Working Paper No. **HDH-09-07**
(9th HDH meeting, 21 to 23 March 2012)

RESEARCH PROGRAM ON AN EMISSIONS TEST PROCEDURE FOR HEAVY DUTY HYBRIDS (HDH)

Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WP3: Non-electric HDHs

Jonas Fredriksson
Department of Signals and Systems
Chalmers University of Technology
Gothenburg, Sweden

Summary

- WT 3-1:
  - Non-electric hybrid powertrain topologies (concepts) fits well into the same categories as for electric hybrid powertrains

  → HILS should be possible for non-electric HDHs

- WT 3-2:
  - Mathematical models for:
    - Flywheel
    - Accumulator
    - Pump/Motor
    - CVT

  → Similar model structures as proposed in Kokujikan No. 281

Summary

- WT 3-3:
  - Parameters specified for:
    - Flywheel
    - Accumulator → Working on getting
    - Pump/Motor relevant data
    - CVT
- WT 3-4:
  - I/O:s identified → Needs standardization
- Work done according to time plan

Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WT 3-1: Technology overview and selection of scope

- Detailed analysis on what non-electric hybrid systems/components to be included in the HILS method. Review of non-electric hybrid topologies proposed in the literature, by OEMs and others. Review of non-electric components, such as flywheels, accumulators etc, used in non-electric powertrains proposed in the literature, by OEM and others. Together with OEMs and other partners decide which topologies that should be covered. Meetings with OEMs, will be co-planned with TU Graz and TU Wien in relation to WP 1-4 (TU Graz and TU Wien offer).

- The preliminary result is a list of non-electric powertrain topologies and a list of components that needs to be modeled.

Results

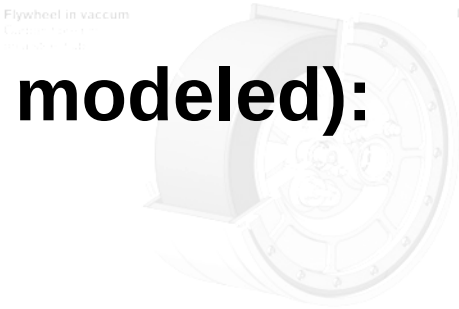
- Non-electric hybrid powertrain topologies (concepts) fits well into the same categories as for electric hybrid powertrains

- Non-electric hybrid powertrains can be divided into:
  - Series powertrain topologies
  - Parallel powertrain topologies
  - Split powertrain topologies

Interesting non-electric powertrain concepts:

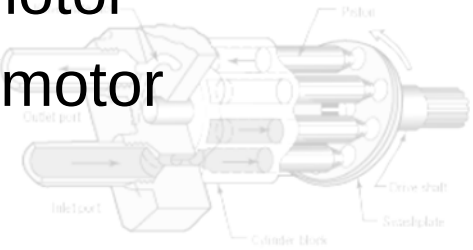
- CVT and flywheel
- Motor/generator and flywheel
- Hydraulic or (pneumatic) pump/motor and accumulator

Results



Component list (to be modeled):

- Energy storages:
  - Flywheel
  - Hydraulic accumulators
  - Pneumatic accumulators
- Energy converters
  - CVT (transmission)
  - Hydraulic pump/motor
  - Pneumatic pump/motor



(a) Swash-plate type, inline axial-piston type

(b) Bent-axis type, axial-piston type

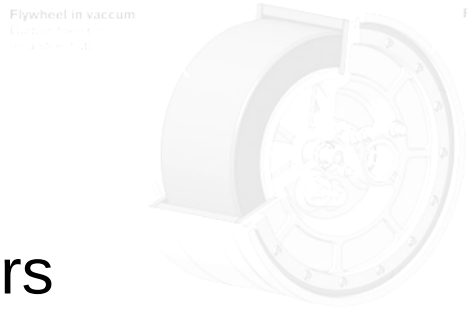
Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

