Viewed in Bar Form or Line Form

Statistics on all Sweeps
HEGO Simulink GUI – Auto Calibration

Select Best Calibration
View Individual Sweeps
Statistics on Individual Sweep
HEGO Simulink GUI – System Robustness

Select Signal Generator

Set up Base Signal

Select Robustness Limits
HEGO Simulink GUI – System Robustness

Calibration Not Robust
Over all Robustness
Limits
Agenda

• Introductions and Agenda          N. Wright
• Background                        N. Wright
• Historical Calibration Process    R. Drane
• New Calibration Process          R. Drane
• Simulink Simulation Tools        N. Wright
   – Generic Simulink GUI
   – HEGO Simulink GUI
• Data Processor Tool               R. Drane
• Summary                           R. Drane

Data Processor Tool

Collected Data

Data Processor Tool
Process data collected for calibration generation

MBC Model
Model calibration Surfaces

CAGE
Generate initial calibrations

Simulink Simulation Tools
Run simulation models with all collected data sets

Tweak Calibration

Data Processor Tool
Conduct validation analysis on output from simulink models

Not OK

OK

Collect Sign-Off Evidence Data
Data Processor Tool - Features

The data processing tool is used to manipulate and analyse data generated from vehicle or from simulink models. Specific features include:

- Flexible – has countless applications
- Graphical display of imported data
- Data filtering to either exclude data or to select data for export prior to analysis
- Has access to Matlab functions
- Allows use of users own written functions
- Enables batch processing of data from multiple files
- Results can be imported into MBC for modeling
- Results can be exported in .csv format for spreadsheets
- Tasks are saved as templates, similar to MBC.

Data Processor Tool – Graph View

[Graph showing combustion and misfire signals, with annotations: Raw Misfire Detection Signal, Generated Misfire Signal (occurs 6 events prior to actual misfire)]
Graph View - Options

Variable Editor

Change Plot Properties

Graph View – Filtering

Filter Sets

Filtering Tool Buttons
Filtering – Removing Data

Data can be removed graphically by use of mouse click and drag operation:

- X filter  -- Removes data along the X axis
- Y filter  -- Removes data along the Y axis
- XY filter -- Removes rectangle area of data

![Filtering - Removing Data](image)

Filtering – Selecting Data

Export filters can be used to select data that is required to be kept for analysis:

- X Export Filter  – Selects data along the X axis
- Y Export Filter  – Selects data along the Y axis
- XY Export Filter – Selects data in a rectangular area

Table View:
Data Processor Tool – Table View

Table View – Columns of Results

User Defined Function:

\[ SNR_{Index} = \frac{\text{Mean}(\text{comb}) - \text{Mean}(\text{mis})}{\text{STD}(\text{Comb})} \]
Data Processor Tool – Batch Run

- **MBCModel**
- **Spreadsheet**

Data Processor Tool – Simulink Model Analysis

- **Simulink GUI Template configured with desired calibration:**
- **Validation Results Files**
Agenda

- Introductions and Agenda  N. Wright
- Background  N. Wright
- Historical Calibration Process  R. Drane
- New Calibration Process  R. Drane
- Simulink Simulation Tools  N. Wright
  - Generic Simulink GUI
  - HEGO Simulink GUI
- Data Processor Tool  R. Drane
- Summary  R. Drane

Summary

Collected Data

Data Processor Tool
Process data collected for calibration generation

MBC Model
Model calibration Surfaces

CAGE
Generate initial calibrations

Simulink Simulation Tools
Run simulation models with all collected data sets

Tweak Calibration

Data Processor Tool
Conduct validation analysis on output from simulink models

Not OK
Collect Sign-Off Evidence Data

OK

Spreadsheets
Generate retail calibrations
Any Questions

???