# Engines Library

## Key features

» Available in two versions: Mean Value for fast simulation and Crank Angle Resolved for more detailed analysis

» A single model including intake and exhaust flow and mechanical dynamics

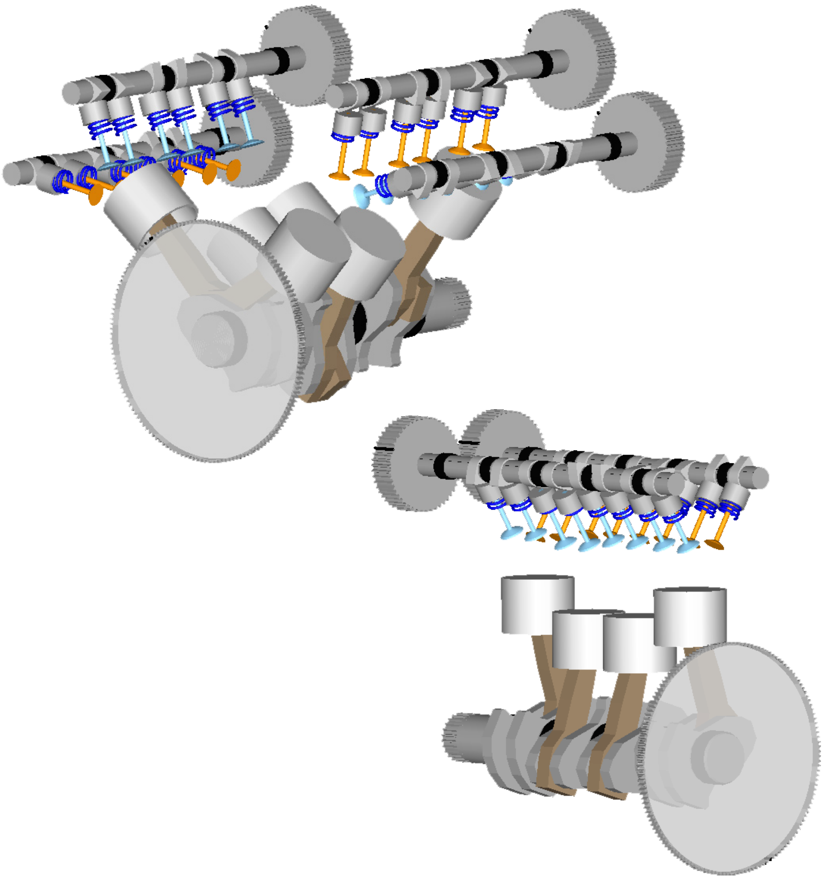
» Spark Ignition and Compression Ignition engines

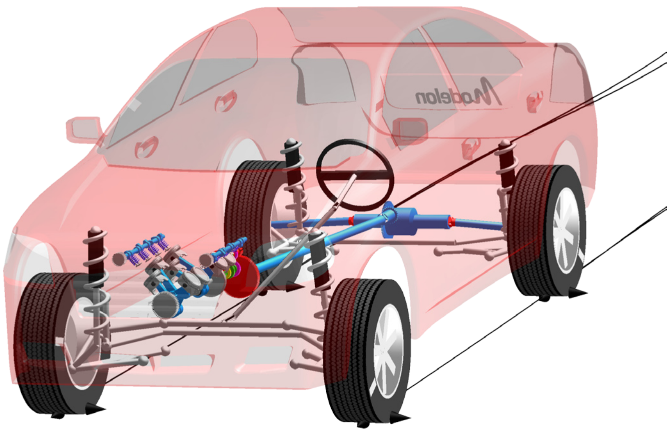
» Supports naturally aspirated and forced induction (turbochargers and superchargers)

» Uses standard Modelica connectors to promote compatibility with other automotive model libraries

» Introduces a new Rotational3D library developed by Claytex for efficient simulation of rotating MultiBody systems

» Compatible with Modelica 3.1 and Dymola 7.4 or later





## Introduction

The Engine library is capable of modelling both Spark Ignition and Compression Ignition engines and is split into two variants with different levels of fidelity. Both versions of the Engines library have been designed to work with common engine architecture templates. This enables quick model set-up and ensures a consistent layout for a variety of engine architectures.

The Mean Value version of the Engines library predicts the cycle averaged intake and exhaust flows, emissions and torque. The Crank Angle Resolved version predicts the complete cyclic intake and exhaust flows and torque.

