BondGraph BG_nonlinear Documentation

This documentation is part of the open source BondGraph library for Modelica, published under GNU Lesser General Public License. Within this document, the models contained in the BG_nonlinear package are specified.

Authors:

Marius Kaspar (documentation)
Ilja Alkov (library)
Robin Diekmann (library)

University of Applied Sciences Bielefeld
Institute of System Dynamics and Mechatronics
Bielefeld, Germany
www.fh-bielefeld.de

Content

Hydraulics

Sources

HSe_acc

Icon HSe_acc

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
a	parameter	a	Real	m / s^2	acceleration
d	parameter	d	Real	m	distance in direction of acceleration
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity

Mathematical description

Equation for pressure: $p = \rho \cdot a \cdot d$

Physical effect description

The HSe_acc element is a hydraulic source of effort. It describes the incurrence of pressure due to the density of fluid, distance and acceleration [1].

Hydraulics

Sources

HSe_ind

Icon HSe_ind

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m3 / s	nominal flow = nominal volume flow
a_1	parameter	a_1	Real	m	inlet cross section
a_2	parameter	a_2	Real	m	outlet cross section
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity

Mathematical description

Equation dynamic pressure:

$$p = \frac{1}{2} \cdot \rho \cdot \left(\frac{f}{a}\right)^2$$

Simplified Bernoulli equation:

$$\frac{1}{2} \cdot \rho \cdot \left(\frac{f}{a_1}\right)^2 + p_1 = \frac{1}{2} \cdot \rho \cdot \left(\frac{f}{a_2}\right)^2 + p_2 = const.$$

$$\Leftrightarrow \Delta p = \frac{1}{2} \cdot \rho \cdot f^2 \cdot (a_1^{-2} - a_2^{-2})$$

Physical effect description

The HSe_ind element is a hydraulic source of effort. It is based on the Bernoulli's equation which describes the conservation of energy for incompressible fluids. It describes the change of pressure due to a change of the pipe cross section [2].

Hydraulics

Resistance

HR

Icon HR

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
a	parameter	a	Real	m	cross sectional area of pipe
l	parameter	l	Real	m	length of pipe
d_h	parameter	d_h	Real	m	hydraulic diameter of pipe
r_h	parameter	r_h	Real	-	relative hydraulic roughness of pipe k/d_h
re_crit	parameter	Re_{crit}	Real	-	critical Reynolds number
re_min	parameter	Re_{min}	Real	-	minimal Reynolds number
re_range	parameter	Re_{range}	Real	-	Reynolds number range for laminar-turbulent transition
r_min	parameter	-	Real	kg / m^4 s	minimal resistance
r_max	parameter	-	Real	kg / m^4 s	maximal resistance
par_caus	parameter	-	Integer	-	constitutive equation causality, par_caus = 1(effort out), par_caus = 2(flow out)
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
re	variable	Re	Real	-	reynolds number
lambda	variable	λ	Real	-	hydraulic pipe friction factor

Mathematical description

Darcy-Weissbach equation:

$$p = \lambda \cdot \rho \cdot \frac{l}{d_h} \cdot \frac{|f|}{2 \cdot a^2} \cdot f$$

Equation for λ:

$$\lambda = \frac{\lambda_l}{1+exp\left(\frac{Re-Re_{crit}}{0.228\cdot Re_{range}}\right)} + \frac{\lambda_t}{1+exp\left(\frac{Re-Re_{crit}}{-0.228\cdot Re_{range}}\right)}$$

$$\lambda_l = \frac{64}{Re+Re_{min}\cdot\left(1-tanh\left(\frac{Re}{Re_{min}}\right)\right)}$$

$$\lambda_t = \left(\frac{-1.8}{\ln(10)}\cdot ln\left(\left(\frac{r_h}{3.7}\right)^{1.11} + \psi_\lambda\right)\right)^{-2}$$

$$\psi_\lambda = \frac{6.9}{Re+Re_t\left(1-\tanh\left(\frac{Re}{Re_t}\right)\right)}$$

Reynolds-Number:

$$Re = \frac{\rho\cdot|f|\cdot d_h}{a\cdot\eta}$$

$$Re_t = \frac{2\cdot 6.9}{1-\left(\frac{r_h}{3.7}\right)^{1.11}}$$

Physical effect description

The HR element is a hydraulic resistance depending on the pipe friction. The causality parameter describes the dependence of Darcy-Weisbach equation for pressure loss from either volume flow (par_caus = 1) or pressure (par_caus = 2) [1]. The approach used to solve the equation for hydraulic pipe friction factor for laminar and turbulent flow explicitly and continuously is based on the Haaland approximation [3].

