Model Based System Testing

eCVT-in-the-loop testing

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Model Based System Testing
Testing frontloading using simulation models
Model Based System Testing
The Marriage of Test and Simulation

Model Based System Testing
• Model validation
• Model correlation & updating
• System-In-The-Loop testing
• Hybrid testing
• Human-in-The-Loop
• Virtual sensing
• Hardware-in-The-Loop

Test
• Functional testing
• Operational testing
• Life cycle testing
• Environmental testing
• Laboratory testing
• Component / Subsystem / System testing

Simulation
• Multi-physical simulation
• Multibody System Dynamics
• Finite Element modelling
Model Based System Testing

Overview tree

Model Based System Testing

Testing for Simulation
- parameter identification
- analysis of simulation data w/ test methods

Testing with Simulation
- model validation & updating
- load identification
- system-in-the-loop

Simulation for Testing
- hybrid testing
- hardware-in-the-loop
- virtual testing
- human-in-the-loop
- optimal sensor/excitation
- measured data augmentation

virtual sensing
Model Based System Testing
Creating a unified testing framework from virtual testing to field testing

Virtual testing

Conventional bench testing

Conventional bench testing

Field testing

Virtual testing

Virtual testing

Conventional bench testing

Conventional bench testing

Field testing

Enable attribute-specific evaluation throughout the development cycle using simulations.

- same metrics and post-processing tools from 100% simulated to 100% real
- model-in-the-loop enables system-level testing for real components/subsystems
- common Test.Lab / SCADAS toolset and same user
System-under-test

Electronically-Controlled Continuously Variable Transmission

- Driving side
- Belt
- Driven side
- Control motor

- Fixed sheaves
- Mobile sheaves
- Clutch
- Comp. spring
Design criteria for CVTs

Market drivers in the automotive sector
• low energy consumption (i.e. low fuel consumption)
• low emissions
• low noise (feeling of superior quality)
• excellent engine performance
• excellent user experience

Transmission development goals
• lightweight and compactness
• enable automatic shifting to improve fuel consumption, emissions, noise without compromising drivability
• enable engine braking in manual mode. Only available for electronically-controlled CVTs.
• automatic shift down & shift limitation functions
• simple operation in automatic and manual mode
CVT component technology

Technological solutions to reach the design targets

belt
• has to be well-suited for ratio control
• rubber belt with high friction coefficient = lightweight + compact
• optimization of cog shape and material properties to minimize slip ratio

pulley
• material: can be made of die cast aluminum alloy
• wear of pulley surface and belt is compensated in the control of the shifting motor

gears
• quietness
• wear reduction & weight reduction = plastic gears for non-lubricated parts =

bearings
• less friction = adjustments to reduce friction due to axial thrust of helical gear
• optimized design according to their loads to decrease friction

transmission oil
• agitation losses reduction
• = optimization of the shape of the ribs in the transmission case
• = reduction of losses due to gear rotation

cooling
• increase of belt life = air cooling
Objective

System-in-the-loop Testing

Enabling component Testing in the lab in near real-life conditions by means of real-time simulations
Real-time Model Based System Testing

- Model Based System Testing
  - Testing for Simulation
  - Testing with Simulation
  - Simulation for Testing

- Model validation & updating
- Hardware-in-the-loop
- Virtual testing
- Human-in-the-loop
- Measured data augmentation

- Analysis of simulation data w/ test methods
- Sensor/excitation

- SUT
- Host PC

- Optimal sensor/excitation
- Load identification
- System-in-the-loop
- Hybrid testing
- Virtual sensing
- Human-in-the-loop
eCVT-in-the-loop test bench
eCVT-in-the-loop virtual test bench

- **Sizing** of electric motors
- **Dynamic behavior** validation
Test bench conceptual scheme
Real-time Amesim motorcycle model

Near real-life excitation of system-under-test
Real-time Amesim engine model

Engine dynamics

• Based on Aprilia Mana 850 GT ABS
• V-Twin engine
• Max. mean Torque = 70 Nm @ 4500 rpm
• Max. mean Power = 56 kW @ 8000 rpm
• Rpm range = 1000 – 8500 rpm
Real-time Amesim motorcycle model

Vehicle dynamics

- Based on Aprilia Mana 850 GT ABS
- Motorcycle geometry
- Motorcycle weight
- Tire & wheel characteristics

Road surface as an input
Virtual sensing
Model based indirect measurements
Belt model for virtual sensing
Belt critical state estimation

Belt path

Belt tension (longitudinal)
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