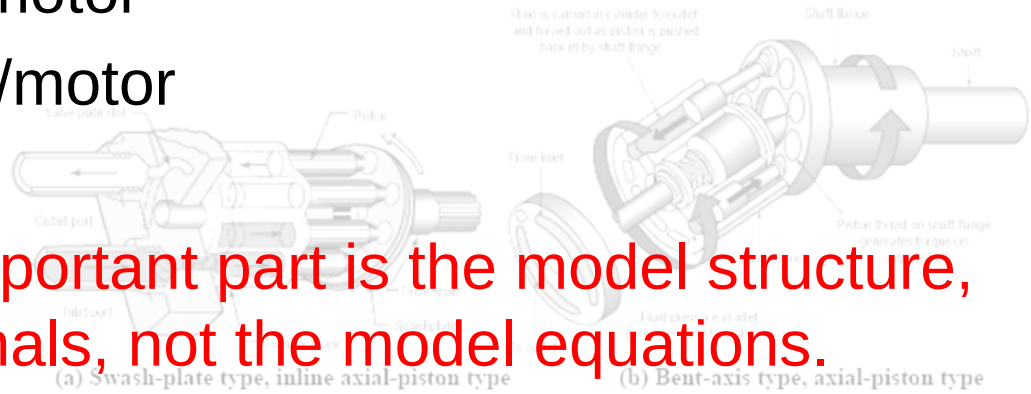
WT 3-2: Development of HIL elements for non-electrical hybrid systems/components

- Based on the list of topologies and components in WP 3-1, develop simple, representative mathematical models of the different powertrain components, such as actuators and energy buffers. The models will be implemented in a simulation software. All models will be documented.

- The result is a set of simulation models of non-electric powertrain components, which are suitable to use in a HILS setup.

Components



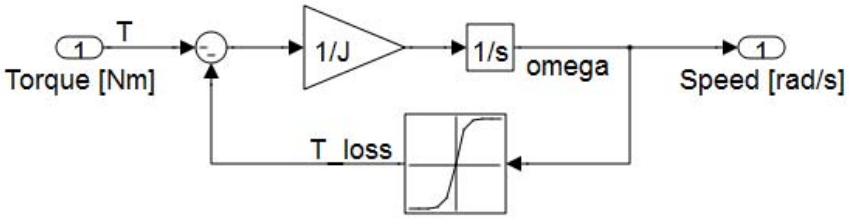


- Energy storages:
  - Flywheel
  - Hydraulic accumulators
  - Pneumatic accumulators
- Energy converters
  - CVT (transmission)
  - Hydraulic pump/motor
  - Pneumatic pump/motor

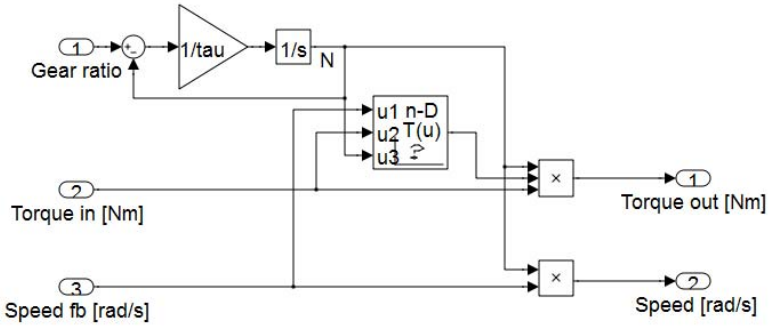
- Notice: The most important part is the model structure, the input-output signals, not the model equations.

