

Generic Engine

Internal combustion engine with throttle and rotational inertia and time lag

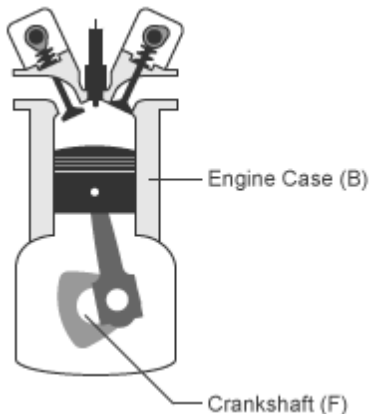
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Description

The block represents a general internal combustion engine. Engine types include spark-ignition and diesel. Speed-power and speed-torque parameterizations are provided. A throttle physical signal input specifies the normalized engine torque. Optional dynamic parameters include crankshaft inertia and response time lag. A physical signal port outputs engine fuel consumption rate based on choice of fuel consumption model. Optional speed and redline controllers prevent engine stall and enable cruise control.



Generic Engine Model

By default, the Generic Engine model uses a programmed relationship between torque and speed, modulated by the throttle signal.

Engine Speed, Throttle, Power, and Torque

The engine model is specified by an *engine power demand* function $g(\Omega)$. The function provides the maximum power available for a given engine speed Ω . The block parameters (maximum power, speed at maximum power, and maximum speed) normalize this function to physical maximum torque and speed values.

The normalized throttle input signal T specifies the actual engine power. The power is delivered as a fraction of the maximum power possible in a steady state at a fixed engine speed. It modulates the actual power delivered, P , from the engine: $P(\Omega, T) = T \cdot g(\Omega)$. The engine torque is $\tau = P/\Omega$.

Engine Power Demand

The engine power is nonzero when the speed is limited to the operating range, $\Omega_{\min} \leq \Omega \leq \Omega_{\max}$. The absolute maximum engine power P_{\max} defines Ω_0 such that $P_{\max} = g(\Omega_0)$. Define $w \equiv \Omega/\Omega_0$ and $g(\Omega) \equiv P_{\max} \cdot p(w)$. Then $p(1) = 1$ and $dp(1)/dw = 0$. The torque function is:

$$\tau = (P_{\max}/\Omega_0) \cdot [p(w)/w].$$

You can derive forms for $p(w)$ from engine data and models. Generic Engine uses a third-order polynomial form:

