Using Modeling and Simulation (M&S) to Support Future Medium and Heavy Duty Regulations/Labeling

EVS 25
Shenzhen, China
November 09, 2010

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Regulations of Medium & Heavy Duty Fuel Consumption Could Use Model-Base Design

- EISA of 2007 requires DOT to establish fuel economy standards for MD and HD vehicles
- Problematic:
  - Huge number of vehicle applications, with some of them being “one of a kind”
  - Very large number of companies, many of them focusing on low volume specialty applications
  - Not enough testing facilities
  - Testing all options would likely be prohibitively costly for the OEMs
- Objective:
  - Propose options to support future regulations/labeling while minimizing costs and burden to implement the program
Modeling and Simulation of the Entire Vehicle for All Applications is Required

- The NAS report (1) makes the following statements in Recommendation 8.4:
  - “Simulation modeling should be used with component test data and additional tested inputs from powertrain tests, which could lower the cost and administrative burden yet achieve the needed accuracy of results.”
  - “This is similar to the approach taken by Japan, but with the important clarification that the program would represent all the parameters of the vehicle (Powertrain, aerodynamics and tires) and relate fuel consumption to the vehicle task.”

- Finding 8.1 for the NAS report states that
  - “While it may seem expedient to initially focus on those classes of vehicles with the largest fuel consumption (i.e., Class 8, Class 6, and Class 2b, which together account for approximately 90 percent of fuel consumption of MHDVs), the committee believes that selectively regulating only certain vehicle classes would lead to very serious unintended consequences and would compromise the intent of the regulation.”

(1) NAS report “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles”, dated March 17, 2010
The M&S Tool Shall Include All the Applications

- Medium and heavy duty applications are so diverse that hundreds or thousands of configurations currently exist.
- With the introduction of electric drive vehicles (HEVs, PHEVs, EVs), the number of options skyrockets!

<table>
<thead>
<tr>
<th>CLASS 1</th>
<th>6,000 lbs or less</th>
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</thead>
<tbody>
<tr>
<td>CLASS 2</td>
<td>6,001–10,000 lbs</td>
</tr>
<tr>
<td>CLASS 3</td>
<td>10,001–14,000 lbs</td>
</tr>
<tr>
<td>CLASS 4</td>
<td>14,001–16,000 lbs</td>
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<tr>
<td>CLASS 5</td>
<td>16,001–19,500 lbs</td>
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<tr>
<td>CLASS 6</td>
<td>19,501–26,000 lbs</td>
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<tr>
<td>CLASS 7</td>
<td>26,001–33,000 lbs</td>
</tr>
<tr>
<td>CLASS 8</td>
<td>33,000 lbs or more</td>
</tr>
</tbody>
</table>
The M&S Tool Shall Address Any of the MBD Steps, from Modeling to HIL and CIL

Different steps of Model based Design (MBD)

Japan already uses different approaches for different powertrains!

Modeling for Conventional

Hardware-in-the-Loop for HEVs

(1) Source A. Hoshi, Ministry of Land, Infrastructure, Transport and Tourism

MBD = Model based Design
The M&S Tool Should Allow Different Model Complexity

- Some technologies might not be accurately predicted using a single model
- Even if one starts with a fixed model, who can predict the future?
The M&S Tool Shall Provide a Streamlined Simulation Process

- Flexibility should be carefully managed. For example, users should not be able to select drive cycles, but they should be able to perform in-depth analysis of their results.

Example of Simulation Process for Labeling

1. Select Application
2. Define Vehicle
3. Launch Simulation
4. Analyze Results
5. Give Results
The M&S Tool Should Manage Process Security vs. User Needs

- Intellectual property should be protected, yet users should have access to the equations to perform validation of their component technologies.
- Users should not be able to change any of the model parameters, but yet have access to the information to ensure the simulation performed as expected (i.e., post-processing).

Example of Sfunctions to Protect Model IP

![Simulink block diagram](image)

**SFunction**
Implementation Example with Autonomie
Autonomie Example

Applications diversity is handled by automatically building the models.

The List of Available Parameters Can Be Quickly Customized.

GUI Allow Quick Selection of Main Initialization Files
Autonomie Example (Cont’d)

Initialization Files Can Be Quickly Added

Results Can Be Thoroughly Analyzed

Detailed Models Can Be Handled in the Future (example using GTPower, AmeSim and TruckSim)
Autonomie Example (Cont’d)

Different Steps of Model Base Design Are Already Implemented (engine-in-the-loop example)

Specific Reports Can be Automatically Generated

Results are Managed Through Database

Rest of the Vehicle Modeled

Engine behaves as if in vehicle
M&S Tool Requirements

- Use the same tool for any of the MDB processes (HIL, MIL, RCP, CIL...)
- Ability to reuse any existing legacy code written in any language or in any expert software
- Allow experts to develop/test plant and controls for subsystems, systems or vehicles
- Easy to use GUI
- Generation of generic reports specific to regulations
- Single database allowing sharing of models and data between companies while protecting the IP

Currently, no Off-the-Shelves Tool meet all the requirements, but several have the ability to quickly be customized for regulations/labeling purposes.
Acknowledgements / Contact

Argonne Vehicle Simulation Tool development was funded by Lee Slezak and David Anderson from the U.S. DOE, Vehicle Technologies Program

For additional information, please contact arousseau@anl.gov or visit www.autonomie.net