VehProLib – Vehicle Propulsion Library - Including Turbocharged Gasoline and Diesel Engines

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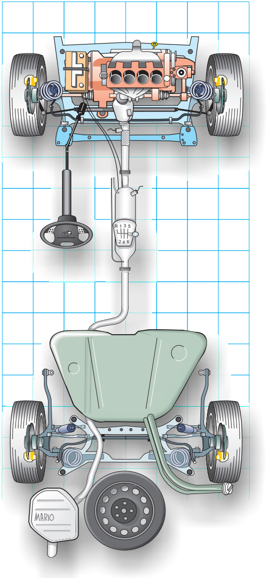
VehProLib – Goal of the library

VehProLib – Vehicle Propulsion Libary

- Simulate, analyze and control
  – Energy conversion and fuel consumption in vehicles.
- Investigate design choices.
- Details of relevance for control in the Powertrain.
- Only longitudinal motion.
- Possible to integrate it with other libraries using Modelica standard connectors.



Intended users – Guidelines for development

Heterogeneous usergroups

- Beginners/students:
  Have a set of simple models available
  Easy to use = simple structure
- Advanced users:
  Provide interface and connectors
  Refine the models to more advanced components
  Use standard components in some evaluations Easy to use

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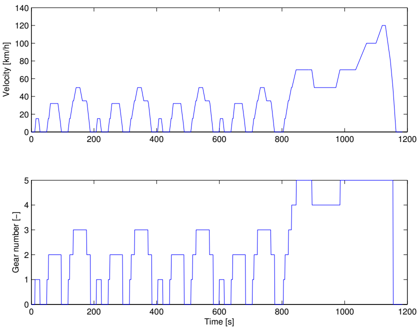
Driver and Driving Cycles

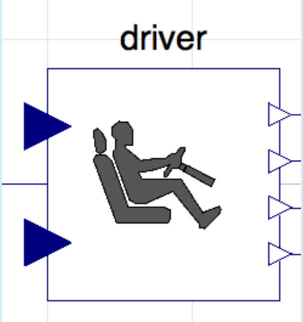
Driving cycles

Specify the driving mission



Driver

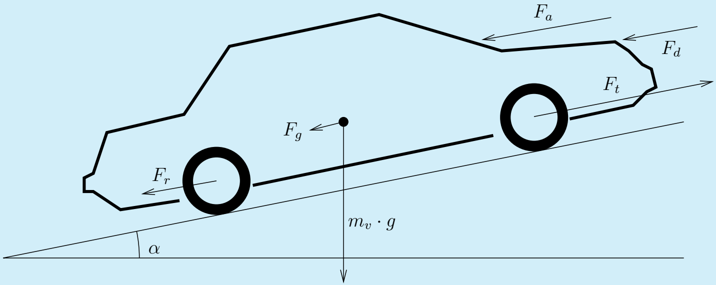
Controller that follows the cycle



Vehicle Properties

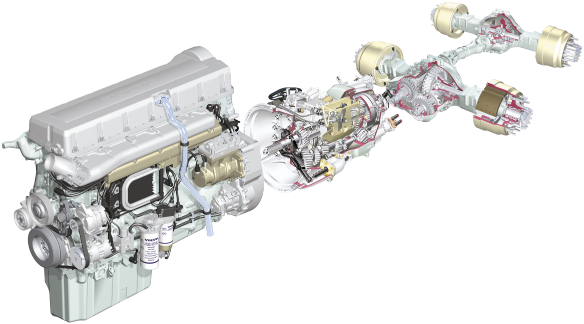
Submodels in the Vehicle

- Air Drag
- Rolling resistance
- Vehicle mass
- Road Slope



Drivetrain

- Couples the engine to the wheels, transferring the propulsive torque
- Includes gearboxes
  - Manual gearbox
  - Automatic gearbox



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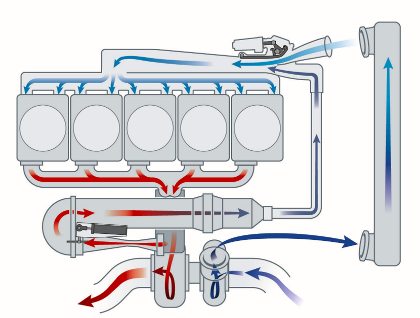
Engines and their layouts