$$p(w) = p_1 \cdot w + p_2 \cdot w^2 - p_3 \cdot w^3$$

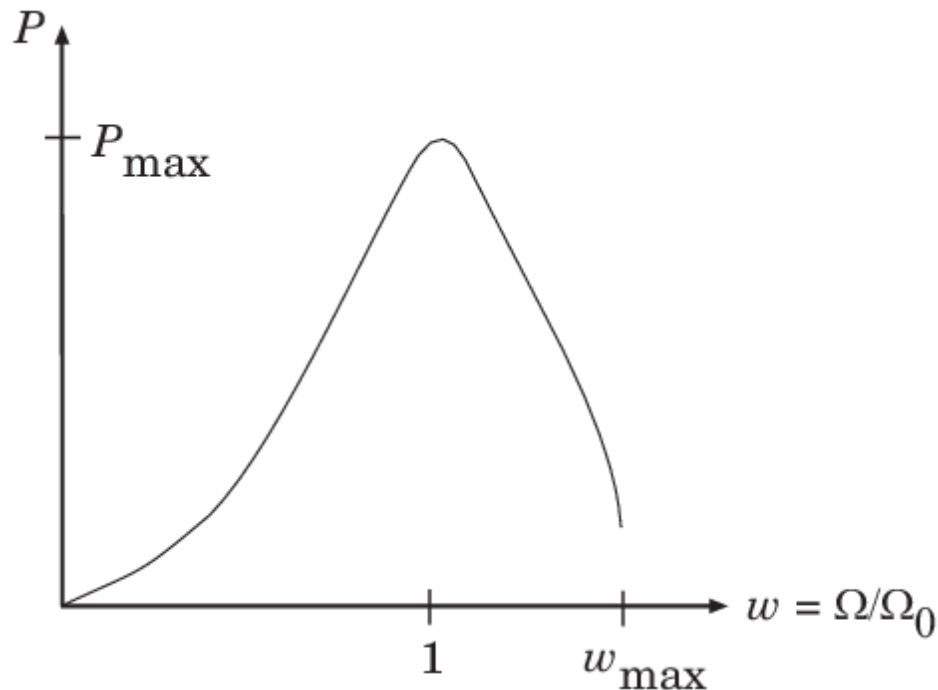
satisfying

$$p_1 + p_2 - p_3 = 1, p_1 + 2p_2 - 3p_3 = 0.$$

In typical engines, the p_i are positive. This polynomial has three zeros, one at $w = 0$, and a conjugate pair. One of the pair is positive and physical; the other is negative and unphysical:

$$w_{\pm} = \frac{1}{2} \left(-p_2 \pm \sqrt{p_2^2 + 4p_1 p_3} \right)$$

Typical Engine Power Demand Function



Restrictions on Engine Speed and Power

- For the engine power polynomial, there are restrictions, as shown, on the polynomial coefficients p_i , to achieve a valid power-speed curve.
- If you use tabulated power or torque data, corresponding restrictions on $P(\Omega)$ remain.

Specify the speed and power as $w = \Omega/\Omega_0$ and $p = P(\Omega)/P_0$ and define the boundaries as $w_{\min} = \Omega_{\min}/\Omega_0$ and $w_{\max} = \Omega_{\max}/\Omega_0$. Then:

- The engine speed is restricted to a positive range above the minimum speed and below the maximum speed: $0 \leq w_{\min} \leq w \leq w_{\max}$.
- The engine power at minimum speed must be nonnegative: $p(w_{\min}) \geq 0$. If you use the polynomial form, this condition is a restriction on the p_i :

$$p(w_{\min}) = p_1 \cdot w_{\min} + p_2 \cdot w_{\min}^2 - p_3 \cdot w_{\min}^3 \geq 0.$$
- The engine power at maximum speed must be nonnegative: $p(w_{\max}) \geq 0$. If you use the polynomial form, this condition is a restriction on w_{\max} : $w_{\max} \leq w_+$.

Engine Power Forms for Different Engine Types

For the default parameterization, Generic Engine provides two choices of internal combustion engine types, each with different engine power demand parameters.

Power Demand Coefficient	Engine Type:	
	Spark-Ignition	Diesel
p_1	1	0.6526
p_2	1	1.6948
p_3	1	1.3474

Idle Speed Controller Model

The idle speed controller adjusts the throttle signal to increase engine rotation below a reference speed according to the following expressions:

$$\Pi = \max(\Pi_i, \Pi_c)$$

and

$$\frac{d(\Pi_c)}{dt} = \frac{0.5 \cdot \left(1 - \tanh\left(4 \cdot \frac{\omega - \omega_r}{\omega_t}\right)\right) - \Pi_c}{\tau}$$

where:

- Π — Engine throttle
- Π_i — Input throttle (port T)
- Π_c — Controller throttle
- ω — Engine speed
- ω_r — Idle speed reference
- ω_t — Controller speed threshold
- τ — Controller time constant

The controlled throttle increases with a first-order lag from zero to one when engine speed falls below the reference speed. When the engine speed rises above the reference speed, the controlled throttle decreases from one to zero. When the difference between engine velocity and reference speed is smaller than the controller speed threshold, the *tanh* function smooths the time derivative of the controlled throttle. The controlled throttle is limited to the range 0–1. The engine uses the larger of the input and controlled throttle values. If engine time lag is included, the controller changes the input *before* the lag is computed.

Redline Controller Model

While the idle speed controller determines the minimum throttle value for maintaining engine speed, the redline controller prevents excessive speed based on a maximum throttle input. To determine the maximum throttle value, the redline controller uses the idle speed controller model equation. However, for the redline controller:

- ω_r is the redline speed reference.
- ω_t is the redline speed threshold.
- τ is the redline time constant.

Limitations

This block contains an engine time lag limitation.

Engine Time Lag

Engines lag in their response to changing speed and throttle. The Generic Engine block optionally supports lag due to a changing throttle only. Time lag simulation increases model fidelity but reduces simulation performance.