Hydraulics

Resistance

HRL

Icon HRL

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
e_ref	parameter	p_{ref}	Real	Pa	reference pressure difference
f_ref	parameter	f_{ref}	Real	m^3 / s	reference volume flow
eta_ref	parameter	η_{ref}	Real	kg / s m	reference viscosity
p	parameter	k	Real	-	volume flow exponent for resistance calculation
r_min	parameter	-	Real	kg / m^4 s	minimal resistance
r_max	parameter	-	Real	kg / m^4 s	maximal resistance
par_caus	parameter	-	Integer	-	constitutive equation causality, par_caus = 1(effort out), par_caus = 2(flow out)
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
r	variable	r	Real	kg / m^4 s	resistance

Mathematical description

Equation for resistance:

$$p = \frac{p_{ref} \cdot \eta}{\eta_{ref} \cdot {f_{ref}}^{k}} \cdot f^{k}$$

Physical effect description

The HRL element is a hydraulic resistance equivalent to the HR element but only for laminar flow. The causality parameter describes the dependence of the equation for pressure loss from either volume flow (par_caus = 1) or pressure (par_caus = 2) [1].

Hydraulics

Resistance

HRT

Icon HRT

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
e_ref	parameter	p_{ref}	Real	Pa	reference pressure difference
f_ref	parameter	f_{ref}	Real	m^3 / s	reference volume flow
rho_ref	parameter	ρ_{ref}	Real	kg / s m	reference viscosity
p	parameter	k	Real	-	volume flow exponent for resistance calculation
r_min	parameter	-	Real	kg / m^4 s	minimal resistance
r_max	parameter	-	Real	kg / m^4 s	maximal resistance
par_caus	parameter	-	Integer	-	constitutive equation causality, par_caus = 1(effort out), par_caus = 2(flow out)
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
r	variable	r	Real	kg / m^4 s	resistance

Mathematical description

Equation for resistance:

$$p = \frac{p_{ref} \cdot \rho}{\rho_{ref} \cdot f_{ref}^{\,k}} \cdot f^k$$

Physical effect description

The HRT element is a hydraulic resistance equivalent to the HR element but only for turbulent flow. The causality parameter describes the dependence of the equation for pressure loss from either volume flow (par_caus = 1) or pressure (par_caus = 2)[1].

Hydraulics

Resistance

MHRT

Icon MHRT

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density
port_in	input	input for control signal

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
e_ref	parameter	p_{ref}	Real	Pa	reference pressure difference
f_ref	parameter	f_{ref}	Real	m^3 / s	reference volume flow
rho_ref	parameter	ρ_{ref}	Real	kg / m^3	reference density
p	parameter	k	Real		volume flow exponent for resistance calculation
par_caus	parameter	-	Integer	-	constitutive equation causality, par_caus = 1(effort out), par_caus = 2(flow out)
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
s_c	variable	s_c	Real	-	control signal

Mathematical description

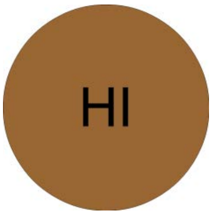
Equation for resistance:

$$p = \frac{1}{s_c} \cdot \frac{p_{ref} \cdot \rho}{\rho_{ref} \cdot \mathrm{f}_{ref}{}^{k}} \cdot f^k$$

Physical effect description

The MHRT element is a modulated hydraulic resistance for turbulent flow equivalent to the HRT element but with an additional control signal. The causality parameter describes the dependence of the equation for pressure loss from either volume flow (par_caus = 1) or pressure (par_caus = 2) [1].

Hydraulics



Icon HI

Inductance

HI

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort
f_nom	parameter	-	Real	m^3 / s	nominal flow
a	parameter	a	Real	m^2	cross sectional area of pipe
l	parameter	l	Real	m	length of pipe
f_0	parameter	f_0	Real	m^3 / s	initial flow
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity

Mathematical description

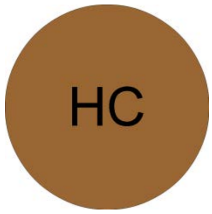
Equation for inductance: $p = \frac{d}{dt}\left(\frac{l}{a} \cdot \rho \cdot f\right)$

Physical effect description

The HI element is a hydraulic inductance. It describes the pressure difference within a tube that is necessary for a change of volume flow [1].