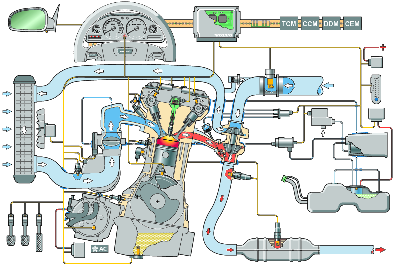
Common themes

- Controlling fluids: gas, liquids.
- Torque to drive the vehicle

Diesel engine



Gasoline engine



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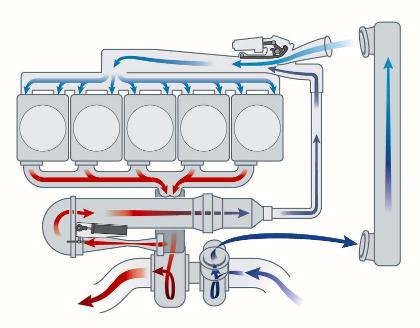
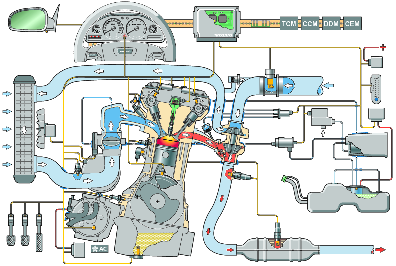


Gasoline engine



Pipes, flow devices (pumps & restrictions)

Modelling the gas flows

Restrictions and pumps in series with control volumes

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Restrictions and pumps in series with control volumes

Restrictions

- Incompressible laminar $\Delta p \propto \dot{m}$
- Incompressible turbulent $\Delta p \propto \dot{m}^2$
- Compressible isentropic (Appendix C in Heywood (1988))

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Restrictions and pumps in series with control volumes

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Control volume

- Filling and emptying
- Energy and mass balance

Modelling the gas flows

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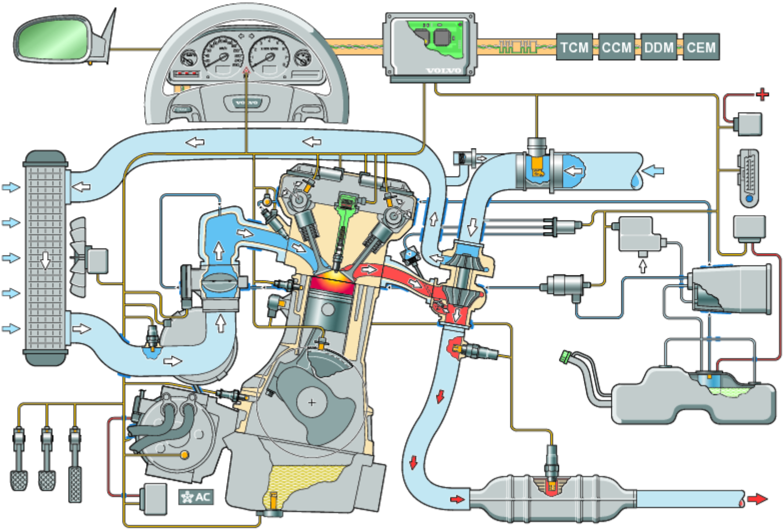
Sources (testing and boundary conditions)