Ports

Port	Description
B	Rotational conserving port representing the engine block
F	Rotational Conserving port representing the engine crankshaft
T	Physical signal input port specifying the normalized engine throttle level
P	Physical signal output port reporting the instantaneous engine power
FC	Physical signal output port reporting the fuel consumption rate

Port T accepts a signal with values in the range 0–1. The signal specifies the engine torque as a fraction of the maximum torque possible in steady state at fixed engine speed. The signal saturates at zero and one. Values below zero are interpreted as zero. Values above one are interpreted as one.

Parameters

Engine Torque

Model parameterization

- Select how to model the engine. Choose between these options, each of which enable other parameters:
- `Normalized 3rd-order polynomial matched to peak power` — Parametrize the engine with a power function controlled by power and speed characteristics. This is the default option.
 - `Tabulated torque data` — Engine is parametrized by speed–torque table that you specify.
 - `Tabulated power data` — Engine is parametrized by speed–power table that you specify.

Engine type

Choose type of internal combustion engine. Choose between `Spark-ignition`, the default option, and `Diesel`. Selecting `Normalized 3rd-order polynomial matched to peak power` for the **Model**

parameterization parameter enables this parameter.

Maximum power

Maximum power P_{\max} that the engine can output. The default is 150 kW. Selecting `Normalized 3rd-order polynomial matched to peak power` for the **Model parameterization** parameter enables this parameter.

Speed at maximum power

Engine speed Ω_0 at which the engine is running at maximum power. The default is 4500 rpm. Selecting `Normalized 3rd-order polynomial matched to peak power` for the **Model parameterization** parameter enables this parameter.

Maximum speed

Maximum speed Ω_{\max} at which the engine can generate torque. The default is 6000 rpm. Selecting `Normalized 3rd-order polynomial matched to peak power` for the **Model parameterization** parameter enables this parameter.

During simulation, if Ω exceeds this maximum, the simulation stops with an error. The engine maximum speed Ω_{\max} cannot exceed the engine speed at which the engine power becomes negative.

Stall speed

Minimum speed Ω_{\min} at which the engine can generate torque. The default is 500 rpm. Selecting `Normalized 3rd-order polynomial matched to peak power` for the **Model parameterization** parameter enables this parameter.

During simulation, if Ω falls below this minimum, the engine torque is blended to zero.

Speed vector

Vector of values of the engine function's independent variable, the speed Ω . The default is [500, 1000, 2000, 3000, 4000, 5000, 6000, 7000] rpm. Selecting `Tabulated torque data` or `Tabulated power data` for the **Model parameterization** parameter enables this parameter.

The first and last speeds in the vector are interpreted as the stall speed and the maximum speed, respectively. If the speed falls below the stall speed, engine torque is blended to zero. If the speed exceeds the maximum speed, the simulation stops with an error.

Torque vector

Vector of values of the engine function's dependent variable, the torque τ . The default is [380, 380, 380, 380, 350, 280, 200, 80] N*m. Selecting `Tabulated torque data` for the **Model parameterization** parameter enables this parameter.

Power vector

Vector of values of the engine function's dependent variable, the power P . The default is [20, 40, 78, 120, 145, 148, 125, 60] kW. Selecting `Tabulated power data` for the **Model parameterization** parameter enables this parameter.

Interpolation method

Method to interpolate the engine speed–torque or speed–power function between discrete relative velocity values within the range of definition. Choose between `Linear`, the default choice, and `Smooth`. Selecting `Tabulated torque data` or `Tabulated power data` for the **Model parameterization** parameter

enables this parameter.

Dynamics

Inertia

Select how to model the rotational inertia of the engine block. Choose between these options, each of which enables other parameters:

- `No inertia` — Engine crankshaft is modeled with no inertia. This option is the default.
- `Specify inertia and initial velocity` — Engine crankshaft is modeled with rotational inertia and initial angular velocity.

Engine Inertia

Rotational inertia of the engine crankshaft. The default is $1 \text{ kg}\cdot\text{m}^2$. Selecting `Specify inertia and initial velocity` for the **Inertia** parameter enables this parameter.