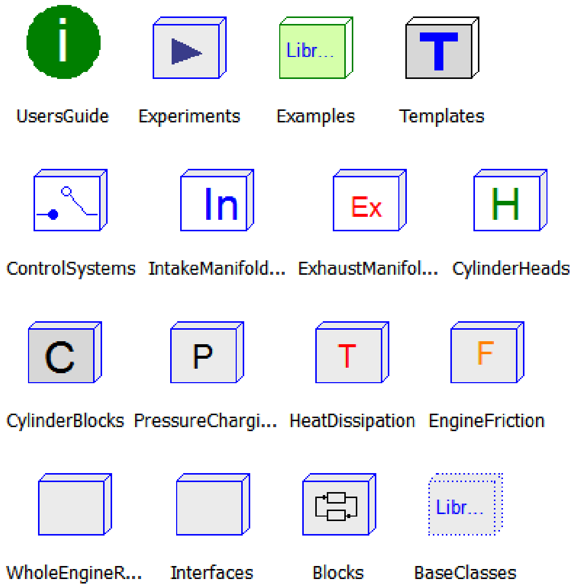
## Engines library

The Engines library provides a common model architecture for both the Mean Value and Crank Angle Resolved variants of the library. The library uses the new Modelica Fluid library and extends the range of fluid components to provide turbocharger, supercharger and catalytic converter models. Medium models have been developed to track the intake gases and exhaust emissions.

The mechanics are modelled in detail using the Rotational3D approach which enables the friction in every bearing and within the valve train to be accounted for and compliance in the crankshaft to be included.

Typical applications of the Engines library are for investigating/modelling:

- Control algorithm development
- Transient response of the complete system
- Mount forces
- Excitation of driveline with full cyclic torque
- Cranking (start-up) and engine warm up
- Detailed friction modelling
- Downsizing



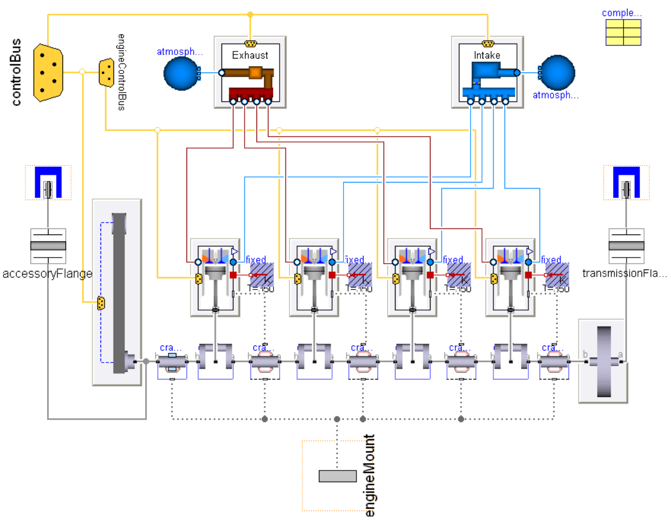

## Mean Value Version

The Mean Value version predicts the cycle averaged air flow and torque produced by the engine.

The cylinder mass flow rates are calculated through an equation based approach allowing the engine capacity to be scaled withi reasonable limits. This enables downsizing studies to be carried out using the library.

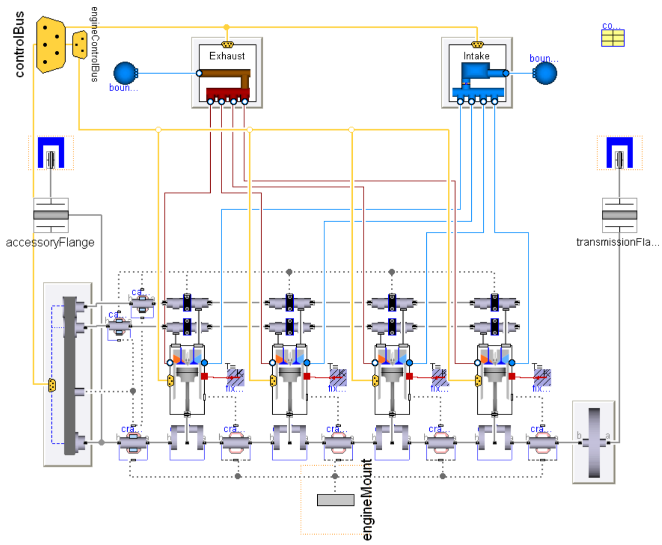
The combustion and emissions modelling is map based using manifold pressure and engine speed as the primary inputs to the maps with further corrections for spark timing and afr.

This version of the Engine library is particularly suited to driveability analysis where the effect of throttle transients on the driveline behaviour are investigated. In addition, this version of the library is also suited to catalyst light-off investigations.




## Crank Angle Resolved Version

The Crank Angle Resolved version predicts the cyclic variations for air flow and torque. This is an extension to the Mean Value version of the library.




