PowerTrain Library 1.0

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Outline
Library overview
Components
Applied concepts
  Usage
  Implementation
Case study
Online demonstration
Conclusions and outlook
The DLR PowerTrain Library

Commercial library of DLR with primarily 1D rotational mechanical components. Suitable for

- Examination of gear shift dynamics
- Hardware-in-the-loop simulation of automatic gearboxes
- Concept studies of drive lines (e.g. fuel consumption reduction)
- ...

History

1996: Project with BMW for HIL simulation of automatic gearboxes (using the Dymola language)
2000: Version 0.95 of PowerTrain library using the Modelica language (sold to BMW and other automotive companies)
2001: Start to considerably enhance the PowerTrain library
2002: Release of PowerTrain 1.0

Direct Contributors

- Ingrid Bausch-Gall, Bausch-Gall GmbH, Germany
- Mike Dempsey, Claytex Services Ltd, UK
- Martin Otter, DLR, Germany
- Clemens Schlegel, Schlegel Simulation GmbH, Germany
- Christian Schweiger, DLR, Germany
PowerTrain Library Features

- 45 user-callable components
- Signal bus concept
- Variant selection
- Robust friction modeling
  - Torque dependent losses (e.g. mesh efficiency)
- Animation of transmission components
- 10 introductory and sophisticated examples
- Universal control units
- Online tutorial

Library Structure
**Model DriveLine**

Library top-level view: generic drive train

Different configurations selectable for every component (e.g. 3 gearbox variants)

User can add own variants

Template for building own models

Used as a basis for sophisticated demo examples

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**Sublibrary Main**

Collection of models for generic power train
Sublibrary Main

Different configurations selectable
Realized by replaceable-redeclare-concept

Sublibrary Gears

Content
- Gear components
- Standard gears
- Complete wheelsets

Color coding
- Red: losses due to mesh efficiency and bearing friction
- Brown: built-in animation
Other Sublibraries

Clutches

- LaminarClutch
- FreeWheel
- OneWayLaminarCl

ControlUnits

- Bus
- ResBus
- BasicStrategy
- ShiftSchedule
- LookUpControl
- Governor
- FuelMap
- ORPOD

Auxiliaries

- BaseEngine1
- EngineLosses
- HeatModel
- WarmUpModel
- StarterMotor
- Fan
- TorqueConverter

Modelica connector containing all signal- or other sub-connectors used in the drive line
**Efficiency Modeling**

Locking due to mesh friction

Usual approach

\[ i = 1 \quad \eta_{mf} = 0.9 \]

\[ \tau_1 = 200 \quad \tau_2 = 190 \]

Flange 1 driving: \( \tau_1 \eta_{mf} < \tau_2 \)

Flange 2 driving: \( \tau_2 \eta_{mf} < \tau_1 \)

Chattering possible

Efficiency is free variable while stuck mode is active

Modelica friction implementation extended for torque dependent losses

Allows robust efficiency modeling

- LossyGear
- LossyPlanetary
- LossyRavigneaux
- ...
Efficiency Modeling

Takes stuck / rolling behaviour into account
Very much better than usual approach

Example
**Animation**

Built-in animation for gears, clutches, shafts

Easy parametrization

```
parameter Real position=4;
```

Possibility to turn off

- `parameter Boolean animation=false;`
- Animation equations removed from code (necessary for e.g. real-time simulation)

**Universal Control Units**

Fully parametrizable, independent from gear type or speed number

- Transmission: shift schedule, lock-up clutch control
- Engine: governor, fuel map, over-run fuel cut-off control

Example
**PowerTrain.Examples**

**Purposes**
- Introduction to library
- Hints for development of own models
- Starting point for own models

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**Example: 6-speed automatic gearbox**

Lepelletier type

**ZF 6 HP 26**

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**DLR Institute of Robotics and Mechatronics**
Modelica Object Diagram

Complexity:
- 1304 variables (with animation)
- 632 variables (without animation)
- 15 continuous states

Embedding

Complexity:
- 1304 variables (with animation)
- 632 variables (without animation)
- 15 continuous states
45 New Components for the Modelica Standard Library

Conclusions and Outlook

Powerful library for different power train modeling tasks

- Examination of gear shift dynamics
- Hardware-in-the-loop simulation
- Drive line studies

Well-designed structuring

Planned for future:

- 3D Coupling with vehicle dynamics library
- Additional standard wheelsets, drivers, engines, ...
- Vendor gearboxes
  (user does not need to identify gearbox, since complete model data set will be provided)