Initial velocity

Initial angular velocity $\Omega(0)$ of the engine crankshaft. The default is 800 rpm. Selecting `Specify inertia and initial velocity` for the **Inertia** parameter enables this parameter.

Time constant

Select how to model the time lag of the engine response. Choose between these options, each of which enables other options:

- `No time constant - Suitable for HIL simulation` — Engine reacts with no time lag. This option is the default.
- `Specify engine time constant and initial throttle` — Engine reacts with a time lag.

Engine time constant

Engine time lag. The default is 0.2 s.

Initial normalized throttle

Initial normalized engine throttle $T(0)$, ranging between zero and one. The default is 0.

Limits

Speed threshold

Width of the speed range over which the engine torque is blended to zero as Ω approaches the stall speed. The default is 100 rpm.

Fuel Consumption

Fuel consumption model

Select model to specify engine fuel consumption. Models range from simple to advanced parameterizations compatible with standard industrial data. Choose between these options, each of which enables other options:

- `Constant per revolution` — The default option

- Fuel consumption by speed and torque
- Brake specific fuel consumption by speed and torque
- Brake specific fuel consumption by speed and brake mean effective pressure

Fuel consumption per revolution

Enter the volume of fuel consumed in one crankshaft revolution. The default is 25 mg/rev. Selecting `Constant per revolution` for the **Fuel consumption model** parameter enables this parameter.

Displaced volume

Enter the volume displaced by a piston stroke. The default is 400 cm³.

Selecting `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

Revolutions per cycle

Enter the number of crankshaft revolutions in one combustion cycle — e.g. 2 for a four-stroke engine, or 1 for a two-stroke engine. The default is 2.

Selecting `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

Speed vector

Enter vector of engine speeds used in lookup table parameterizations. Vector size must match **Torque vector size**. The default is [1000, 2000, 3000, 4000, 5000, 6000] rpm. Selecting `Fuel consumption by speed and torque`, `Brake specific fuel consumption by speed and torque`, or `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

Torque vector

Enter vector of engine torques used in the lookup table parameterizations. Vector size must match **Speed vector size**. The default is [0, 80, 160, 200, 240, 320, 360, 400] N*m. Selecting `Fuel consumption by speed and torque` or `Brake specific fuel consumption by speed and torque` for the **Fuel consumption model** parameter enables this parameter.

Fuel consumption table

Enter matrix with fuel consumption rates corresponding to engine speed and torque vectors. The number of rows must equal the number of elements in the **Speed vector**. The number of columns must equal the number of elements in the **Torque vector**. The default is [.5, .9, 1.4, 1.6, 1.9, 2.7, 3.4, 4.4; 1, 1.7, 2.7, 3.1, 3.6, 5, 6, 7.4; 1.4, 2.7, 4, 4.8, 5.6, 7.5, 8.5, 10.5; 2, 3.6, 5.8, 6.7, 8, 10.4, 11.7, 13.3; 2.5, 4.8, 7.9, 9.4, 10.8, 14, 16.2, 18.6; 3.1, 6, 10.3, 11.9, 13.8, 18.4, 22, 26.5] g/s.

Selecting `Fuel consumption by speed and torque` for the **Fuel consumption model** parameter enables this parameter.

Brake mean effective pressure vector

Enter vector of brake mean effective pressure (BMEP) values. The default is [0, 250, 500, 625, 750, 1000, 1150, 1250] kPa. The BMEP satisfies the expression:

$$BMEP = T \cdot \left(\frac{2\pi \cdot n_c}{V_d} \right)$$

where:

- T — Output torque
- n_c — Number of cycles per revolution
- V_d — Cylinder displaced volume

Selecting `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

Brake specific fuel consumption table

Selecting `Brake specific fuel consumption by speed and torque` or `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

For the `Brake specific fuel consumption by speed and torque` fuel model, enter the matrix with brake specific fuel consumption (BSFC) rates corresponding to engine speed and torque vectors. BSFC is the ratio of the fuel consumption rate to the output power. The number of rows must equal the number of elements in the **Speed vector**. The number of columns must equal the number of elements in the **Torque vector**.

