Creating a high-performance testbed for multi-axle drivetrain innovation

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Researcher
Outline

- What is Flanders Make
- Test setup and intended usage
- Methodology
- Toolchain
Our mission

Strengthening the international long-term competitiveness of the Flemish manufacturing industry by performing industry-driven, pre-competitive, top-class research in 2 fields of application:

△ Products: vehicles and machines
△ Production: assembly plants
Innovation through collaboration
Our people

400 highly specialised researchers operating from our sites in Lommel and Leuven and from 10 research facilities at the Flemish universities.
Large companies and SME’s
Our organisation

Decision & Control

Design & Optimisation

Motion Products

Flexible Assembly

PRODUCTS

vehicles

machines

PRODUCTION

assembly plants
Summary: Flanders Make

- Bring technology to industry
- Steer research to industrial needs

How?
- Joint or long term research projects
- Consulting
- Test infrastructure
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Test bed overview

△ When should we use a drivetrain test bed?

△ For any of the following
  △ New or modified
  △ Drivetrain, drivetrain component, controller, ...
  △ For which we want to test feasibility, tune, validate, evaluate, demonstrate ...
Why use a test bed at all?

- Easier than testing on real machine
  - No need for full physical prototype
  - Improved observability – better instrumentation – improved measurement
  - Much more repeatable conditions
  - Quicker, cheaper and more energy efficient

- Much more realistic than simulations (also more difficult)
  - Test on real physical system
  - Possibly also with real physical controller

→ Step before deployment
Test bed overview

▲ What is available at our test bed
  ▲ Test infrastructure
  ▲ To facilitate future drivetrain innovations
  ▲ Of ourselves and others
  ▲ Which can be flexibly adapted

Insert device under test
Test bed overview

- Multifunctional Drivetrain test facility
  - Motors, drives, sensors, cooling units, ...
  - Interfacing and software toolchain
Example of test bed usage

▲ Hybrid or regular drivetrains
▲ Automotive or off-highway/heavy duty
Example of test bed usage

- Mechanical, hydrostatic, hydraulic, pneumatic drivetrains
- High powers, low speeds, high torques
- Power take-offs other than wheels as well
Test bed: Overview

- Multifunctional Drivetrain HIL test facility
  - Heavy duty mobile and machine applications
  - Complex multi-axle drivetrains or their components
  - 100-500 kW applications
  - CNH, DANA, MVDW, HTI, eTrucks, VDL, MVDW, Mazaro, SISW, ...

- Intended usage
  - Feasibility studies
  - Development and evaluation of controllers
  - Drivetrain topology evaluation
  - *Usage by internals, partners, externals*
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How to test drivetrains?

- Test data typically defined by vehicle speed/displacement
- Accurate control (more repeatable) ⇔ soft control (driver-like)
How to test drivetrains?

- Simply having output run at desired speed not good enough
- Emulate vehicle inertia, wheel slip, drag torque, ...
- Sometimes also needed to emulate ICE and its torque ripple

![Diagram of test setup]

- Controller
  - Driving motor
    - Torque control
    - + inertia emulation
    - + torque ripple emulation

- DUT
- Load motor
  - Load emulation
Methodology for testing

△ High bandwidth feedback needed
△ Repeatability of tests
△ Emulation of inertia, friction, torque ripple

△ Difficult control problem → Intrinsically unstable with normal feedback

<table>
<thead>
<tr>
<th>Component</th>
<th>Inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flywheel (dominant ICE inertia)</td>
<td>0.063211 kgm²</td>
</tr>
<tr>
<td>Driveshaft</td>
<td>0.0065845 kgm²</td>
</tr>
<tr>
<td>Tire inertia</td>
<td>&gt;0.5 kgm²</td>
</tr>
<tr>
<td>PMSM inertia</td>
<td>0.457 kgm²</td>
</tr>
</tbody>
</table>

Driving motor
Speed control

DUT

Load motor
Load emulation - FB
Methodology for testing

△ Improved approach: **Iterative learning control**
  △ Learn the correct load behavior from previous experiments
  △ Resulting in feedforward emulation
  △ No stability issues, at cost of convergence needed

![Diagram of driving motor, DUT, and load motor for load emulation using ILC.](image-url)
Methodology for testing: results

- Results for load motor emulation
  - Real inertia: 0.75 kgm²
  - Emulated inertia: 0.75*15 = 11.5 kgm²
  - Good emulation after 10 trials
Methodology for testing: results

- Results for driving *and* load motor emulation
- One higher one lower
- Still good emulation after **10 trials**

→ Repeatable tests
→ Stable broadband emulation
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Toolchain

What kind of toolchain do we use?
- Interfacing motors, sensors, ...
  - But also DUT controllers, new sensors, ...
- Quick and flexible software
  - Define controller for DUT
  - Emulate load, emulate inertia, ...
- Interactive operation, logging, debugging, ...

Solution: Speedgoat system + MATLAB + Simulink Real-Time

Modular I/O

Automatic codegen from MATLAB/Simulink

Rapid-prototyping environment
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Flanders Make test bed
  For various types of drivetrains
  Accurate load emulation and repeatable tests
  Easy to use toolchain
Available and ready for use
Is it relevant for you?

- Yes ... if you are in need of
  - Realistic physical testing
  - Of new/modified controllers, components, drivetrain topologies
  - Under repeatable and accurate conditions
  - With additional sensing
  - Efficient to set up and reconfigure