INTEGRATED CO-SIMULATION TO PREDICT VEHICLE AND POWERTRAIN PERFORMANCE

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Powertrain CAE - Systems

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INTRODUCTION

A) Importance of Subsystem
B) Importance of Model Integration
C) Motivation & Challenges
Importance of Subsystem

- Engine
- Coolant Circuit
- Oil & Friction Circuit
- Electrical System
- Vehicle + Driver
- Drive Train + Gear Box
- HVAC
- Control Strategy
1- INTRODUCTION

Model Integration

Trade off Performance

- Consumer demand
- Regulations
- Energy security
- Environment

- Electric Machines
- Power Electronics Modules
- Battery
- Energy Storage

- Safety
- Reliability
- Performance
- Comfort

- Energy Use
- Vehicle Thermal Management
- Advanced Technologies
- Cost
1- INTRODUCTION

Energy Management

Importance

Combined cooling loops
- Quicker engine warm-up
- Enhance fuel economy

Exhaust gas waste heat
- To recover exhaust energy –T/C

1) Integrate Systems

2) Remove Heat Efficiently
- Improve cooling system control
- Electric pumps and valves

3) Reuse Waste Heat

4) Reduce Thermal Loads
- Reduce parasitic power losses
- Parked car ventilation

Improved operating robustness and reduced energy use.
Background

Migration to Virtual Environment

- Engine
- Brake
- HVAC
- Transmission
- Controls

detailed physics of system to be modeled !!

How to integrate them in virtual environment ..??

1- INTRODUCTION

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Motivation and Challenges

Opportunities

- System design optimization and performance enhancement
- Modeling using system simulation during upstream development
- Advance simulation by co-simulation techniques (Integrated simulation)

Modeling Challenges in Current Scenario

- System Complexity
- Validation
- Integration
- Countermeasures

Benefits with Simulation

- Minimal Prototype
- Reduced efforts
- Reliability
- Prediction
1- INTRODUCTION

Outcome

- Modelling & Validation of full vehicle model by Co-simulation using GT-SUITE & SIMULINK
- Analyzing of each sub-system and its performance improvement with counter measure
VALIDATION OF SYSTEMS : EXAMPLE
A) HVAC
B) Engine Model
C) Vehicle + Transmission
D) ..
E) ....
HVAC System

Evaporator

Condenser with Receiver Dryer

Compressor

System Integration Inputs

Air From Car interior

Blower

Low Pressure & Low Temperature Liquid

High Pressure Liquid Line

High Temperature & High Pressure Vapour line

Low Pressure Vapour Line

Equation simulation model in GT-SUITE
2- VALIDATION OF SYSTEMS

Methodology

Tuning Parameters

➢ Multipliers (Friction, Heat Transfer)
➢ Lumped Mass
➢ Heat transfer coefficients
Simulation Steps for WOT calibration, Neural network training and PLP prediction

- **INPUTS**
  - Burn rate prediction
    - Air fuel ratio (A/F)
    - Engine speed
    - Intake pressure
    - Ignition timing
    - Volumetric efficiency

- **Training Neural networks:**
  - Air fuel ratio at WOT
  - Engine speed
  - Intake pressure at WOT
  - Ignition timing at WOT
  - Volumetric efficiency

- **FTP calibration:**
  - Engine speed
  - Intake and exhaust boundary
  - Intake and exhaust valve train and length
  - Intake and exhaust valve train and center angles
  - Intake and exhaust valve train
  - Valve train overlap
  - Intake valve closing angle
  - Intake valve opening angle
  - Intake valve closing angle
  - Intake valve opening angle

- **OUTPUTS**
  - Burn rate prediction
  - Training Neural networks for PLP prediction
  - FTP Calibration

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**Training Output Parameters**

- Anchor angle
- Burn duration
- Wiebe exponent

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2- VALIDATION OF SYSTEMS

Vehicle & Powertrain model

Output Parameters

- Vehicle Velocity
- Indicated Torque
- Gear Shift & Brake Pedal State

Vehicle Speed (Kmph)

Engine Brake Torque (Nm)
03

System Integration
A) Co-simulation
B) Application
Full Vehicle model layout

Virtual Environment

- Velocity & Road Profile
- AC Control
- Driver
- ECU & TCU
- Brakes
- Engine
- Transmission
- Vehicle Body
- Other Systems
- AC loop
- Cabin Comfort
- Environment

3- SYSTEM INTEGRATION – [CO-SIMULATION]
3- SYSTEM INTEGRATION – APPLICATION

Vehicle Performance – Fuel Economy

**System and Impact**

- **Engine Performance**
  - Combustion
  - Friction Load
  - Fuel consumption

- **Engine Thermal Management**
  - Coolant Temperature
  - Oil Temperature
  - Transmission Oil Temperature

- **Air Conditioning**
  - Cabin Temperature
  - Compressor Torque
  - Condenser air outlet temp.

- **Vehicle Cooling**
  - Bypass activation
  - EGR activation
  - Warmup fuel flow

- **Aerokit+ Tires**
  - Drag Force
  - Rolling resistance

- **Transmission Model**
  - Gear Shift Position
  - Engine Speed
  - Transmission friction torque

- **Auxiliaries**
  - Electrical/ Mechanical Power demand
  - ON/OFF strategy

- **Controllers**
  - Fuel Cut, AC Cut
  - Speed Control
  - Activation Control

- **Air Filling**
  - Volumetric efficiency
  - Combustion
  - Booster Vacuum

- **Vehicle Dynamics**
  - Stability
  - Acceleration
  - Cornering, Tip in & Tip out

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**Impact of Co-simulation on IDC Fuel Economy**

- 6.1%
- 5.8%
- 4.0%
- 2.0%
- 1.6%

**Accuracy Improved**

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Better cabin cooling temperature was observed using Variable Displacement Compressor.

VDC displacement is a function of Suction pressure & Evaporator air outlet temperature.

Engine Indicated Torque for VDC is Lesser than FDC due to less compressor torque demand by VDC by changing compressor displacement.
CONCLUSION
A) Benefits: Accuracy & Lead time Reduction
B) Continual Improvement
<table>
<thead>
<tr>
<th>Benefits</th>
<th>Description</th>
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<tr>
<td><strong>Accuracy and Lead time reduction</strong></td>
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<tr>
<td>✓ Good Accuracy – Prediction of Vehicle and Powertrain <strong>performance</strong> by integrating all sub-systems with complex control system and its interface variable.</td>
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<td>✓ Cost Avoidance – Eliminate the model <strong>duplication</strong> and reduce prototype testing.</td>
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<td>✓ Time Reduction – <strong>Plug-in concept</strong> technique (Data base from MBSE Models).</td>
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<td>✓ Quick Adaptive - New innovative ideas using <strong>virtual simulation</strong> and its impact ( Proof of Concept).</td>
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Continual Improvements

Digital Validation [Less Lead time & More Confidence Level]

- **Integration of models** is complex and challenging – Software Compatibility.
- **Standard Process in place** to provide fast accurate results.
- **MBSE challenges** – Collaboration with Suppliers and Software developers.
- **New simulation methods** is part of process – Techno Brick.
- **Co-simulation In Place** – Interaction with Multiple software’s for better prediction and lead time reduction.
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Thank You