For the `Brake specific fuel consumption by speed and brake mean effective pressure` fuel model, enter the matrix with brake specific fuel consumption (BSFC) rates corresponding to engine speed and brake mean effective pressure (BMEP) vectors. BSFC is the ratio of the fuel consumption rate to the output power. The number of rows must equal the number of elements in the **Speed vector**. The number of columns must equal the number of elements in the **Brake mean effective pressure vector**.

For both fuel-consumption models, the default is [410, 380, 300, 280, 270, 290, 320, 380; 410, 370, 290, 270, 260, 270, 285, 320; 415, 380, 290, 275, 265, 270, 270, 300; 420, 390, 310, 290, 285, 280, 280, 285; 430, 410, 340, 320, 310, 300, 310, 320; 450, 430, 370, 340, 330, 330, 350, 380] g/hr/kW.

Interpolation method

Select the interpolation method used to calculate fuel consumption at intermediate speed-torque values. Methods are `Linear` and `Smooth`. Outside the data range, fuel consumption is held constant at the last value given in the lookup table. Selecting `Fuel consumption by speed and torque`, `Brake specific fuel consumption by speed and torque`, or `Brake specific fuel consumption by speed and brake mean effective pressure` for the **Fuel consumption model** parameter enables this parameter.

Speed Control

Idle speed control

Select speed control model. The options are:

- `No idle speed controller` — Omit idle speed controller. Throttle input is used directly. This option is the default.

- `Enable idle speed controller` — Include idle speed controller to prevent engine stalling. This option enables other parameters. For more information, see [Idle Speed Controller Model](#).

Idle speed reference

Enter the value of the speed reference below which speed increases, and above which speed decreases. The default is 1000 rpm.

Selecting `Enable idle speed controller` for the **Idle speed control** parameter enables this parameter.

Controller time constant

Enter the value of the time constant associated with an increase or decrease of the controlled throttle. The constant value must be positive. The default is 1 s.

Selecting `Enable idle speed controller` for the **Idle speed control** parameter enables this parameter.

Controller threshold speed

Parameter used to smooth the controlled throttle value when the engine's rotational speed crosses the idle speed reference. For more information, see [Idle Speed Controller Model](#). Large values decrease controller responsiveness. Small values increase computational cost. This parameter must be positive. The default is 1 rpm.

Selecting `Enable idle speed controller` for the **Idle speed control** parameter enables this parameter.

Redline control

Select redline control model. Options include `No redline controller` and `Enable redline controller`.

- `No redline controller` — Omit redline controller. Throttle depends only on the idle speed controller. This option is the default.
- `Enable redline controller` — Include redline controller to prevent excessive speed. This option enables other parameters.

Redline speed

Enter the value of the speed reference above which the redline control activates. The default is 5000 rpm.

Selecting `Enable redline controller` for the **Redline control** parameter enables this parameter.

Redline time constant

Enter the value of the time constant associated with an increase or decrease of the controlled throttle. The constant value must be positive. The default is 1 s.

Selecting `Enable redline controller` for the **Redline control** parameter enables this parameter.

Redline threshold speed

Specify the width of the region around the redline speed where the controller goes from fully enabled to not enabled. The block uses this parameter for smoothing the controlled throttle value when the engine's rotational speed crosses the redline speed reference. Large values decrease controller responsiveness. Small values increase computational cost. This parameter must be positive. The default is 1 rpm.

Selecting `Enable redline controller` for the **Redline control** parameter enables this parameter.

Extended Capabilities

Real-Time and Hardware-in-the-Loop Simulation

For optimal simulation performance, set the **Dynamics > Time Constant** parameter to `No time constant`
- Suitable for HIL simulation.

See Also

Simscape Blocks

[Piston Engine](#)

Topics

[Complete Vehicle Model](#)

[Adjust Model Fidelity](#)

[Hydraulically-Actuated Driveline Clutch](#)

[Vehicle with Dual Clutch Transmission](#)

[Vehicle with Four-Speed Transmission](#)

[Vehicle with Four-Wheel Drive](#)

[Vehicle with Manual Transmission](#)

[Prepare Simscape Driveline Models for Real-Time Simulation Using Simscape Checks](#)