The combustion heat release is modelled though a Wiebe model with table based coefficients. The table defines the Wiebe model coefficients at different engine speeds. Both Compression and Spark ignition heat release models are available. Port fuel and direct injection are also supported.

The flow though the engine block is dictated by the valve geometry and opening characteristics and the piston-cylinder assembly model. Valve and spark timing effects on the fluid dynamics and combustion model mean that the engine performance can be investigated using this version of the library.

This version of the Engine library is particularly suited to driveline nvh analysis, mount excitations, cranking and detailed friction modelling.

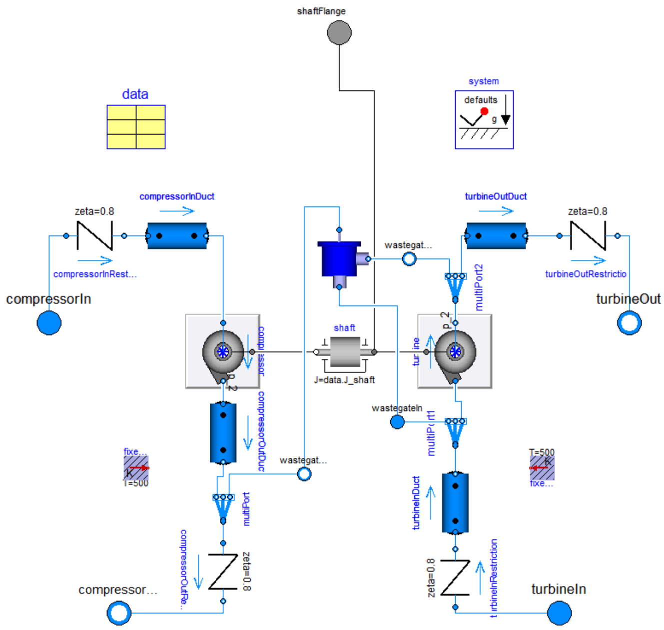
## Tailpipe Emissions

Emissions are modelled using a map based system. Fluid species are tracked throughout the engine model intake and exhaust models and three way catalytic converter models are available within the library with map based conversion efficiency.

The catalytic converter models include thermal effects so that catalyst light-off can be predicted. The heat transfer network for the catalyst links the fluid, brick, casing and environment temperatures to the rate of heat release from the chemical reactions.

## Pressure Charging

Pressure charging devices such as turbochargers and superchargers are available within the Engines library alongside intake and exhaust system models which support the use of pressure charging devices.



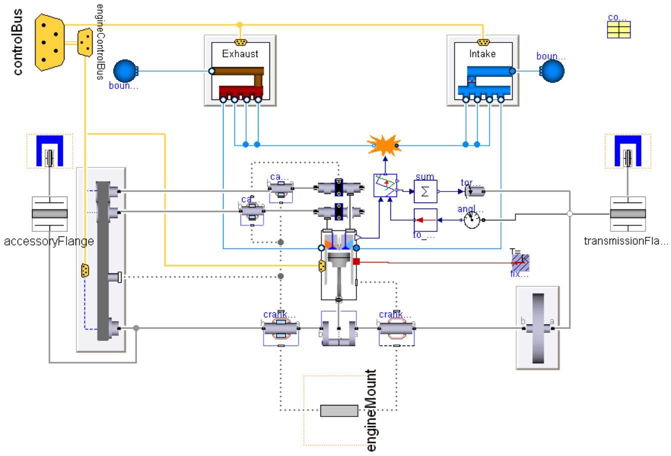

Radiator models, which are essentially heat exchangers, that are found within the Engines.Cooling package can be parametised and used as intercoolers. Test rigs within the library are available for map validation and bench testing of the components.

## Surrogate versions

Engine model simplification can be achieved through surrogate models. These are effectively multi-cylinder representations of engines using a single cylinder with flow and torque replication.

For the Mean Value version, the flow replication is continuous. The variables included in the replication are the port fluid mass flow rates, temperatures and composition.

The Crank Angle Resolved version replicates the same variables as the Mean Value version with the addition of the combustion torque. The flow and torque pulsations are replicated as a function of crank angle with varying angular resolution.




The surrogate models within both Mean Value and Crank Angle Resolved library versions seek to offer vastly reduced cpu times (up to 4.8 times reduction) whilst retaining levels of accuracy within 2% of a full model.

## Heat Transfer

Heat transfer models within the pipes and volumes in the Engines library are based on the Modelica.Fluid library with a number of customisations to support more detailed heat transfer correlations.

