Model Library

Torsional Vibration Analysis

The SimulationX model library Torsional Vibration Analysis (TVA) provides all necessary means for steady-state vibration analyses of drive systems with focus on ship propulsion systems. All elements are specially adapted to this specific use case for maximum usability and reliable results. The required parameters are either common mechanical values or available from manufacturer’s product data sheets. For unknown parameters, several physical estimation approaches are available.

Many models support the computation of stress, torque and power loss limits. Powers are computed as spectral powers.

All elements which take inertia, stiffness or damping into account can be parameterized with either real or reduced data (data of an equivalent system) and the corresponding speed ratio. The results are provided as real data in both cases.

Models with user-defined and frequently used parameter sets can be saved as custom elements directly in the library for further use in other simulation models (except for the Basic Elements sub-library).

- Specially designed for steady-state vibration analyses of propulsion systems
- Efficient modeling of torsional vibration systems including engines, gears, shafts, couplings, dampers and electrical machines
- Parameter input by design data and catalog data
- Quasi-static, rigid and dynamic model properties available
Basic Elements

The Basic Elements sub-library comprises basic elements for powertrain modeling. They can be used to create complex engine and machine models and to compute torsional stress in each element. All elastic elements can also represent rigid behavior, for example, to simulate quasi-stationary parts. The corresponding torsional stress is calculated regardless.

<table>
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<tr>
<th>Element</th>
<th>Description</th>
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| Inertia                  | • Represents a rotational inertia  
• Computes acceleration torque and kinetic quantities  
• Can also be configured with reduced data |
| External Torque          | • Torque between two inertias or between inertia and environment (considers Newton’s third law)  
• Can be used for individual spring, damper and coupling models, for example |
| Spring-Damper            | • A spring and a damper connected in parallel with constant stiffness and damping  
• Damping parameterized with damping constant, relative damping, Lehr’s damping factor or by approximation  
• Computation of torsional stress and stress limits (approaches for the propulsion and auxiliary shaft selectable)  
• Can be configured with reduced data |
| Elastic Coupling         | • Considers a coupling’s rotational inertia and elastic properties  
• Dynamic stiffness can be configured with constant value or as characteristic curve depending on mean speed or mean torque |
| Shaft Model              | • Considers rotational inertia, elastic properties and transmission ratio  
• Parameterized with design data |
| Absolute Damper          | • Damper between element and environment  
• Available damping types:  
  • Oscillation damping behavior (no damping of mean value)  
  • Total damping (damping of oscillation and mean value) |
| Spring Captive Damper    | • Considers rotational inertia and elastic properties  
• Can be used at shaft ends, e.g. as engine crankshaft damper |
| Viscous Damper           | • Considers the inertias of the damper housing and the (inner) ring  
• Damping coefficient can be set as parameter or is determined by approximation  
• Can be used at shaft ends, e.g. as engine crankshaft damper |
| Gear                     | • Simple gear model, parameterized with a constant ratio  
• Considers rotational gear stiffness and damping  
• Can also be used as general transmission model for the representation of belt drives and chain drives |
| Sensor                   | • Sensor for transforming rotational kinetic quantities into signals (interface element between mechanical and signal-oriented model structures) |
Function \( f(x) \)
- Signal block for the implementation of functions in signal-oriented model structures
- Results are provided at an output pin
- Input functions: constant values, reference expressions to any variable or mathematical formula expression depending on the input signal

Curve
- Special signal block for the implementation of a characteristic curve depending on the input signal
- Application example: representation of speed-dependent load torque curves

**Engine Models**

The sub-library *Engine Models* provides inline and vee cylinders as well as ready-made engine model elements. Together with models from the *Basic Elements* library, any engine configuration can be modeled. All models contain an excitation approach optionally based on given crank excitation torques (torques can be computed by effective pressures) or on cylinder pressures. They can be controlled by the injection and are able to compute torsional stress of the cranks. The crank of the cylinder and engine models can be either defined with rigid or elastic behavior.

The engine models can be modified and extended by the user for specific applications. The mechanical data of the rotational system can also be entered as reduced data of an equivalent system.

**Inline Cylinder**
- Cylinder model for inline engines and model of a vee cylinder pair for vee engines
- Consideration of cylinder geometry (firing angle, piston stroke, bore diameter etc.), mechanical properties of the crank (rotating and reciprocating masses, stiffness and damping of the crank etc.)
- Consideration of absolute damping at the crank, for modeling of speed-dependent losses (e.g. losses in the oil sump)
- Consideration of a torque or force excitation model (individual setup for vee cylinders)
- Interpolation between two load cases based on the injection setting (control parameter)
- Consideration of misfiring cylinders or cylinder with open valves (no compression)
- Computation of stress, powers and kinetic quantities

**Vee Cylinder Pair**
- Based on the Inline Cylinder model
- Global setup of all necessary mechanical data (inertias, stiffnesses etc.) and optional excitation data (cylinder force or torque excitation)
- Computation of firing angles based on the firing order
- Individual setup of one or more misfiring cylinders
- Control of the engine torque via the injection (compensation parameter)

**Inline Engines**: L4, L6, L8 (picture: L4 Engine)
- Based on the Inline Cylinder model
- Global setup of all necessary mechanical data (inertias, stiffnesses etc.) and optional excitation data (cylinder force or torque excitation)
- Computation of firing angles based on the firing order
- Individual setup of one or more misfiring cylinders
- Control of the engine torque via the injection (compensation parameter)

**Vee Engines**: V6, V8, V10, V12 (picture: V6 Engine)
- Based on the Vee Cylinder Pair model
- Same parameterization option as for inline engines
- Direct input of firing angles
- Individual setup of one or more misfiring cylinders
- Control of the engine torque via the injection (compensation parameter)
## Machines

The *Machines* sub-library provides a collection of load elements typical of marine applications. All elements are modeled from a mechanical load behavior’s point of view and its influences on the propulsion system.

<table>
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<tr>
<th>Element</th>
<th>Features</th>
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<td><strong>Motor</strong></td>
<td>- Consideration of rotor inertia&lt;br&gt;- Load is computed based on the nominal power and the nominal speed&lt;br&gt;- Computation of the motor/generator torque (internal torque limitation) as well as acceleration torque, total torque, kinetic quantities and powers&lt;br&gt;- Different symbols for Motor and Generator for better determination</td>
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<tr>
<td><strong>Generator</strong></td>
<td>- Consideration of rotor inertia&lt;br&gt;- Load is computed based on the nominal power and the nominal speed&lt;br&gt;- Computation of the motor/generator torque (internal torque limitation) as well as acceleration torque, total torque, kinetic quantities and powers</td>
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<tr>
<td><strong>Pump</strong></td>
<td>- Representation of pumps (e.g. centrifugal pump) with consideration of pump inertia&lt;br&gt;- Load is computed based on the nominal power and the nominal speed&lt;br&gt;- Computation of the pump torque (internal torque limitation) as well as acceleration torque, total torque, kinetic quantities and powers</td>
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<tr>
<td><strong>Marine Propeller</strong></td>
<td>- Consideration of the rotor inertia&lt;br&gt;- Averaged rotor load based on the propeller’s characteristic curve, mathematical expression or value (compensation parameter)&lt;br&gt;- Computation of the rotor blade excitation (1st and 2nd blade order) based on the number of rotor blades&lt;br&gt;- Computation of the rotor’s damping through internal approaches for open or ducted propeller</td>
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