EVALUATION OF HYBRID POWERTRAIN CONTROL STRATEGY IN AN NVH SIMULATOR

Experience sound and vibration of a virtual prototype
Hybrid Powertrain Control Strategy

Driver Command

Powertrain Control

Operating Condition

requested torque
gear / gear ratio
RPMs
gear / off
motor on / off

state of charge
temperature
drive mode

...
Hybrid Powertrain Control Strategy

Fuel Economy & Emissions

Powertrain Control

Drivability

NVH Performance

Parallel Hybrid

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Hybrid Powertrain Control Strategy

Trade-Off Conflict

Fuel Economy & Emissions

Drivability

NVH Performance
Motivation – Find trade-off as early as possible

Current vehicle

Timeline

prototypes

Virtual Prototype
NVH Simulator

Next generation
Interactive Simulation of vehicle interior noise based on test and CAE data.
NVH Simulator – Scalable Solution

Desktop Simulator

SoundSeat

steering wheel & seat vibration

SoundCar

context

Vehicle Simulator

Mobile Simulator

virtual reality moving platform

real driving experience
NVH Simulator – Powertrain Model

Vehicle Model

- Throttle
- Gear Lever
- Brake
Interface to IPG CarMaker

CarMaker Integration:
Coupling with different Powertrain Principles / Models
NVH Simulator – Sound Resynthesis

- Loads / RPM Engine / RPM Motor / Speed
- Sound Resynthesis

Vehicle Model

- Throttle
- Gear Lever
- Brake
NVH Simulator - Sound Database

Loads / RPM Engine / RPM Motor / Speed

Sound Resynthesis

Sound Database

Combustion Engine

Electric Motor

Tire-Road

Wind

Filter

Filter

Filter

Sound & Vibration

Brake

Gear Lever

Wind

Tire - Road

Electric Motor

Combustion Engine

Loads / RPMs / Speed
Where does the acoustic data come from?

- **ROLLER DYNO**
- **TEST BENCH**
- **ROAD COAST DOWN**
- **CAE DATA**

**Interior Measurements**

OR **BTPA Input**

- **Sound Synthesis**
  - Load / RPM / Speed
  - **Driving Dynamics Model**
    - Gear Lever
    - Throttle
    - Brake
Where does the acoustic data come from?
Where does the acoustic data come from?

BTPA Input
Synthesis with vehicle model

Load / RPM / Speed

Sound Synthesis

Driving Dynamics Model
Gear Lever
Throttle
Brake

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Where does the acoustic data come from?

Time or Order Based Data Input

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Workflow

Tune Powertrain Control Strategy ➔ Experience and Evaluate ➔ Trade-Off Solution ➔ NVH Performance ➔ Fuel Economy ➔ Drivability

Experience and Evaluate

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Example 1: Hybrid Vehicle

Early concept phase
- Powertrain noise from testbench
- Road noise and wind noise from current model
Example 1: Hybrid Vehicle

NVH Simulator
HEAD acoustics - PreSense
Example 1: Hybrid Vehicle

Vehicle Model
IPG CarMaker
Example 1: Hybrid Vehicle

Gas, Brake
RPMs, Loads, Speed
Example 1: Hybrid Vehicle

Early concept phase
- Powertrain noise from testbench
- Road noise and wind noise from current model
Example 2: Combustion engine with CVT

Shortly before Start of Production
• Powertrain, road and wind noise from late prototype
• Too late for hardware changes but TCU software still adaptable

CVT
*Continuously Variable Transmission*

No fixed gears:
What is the optimal strategy for the transmission ratio?
Example 2: Combustion Vehicle with CVT

CVT: Constant RPM with variable Ratio

CVT: Emulated fixed gears

video with sound example

vs.

video with sound example
Summary

• In a simulator engineers from all departments involved can tune the powertrain control strategy to find the optimum balance between for acoustics, drivability and fuel consumption.

• Different strategies can be compared in a simulator under safe and reproducible conditions. A driving simulator is particularly suitable for the evaluation of complex systems that involve a lot of human interaction.

• Engineers can use the same vehicle dynamic model for powertrain and NVH development.

• Experience a virtual prototype based on combination of test data, CAE data and test bench data.