Component modeling

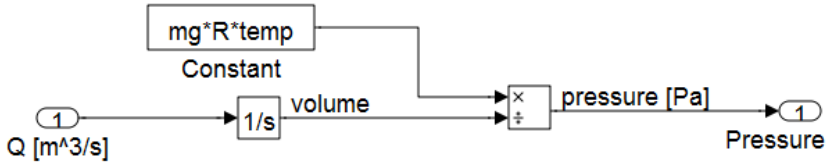
Flywheel



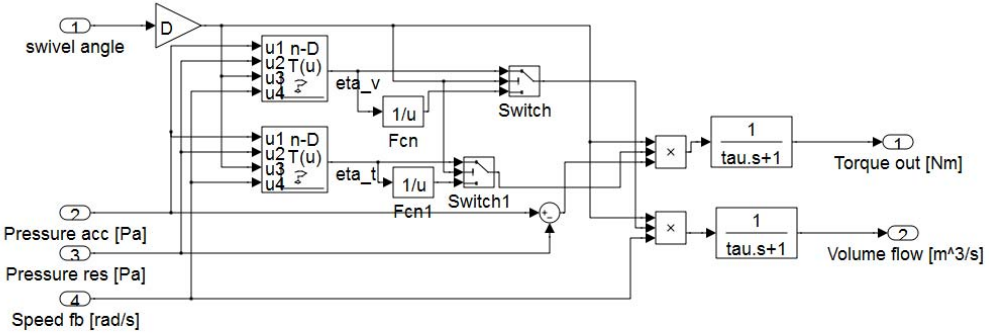
CVT



Accumulator



Hydraulic motor/pump



Results

- Mathematical models for
  - Flywheel
  - Accumulator
  - Pump/Motor
  - CVT
- MATLAB/Simulink implementation

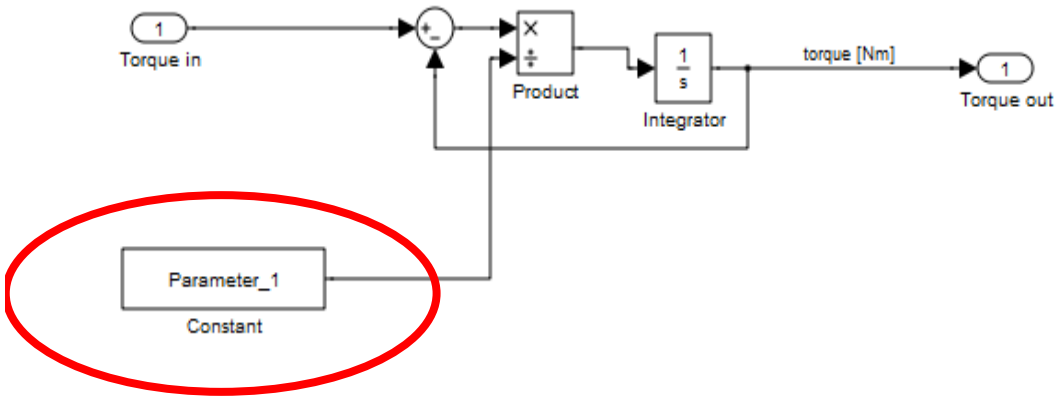
Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

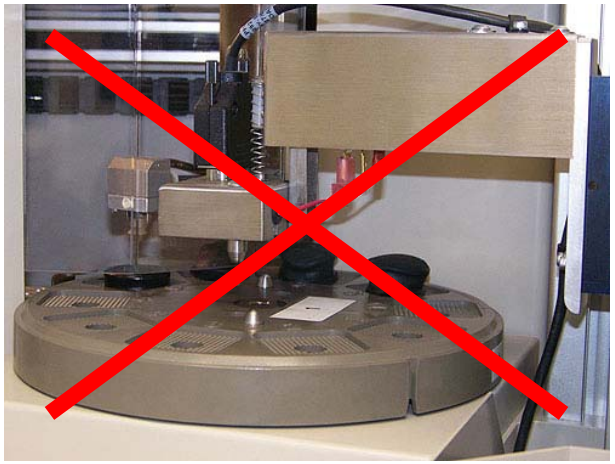
WP 3-3: Test methods for input data to non-electric component models

- In this workpackage, specifications on parameters that need to be determined in order to use the components modeled in WP 3-2 will be written. A feasibility study on how or if the parameters can be determined from experiments will also be conducted. Depending on the feasibility study, modifications on the component modeling might be necessary.

Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WP 3-3: Test methods for input data to non-electric component models





- The deliverable from this WP is the specifications of the component parameters.