Hydraulics

Capacitance



Icon HC

HC

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort
f_nom	parameter	-	Real	m^3 / s	nominal flow
c	parameter	c	Real	m^2	compressibility (dV/dp)/V
v_0	parameter	v_0	Real	m^3	volume at initial pressure
e_0	parameter	p_0	Real	Pa	initial pressure
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
v	variable	v	Real	m^3	volume of hydraulic node

Mathematical description

Equation for capacity: $f = \frac{1}{\rho} \cdot \frac{d(\rho \cdot v)}{dt}$

Equation for volume of hydraulic node: $v = v_0 \cdot e^{c \cdot (p - p_0)}$

Physical effect description

The HC element is a hydraulic capacity. It is based on the effect, that a flexible tube could bear additional volume of a liquid in case of an increase in pressure[1].

Hydraulics

Capacitance

MHC

Icon MHC

Classes

Name	Type	Description
port_p	connector	port for flow and effort
port_n	connector	port for flow and effort
hprop	model	properties of fluid, model of viscosity and density
port_in	input	input for volume at initial pressure

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	parameter	t	Real	K	temperature
part_mass_air	parameter	-	Real	-	mass proportion of undissolved air to total mass of mixture
e_nom	parameter	-	Real	Pa	nominal effort = nominal pressure
f_nom	parameter	-	Real	m^3 / s	nominal flow = nominal volume flow
c	parameter	c	Real	m^2	compressibility (dV/dp)/V
e_0	parameter	p_0	Real	Pa	initial pressure
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
rho	variable	ρ	Real	kg / m^3	fluid density
eta	variable	η	Real	kg / s m	fluid viscosity
v	variable	v	Real	m^3	volume of hydraulic node
v_0	variable	v_0	Real	m^3	volume at initial pressure

Mathematical description

Equation for capacity: $f = \frac{1}{\rho} \cdot \frac{d(\rho \cdot v)}{dt}$

Equation for volume of hydraulic node: $v = v_0 \cdot e^{c \cdot (p - p_0)}$

Physical effect description

The MHC element is a modulated hydraulic capacity equivalent to the HC element but with an additional signal input for the information about the volume at initial pressure [1].

Mechanics

Source

MSe_masy

Icon MSe_masy

Classes

Name	Type	Description
port	connector	port for flow and effort
port_in	input	input for control signal

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
par_dyn_1_1	parameter	-	Real	N m	initial torque, relative value, par_dyn_1_1 in R and par_dyn_1_1 in (0,1)
par_dyn_1_2	parameter	-	Real	N m	torque bild-up, time
par_dyn_1_3	parameter	-	Real	N m	torque bild-up, relative value, par_dyn_1_3 in R and par_dyn_1_3 in (0,1)
par_dyn_2_1	parameter	-	Real	N m	starting oscillation, torque amplitude
par_dyn_2_2	parameter	-	Real	N m	starting oscillation, damping parameter, par_dyn_2_2 in R and par_dyn_2_2 in (0,1)
par_dyn_2_3	parameter	-	Real	N m	starting oscillation, frequency
par_torq_1	parameter	-	Real	Hz	static torque, start value
par_torq_2	parameter	-	Real	Hz	static torque, saddle value
par_torq_3	parameter	-	Real	Hz	static torque, breakdown value
par_torq_4	parameter	-	Real	Hz	static torque, nominal value
par_freq_1	parameter	-	Real	Hz	rotational frequency, start value
par_freq_2	parameter	-	Real	Hz	rotational frequency, saddle value
par_freq_3	parameter	-	Real	Hz	rotational frequency, breakdown value
par_freq_4	parameter	-	Real	Hz	rotational frequency, nominal value
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3 / s	flow = volume flow
t_stat	variable	t_{stat}	Real	N m	static torque
f_rot	variable	f_{rot}	Real	Hz	rotational frequency
u	variable	u	Real	-	input variable, u in R and u in (0,+inf)
x_dyn[3]	variable	x_{dyn}	Real	-	dynamic state

Mathematical description

Equation for effort: $e = t_{stat} \cdot x_{dyn}[1] + x_{dyn}[2]$

Equation for flow: $f = 4 \cdot \arcsin(1) * f_{rot}$

Physical effect description

The MSe_masy element is a mechanical source of effort represented by an asynchronies machine. The model includes the dynamic air gap torque during the starting period of the machine [4].