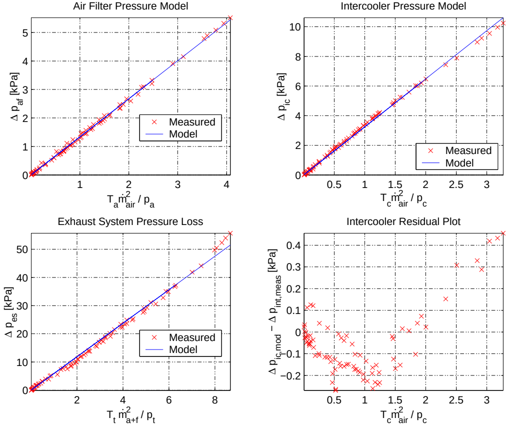
- Ambient
- Flow source

Engine Restrictions



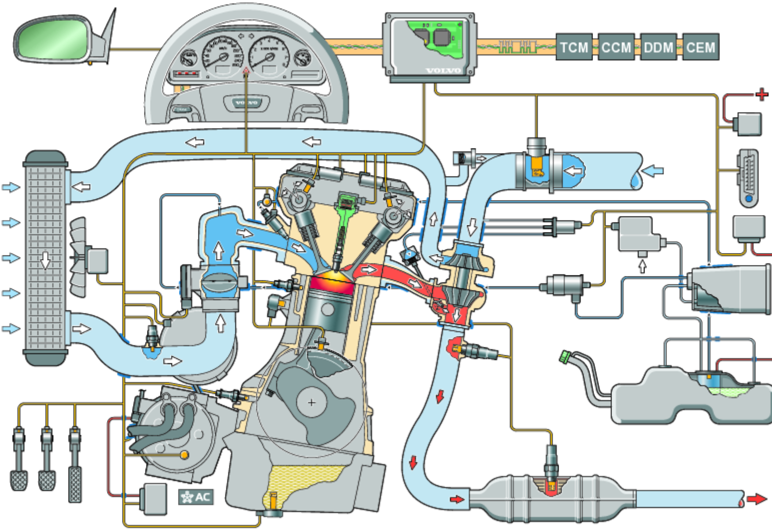
Engine Restrictions – Fluid Flows

Incompressible and turbulent flow



Validated on a component basis

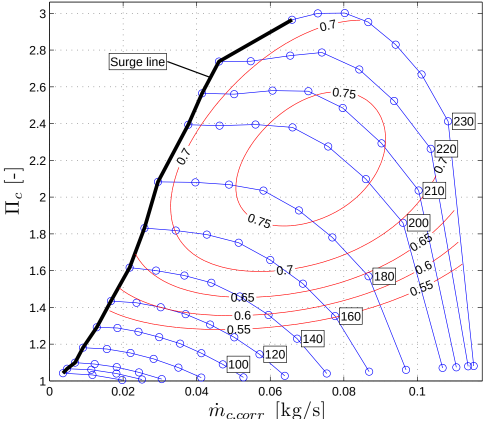
Turbochargers



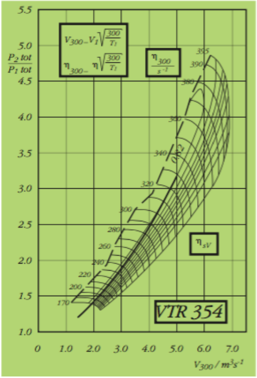
Turbochargers Performance

Different users want to use different models, different applications, favorite models, etc

Small gasoline engine



Large Marine Diesel



Turbochargers

Turbocharger modeling

- Some equations are fitted to the application (1a) & (1b).
- Some equations are generic for all compressors (1c) & (1d).

$$\dot{m}_{\mathsf{c}} = f_{\dot{m},c}(p_{01}, p_{02}, T_{01}, \omega_{\mathsf{c}}) \tag{1a}$$

$$\eta_{\mathsf{c}} = f_{\eta,c}(p_{01}, p_{02}, T_{01}, \omega_{\mathsf{c}}) \tag{1b}$$

$$T_{\mathsf{c}} = T_{01} + \frac{T_{01}}{\eta_c}\left\{ \left(\frac{p_{02}}{p_{01}}\right)^{\frac{\gamma-1}{\gamma}} - 1\right\} \tag{1c}$$

$$\dot{W}_c = \dot{m}_{\mathsf{c}}\, c_{p,c}\,(T_{\mathsf{c}} - T_{01}) \tag{1d}$$

Put generic equations in a base class, `Compressor_Template`.