Flywheel (set_param_flywheel)

```
% HILS parameters for Flywheel
%--------------------------------------------------------------------
% Jonas Fredriksson
% Chalmers University of Technology
% 2012-01-18
%--------------------------------------------------------------------

%--------------------------------------------------------------------
% Flywheel parameters
%--------------------------------------------------------------------
J                           = 4.7;     % Inertia [kgm^2]
w_loss_vec_radps        = ...      % Index vector for "torque losses" [rad/s]
    [0 10000 20000];
T_loss_vec_Nm          = ...      % Torque losses [Nm]
    [0 10000 20000];
```

Results

- Parameters specified for
  - Flywheel
  - Accumulator
  - Pump/Motor
  - CVT

- Working on: getting relevant data

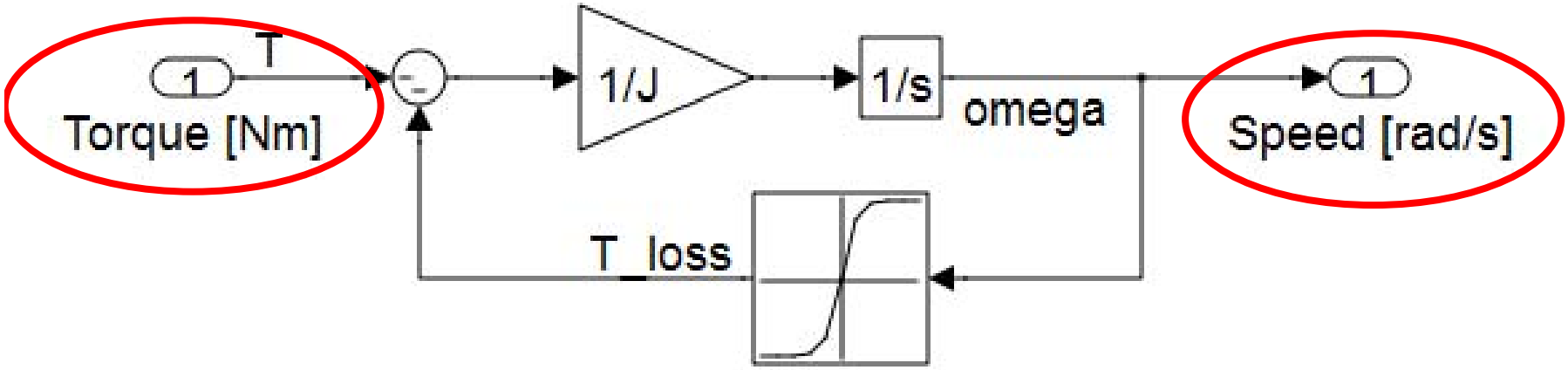
Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WP 3-4: Definition of control signals

- Based on the non-electric component models and also available components on the market today determine which control signals and sensor signals are necessary/available. Analysis for a standard interface connecting the hardware (HDH ECU) with the HILS software. Identifying the modifications needed to get non-electric hybrid components into the HILS method. This work will be in collaboration with WP 1, see TU Graz and TU Wien offer.

Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WP 3-4: Definition of control signals



- The result is a list of input and output signals to and from the non-electric components.

- Names need to be standardized
  - Suggestion: (`Component_description_unit`)

Development of Emissions and CO2 Test Procedure for Heavy Duty Hybrid Vehicles

WP 3-5: Alignment with HILS for HEV and verification

- Review of the HILS method to understand what modifications are needed to get the new components into the method. Hypothesis: No major modifications is needed, the non-electric components/subsystems have the same purpose as the electric components/subsystems. Verification of hypothesis.

- Result: Hypothesis is verified or suggestion on modification of method.

Next...

- Implementation
  - MATLAB/Simulink
- Parameterization/Verification (WT 3.3)
  - Data (Need to get real model data from suppliers or OEMs to verify model structure)
- Standardization of variable names (parameter names)
- System modelling (Parallel hydraulic hybrid)
  - Incorporate into the Japanese open-source model
  - Controller design (Started, a simple rule based controller)