Mechanics

Source

MSe_masy_stat

Icon MSe_masy_stat

Classes

Name	Type	Description
port	connector	port for flow and effort
port_in	input	input for control signal

Parameters, variables and constants

Name	Element	Formula Symbol	Type	SI-Unit	Description
par_torq_1	parameter	-	Real	N m	static torque, start value
par_torq_2	parameter	-	Real	N m	static torque, saddle value
par_torq_3	parameter	-	Real	N m	static torque, breakdown value
par_torq_4	parameter	-	Real	N m	static torque, nominal value
par_freq_1	parameter	-	Real	Hz	rotational frequency, start value
par_freq_2	parameter	-	Real	Hz	rotational frequency, saddle value
par_freq_3	parameter	-	Real	Hz	rotational frequency, breakdown value
par_freq_4	parameter	-	Real	Hz	rotational frequency, nominal value
e	variable	p	Real	Pa	effort = pressure
f	variable	f	Real	m^3	flow = volume flow
t_stat	variable	t_{stat}	Real	N m	static torque
f_rot	variable	f_{rot}	Real	Hz	rotational frequency
u	variable	u	Real	-	input variable, u in R and u in (0,+inf)

Mathematical description

Equation for effort: $e = t_{stat} \cdot u$

Equation for flow: $f = 4 \cdot \arcsin(1) * f_{rot}$

Physical effect description

The MSe_masy_state element is a mechanical source of effort based on the MSe_masy element. The difference is that the mathematical description of the torque characteristic of the asynchronies machine is based on a static model [4].

Media

Generic

eta_air

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
press	input	p	Real	Pa	pressure
temp	input	T	Real	K	temperature
eta	output	η	Real	kg / s m	air viscosity
press_ref	parameter	p_{ref}	Real	Pa	reference pressure
temp_ref	parameter	T_{ref}	Real	T	reference temperature
par_eta_press	parameter	C_1	Real	$Pa^{-0.01}$ $K^{-0.75}$	viscosity index for pressure dependency of air
par_eta_temp	parameter	C_0	Real	K^2 / Pa	viscosity index for temperature dependency of air
eta_ref	parameter	η_{ref}	Real	kg / s m	viscosity at reference conditions of air

Mathematical description

Equation for viscosity of air:

$$\eta = \eta_{ref} \cdot \left(\frac{C_1 \cdot p^{0.01} \cdot T^{0.75} + C_0 \cdot p \cdot T^{-2}}{C_1 \cdot p_{ref}^{0.01} \cdot T_{ref}^{0.75} + C_0 \cdot p_{ref} \cdot T_{ref}^{-2}} \right)$$

Function description

Eta_air is an approximation function of experimental data for the viscosity of air [5].

Media

Generic

eta_roelands

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
press	input	p	Real	Pa	pressure
temp	input	T	Real	K	temperature
press_ref	input	p_{ref}	Real	Pa	reference pressure
temp_ref	input	T_{ref}	Real	T	reference temperature
par_eta_press	input	ζ	Real	-	viscosity index for pressure dependency of oil
par_eta_temp	input	ξ	Real	-	viscosity index for temperature dependency of oil
eta_ref	input	η_{ref}	Real	kg / s m	viscosity at reference conditions of oil
eta	output	η	Real	kg / s m	oil viscosity

Mathematical description

Equation for viscosity of oil:

$$\eta = \eta_{ref} \cdot \exp\left(ln\left(\frac{\eta_{ref}}{6.315 \cdot 10^{-5} Pa \cdot s}\right) \cdot \psi_{exp}\right)$$

$$\psi_{exp} = -1 + \left(1 + \frac{p - p_{ref}}{1.96 \cdot 10^{8} Pa}\right)^{\zeta} \cdot \left(\frac{T - 138\,K}{T_{ref} - 138\,K}\right)^{-\xi}$$

Function descriptionn

Eta_roelands is a function for the viscosity of hydraulic oil developed by Roelands [6].