Torque – MVEM Engine Model

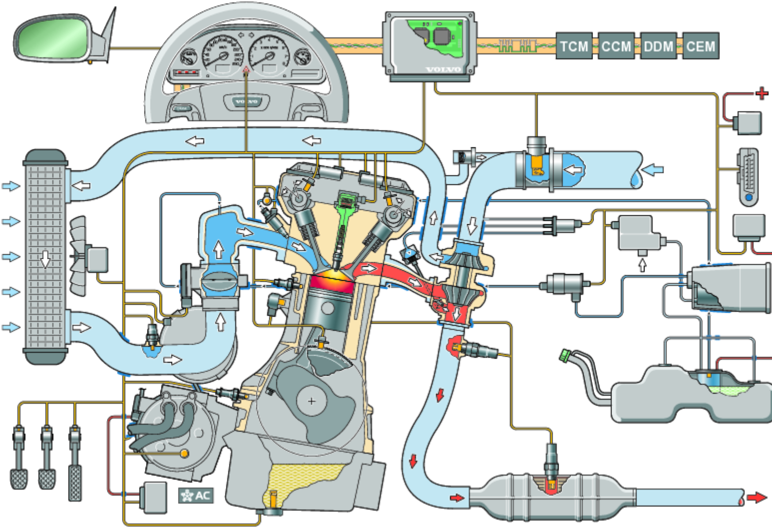
Use replaceable functions to let users tailor their models.

```
model Compressor "Complete compressor" extends
  VehProLib.Interfaces.Turbocharger.Compressor_Template;
replaceable function mass_flow =
  VehProLib.Functions.CompressorMaps.Model_8_9;
replaceable function efficiency =
  VehProLib.Functions.CompressorMaps.Model_8_5;
equation
  f_m = mass_flow(p_in = i.p, p_out = o.p, T_in = i.T, w = w);
  f_eta = efficiency(p_in = i.p, p_out = o.p, T_in = i.T, w = w);
end Compressor;
```

Base models from textbooks provide startingpoints for students and engineers.

```
VehProLib.Engine.Turbocharger.Compressor
  compressor(mass_flow = MyModel);
```

Engine As Torque Generator



Torque – MVEM Engine Model

- Mvem engine – Pump
- Torque calculation based upon:
  Ideal cycle
  –heat transfer
  –pumping work
  –friction
- Fast simulations
- Validated against detailed cylinder model
- Useful for Diesel and Gasoline

A Simple Physics Based Torque Model

Relation between work and torque

$$W = \oint M_c(\theta) d\theta = M\, 2\, n_r\, \pi \quad \Rightarrow \quad M = \frac{W}{n_r\, 2\, \pi}$$

Three component torque model

$$M = \frac{W_{ig} - W_{\text{pump}} - W_{fric}}{n_r\, 2\, \pi}$$

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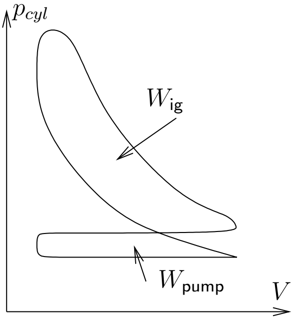

Three component torque model

$$M = \frac{W_{ig} - W_{\text{pump}} - W_{fric}}{n_r\, 2\, \pi}$$

Gross indicated work, W_{ig}

$$W_{ig} = m_f\, q_{LHV}\, \frac{1}{1 - r_c^{\gamma - 1}}\, \eta_{ig}\, \eta_{\lambda}\, \eta_{ign}$$

Pumping work, W_{pump}

$$W_{\text{pump}} = V_d\, (p_{em} - p_{im})$$

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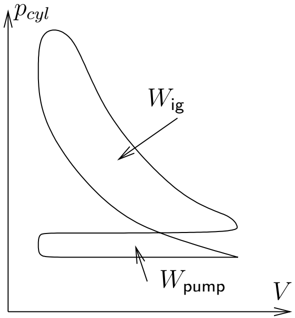

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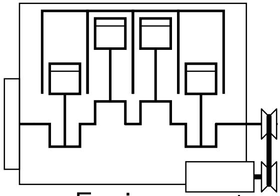
$$W_{\text{pump}} = V_d\, (p_{em} - p_{im})$$