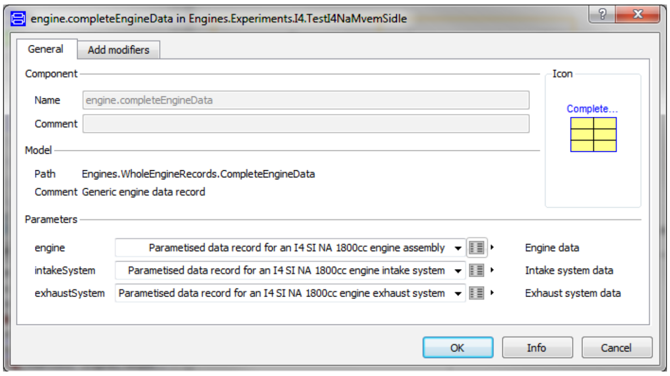
In addition to the standard models, a heat transfer model has been developed that uses a replaceable Nusselt number correlation. This enables the user to generate very accurate representations of the heat transfer characteristic of the engine being modelled using measured data. A wide range of published Nusselt number correlations are provided but the mechanism allows the user to easily add their own custom correlation.

## Model Architecture

Both versions use a common architecture. Predefined templates for a number of different engine and engine subsystem configurations are available. Each engine subsystem is template based to ensure compatibility when replacing the models. New customised models can be robustly built and integrated into the pre-defined testing environments.

Engines of similar architecture can be represented using the same underlying model while simply replacing the master data record of the engine containing maps and component geometry at the top level of the model. The master data records can also be modified locally for “on-the-fly” sensitivity analysis.

The master data record contains a number of replaceable and editable sub-records each relating to a specific engine component or assembly. The master data record and any of its sub-records can be duplicated to generate data records for different variants of an engine, component or assembly.




## Rotation3D Library

Claytex have developed a new Rotation3D library which is designed for the efficient simulation of rotating MultiBody systems. The Engines library makes extensive use of shafts and bearings from the Rotation3D library. The bearing models include replaceable friction models to represent different types of bearing.

The Rotation3D library uses standard Modelica connectors found within the MultiBody library making it compatible with existing libraries. Claytex are also completing the development of a detailed Powertrain Dynamics library that uses this same approach.

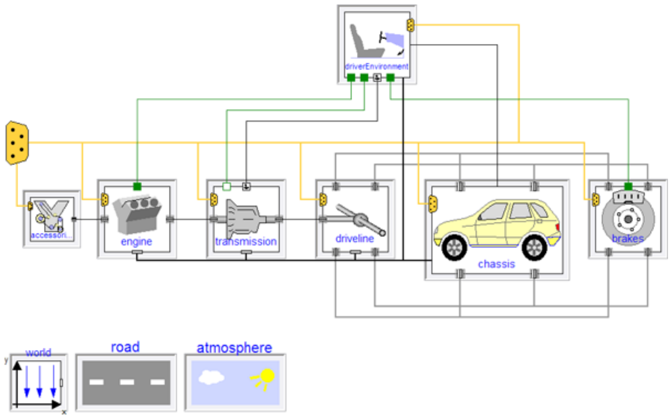
## Fluids Library

The fluid dynamics modelling within the engine models is achieved through using the Fluid library found within the Modelica Standard Library (MSL 3.1 or later). This library supports the modelling of 1D thermofluid pipe networks using single and multiple species medium models.

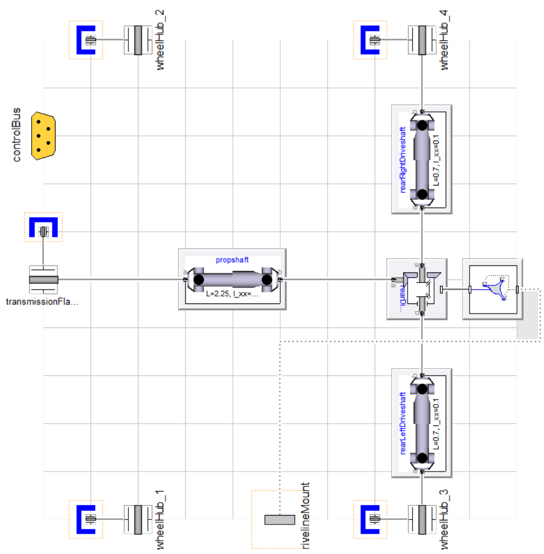
Specialised fluid components for use in Engines are based on interfaces defined within the Fluid library. This maximises the reusability component models and ensures compatibility with the standard library.

## Vehicle Interfaces

All engine models are based on an engine template defined within the VehicleInterfaces library. The VehicleInterfaces library was developed to provide a range of automotive based application/component templates to ensure a common interface is maintained across libraries.




All signal bus components are also based on the VehicleInterfaces bus models. These are used to carry signals between the Engine Control Unit (ECU) and the sensors and actuators on the engine and viceversa.





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