

Utility name : pn2vol

Purpose

pn2vol computes the temperature, the pressure and the gas mass in a variable volume pneumatic chamber with heat exchange.

Description

This function evaluates the temperature variation and the pressure variation in a pneumatic chamber. This function can be used both for fixed and variable volume chambers with or without heat exchange.

We can express the variation of internal energy $\dot{U}$ using the first law of thermodynamics applied to an open system :

$$\frac{dU}{dt} = \sum \dot{m}_i h_i + \frac{dQ}{dt} + \frac{dW}{dt}$$

where $\dot{m}_i h_i$ is the enthalpy flow rate at a port (input is positive), $\frac{dQ}{dt}$ is the heat flow provided to or exiting from the control volume and $\frac{dW}{dt}$ is the work of the pressure forces.

This work is due to mechanical displacement when a piston is connected to the volume :

$$\frac{dW}{dt} = -p \cdot \frac{dV}{dt}$$

where $\frac{dV}{dt}$ is the volume variation.

Now let us introduce the internal energy by mass unit u :

$$U = m \cdot u$$

We can introduce this new variable in the expression of variation of internal energy $\dot{U}$:

$$m \cdot \frac{du}{dt} + u \cdot \frac{dm}{dt} = \sum \dot{m}_i h_i + \frac{dQ}{dt} + \frac{dW}{dt}$$

The internal energy is expressed as follows:

$$du = c_v dT + \left[T \left(\frac{\partial p}{\partial T} \right)_v - p \right] dv$$

Finally after some intermediate calculations, the temperature and pressure time-derivatives are evaluated resolving the following system of two equations traducing the mass balance and enthalpy balance:

$$\begin{aligned}
 & \frac{\partial}{\partial T} \left(\frac{\partial \rho}{\partial p} \right)_T & \frac{\partial}{\partial T} \left(\frac{\partial \rho}{\partial T} \right)_p \\
 & m \left(\frac{\partial h}{\partial p} \right)_T - V & m \left(\frac{\partial h}{\partial T} \right)_p \\
 & \frac{dp}{dt} & \frac{dT}{dt} \\
 & \sum \frac{dm_i}{dt} - \rho \frac{dV}{dt} & \sum \frac{dm_i}{dt} h_i - h \sum \frac{dm_i}{dt} + \Delta Q
 \end{aligned}$$

where density and enthalpy partial derivatives depend on the equation of state.

The mass flow, enthalpy flow and volume variation are given as input from attached submodels.

C call prototype

```

extern void pn2vol_
(
    double *dtemp, double *dpress, double *mgas, double *temp,
    double *press, double *sdm, double *sdh, double *volt,
    double *dvol, double *dq, int *gi
)
pn2vol_(dtemp, dpress, mgas, temp, press, sdm, sdh, &volt, &dvol, &dq, &gi)

```

Arguments

Inputs

- **temp**, temperature into the chamber [K]
- **press**, pressure into the chamber [PaA] (>0)
- **sdm**, sum of input mass flows [kg/s]
- **sdh**, sum of enthalpy flow rates [J/s]
- **volt**, total volume [m³] (>0)
- **dvol**, total derivative volume [m³/s]
- **dq**, heat exchange with the outside [W]
- **gi**, gas type index

Outputs

- **dtemp**, temperature derivative [K/s]
- **dpress**, pressure derivative [PaA/s]
- **mgas**, mass of gas [kg] (>0)