Friction work, W_{fric}

$$W_{fric} = V_d\, FMEP(N)$$



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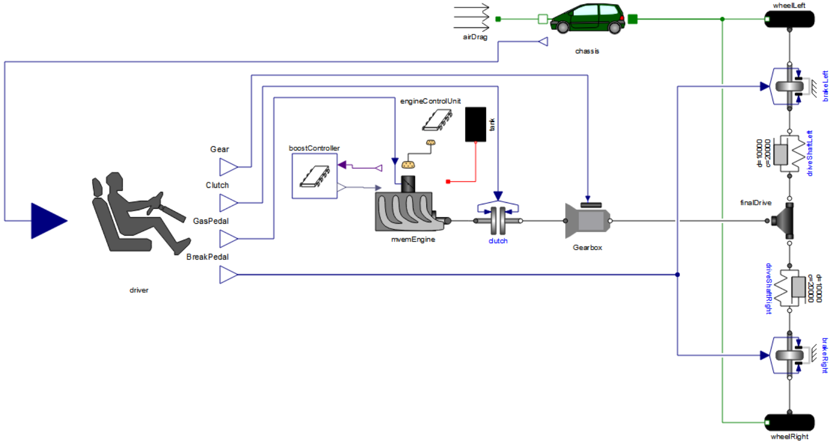
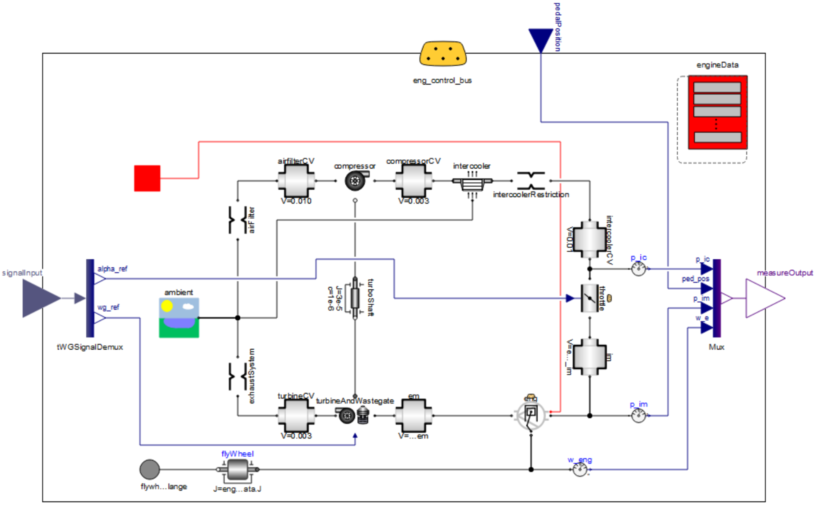
Vehicle with Driver

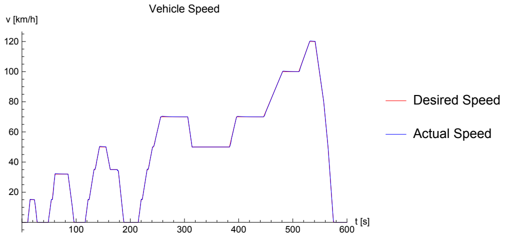
Small engine 1.3 liter, with turbocharger in a normal size vehicle.

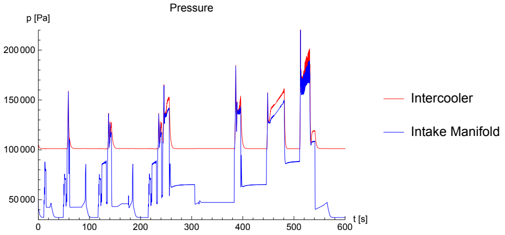


Engine


pedalPosition
eng_control_bus
engineData
airfilterCV
compressor
compressorCV
intercooler
intercoolerRestriction
V=0.010
V=0.003
airFilter
intercoolerCV
V=0.01
p_ic
signalInput
alpha_ref
wg_ref
ambient
tWGSignalDemux
J=3e-5
c=1e-6
turboShaft
throttle
ped_pos
p_im
w_e
Mux
measureOutput
exhaustSystem
im
turbineCV
turbineAndWastegate
em
eng
V=0.003
V=...em
flyWheel
flywh...lange
J=eng...ata.J
w_eng

Vehicle following the cycle





Summary

- VehProLib – Has been presented summarily.
- Vehicle in Longitudinal Motion.
- Some example models shown
- Engine design for both gasoline and diesel applications
- Library and Modelica constructs to aid both new users and advanced.
- A simple showcase, demonstrating turbocharging of a vehicle.

Summary

- VehProLib – Has been presented summarily.
- Vehicle in Longitudinal Motion.
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- Library and Modelica constructs to aid both new users and advanced.
- A simple showcase, demonstrating turbocharging of a vehicle.

- Availability and integration of education material can give penetration.
- OpenModelica provides opportunity for introduction.

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