Media

Generic

eta_mix

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
parts_vol[:]	input	$C_{parts,vol}$	Real	-	volume parts of air and oil in mixture
eta_parts[n]	input	η_{parts}	Real	kg / s m	viscosity of different volume parts
eta	output	η	Real	kg / s m	mixture viscosity

Mathematical description

Equation for viscosity of mixture: $$\eta = \frac{\sum_{i=1}^{n}\left(\eta_{parts,i} \cdot {C_{parts,vol,i}}^{2/3}\right)}{\sum_{i=1}^{n}\left({C_{parts,vol,i}}^{2/3}\right)}$$

Function description

Eta_mix is a function for the viscosity of mixture of oil and air. Index n is the size of the vector parts_vol.

Media

Generic

rho_air

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
press	input	p	Real	Pa	pressure
temp	input	T	Real	K	temperature
rho	output	ρ	Real	kg / m^3	Density of air
press_ref	parameter	p_{ref}	Real	Pa	reference pressure
temp_ref	parameter	T_{ref}	Real	T	reference temperature
par_rho_press	parameter	n	Real	-	density index for pressure dependency (polytropic exponent) of air
par_rho_temp	parameter	m	Real	-	density index for temperature dependency of air
rho_ref	parameter	ρ_{ref}	Real	kg / m^3	density at reference conditions of air

Mathematical description

Equation for density of air:

$$\rho = \rho_{ref} \cdot \left(\frac{T_{ref}}{T}\right)^m \cdot \left(\frac{p}{p_{ref}}\right)^n$$

Function description

Rho_air is a function for the density of air and is described by the ideal gas low.

Media

Generic

rho_exp

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
press	input	p	Real	Pa	pressure
temp	input	T	Real	K	temperature
press_ref	input	p_{ref}	Real	Pa	reference pressure
temp_ref	input	T_{ref}	Real	T	reference temperature
par_rho_press	input	κ	Real	Pa^{-1}	compressibility factor of oil
par_rho_temp	input	γ	Real	K^{-1}	coefficient of thermal expansion of oil
rho_ref	input	ρ_{ref}	Real	kg / m^3	density at reference conditions of oil
rho	output	ρ	Real	kg / m^3	density of oil

Mathematical description

Equation for density of oil: $\rho = \rho_{ref} \cdot e^{\kappa \cdot (p - p_{ref}) - \gamma \cdot (t - T_{ref})}$

Function description

Rho_exp is a function for the density of oil based on the exponential relation with compressibility factor and coefficient of thermal expansion.

Media

Generic

rho_mix

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
parts_mass[:]	input	$C_{parts,mass}$	Real	-	mass parts of air and oil in mixture
rho_parts[n]	input	ρ_{parts}	Real	kg / m^3	density of different mass parts
rho	output	ρ	Real	kg / m^3	density of mixture

Mathematical description

Equation for density of mixture: $\rho = \frac{1}{\sum_{i=1}^{n}\left(\frac{C_{parts,mass,i}}{\rho_{parts,i}}\right)}$

Function description

Rho_mix is a function for the density of mixture of oil and air. Index n is the size of the vector parts_mass.

Media

Generc

parts_vol

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
parts_mass[:]	input	$C_{parts,mass}$	Real	kg	mass parts of air and oil in mixture
rho_parts[xn]	input	ρ_{parts}	Real	kg / m3	density of different volume parts
parts[n]	output	$C_{parts,vol}$	Real	-	volume parts of mass components

Mathematical description

Equation for parts of volume:

$$C_{parts,vol} = \frac{\frac{c_{parts,mass}}{\rho_{parts}}}{\sum_{i=1}^{n}\left(\frac{c_{parts,mass,i}}{\rho_{parts,i}}\right)}$$

Function description

Parts_vol is a function for the volume parts of mass components in the mixture. Index n is the size of the vector parts_mass.

Media

Generic

press_cav

Parameters, inputs and outputs

Name	Element	Formula Symbol	Type	SI-Unit	Description
temp	input	T	Real	K	temperature
temp_ref	input	T_{ref}	Real	K	reference temperature
par_press_cav_temp	input	C_0	Real	K^{-1}	temperature index for cavitation pressure dependency of oil
press_cav_ref	input	$p_{cav,ref}$	Real	Pa	reference cavitation pressure
press	input	p	Real	Pa	cavitation pressure

Mathematical description

Equation for cavitation pressure: $p = p_{cav,ref} \cdot \left(\frac{T}{T_{ref}}\right) \cdot e^{C_0 \cdot (T - T_{ref})}$

Function description

Press_cav is an approximation function of experimental data for the cavitation pressure of liquid fluid.

References

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