

Utility name : pn2vol2

Purpose

pn2vol2 computes the temperature and pressure variation in a pneumatic chamber with heat exchange.

Description

This function evaluates the temperature variation and the pressure variation in a pneumatic chamber assuming a perfect gas hypothesis. This function is used both for fixed and variable volume chambers.

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 to the control volume and $\frac{dW}{dt}$ is the work done by the system.

The enthalpy flow rate is an input from attached submodels. The heat flow to the control volume is defined as follows :

$$\frac{dQ}{dt} = K \cdot A \cdot (T_{\text{ext}} - T)$$

where K is the thermal exchange coefficient in $[J/s/m^2]$, A is the area of thermal exchange in $[m^2]$, T_{ext} is the external temperature (constant) in $[K]$ and T is the temperature of the chamber in $[K]$.

The work done by the system 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 due to piston displacement.

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 $\dot{U}$:

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

For a perfect gas, the internal energy is a function of the temperature (T) :

$$u = c_v \cdot T$$

Finally, we can define the temperature derivative after some intermediate calculations :

$$\frac{dT}{dt} = \frac{1}{m} \left(\frac{1}{c_v} \sum \{\dot{m}_i h_i\} - \dot{m}_i T \right) - \frac{p}{m c_v} \frac{dV}{dt} + \frac{1}{m c_v} \frac{dQ}{dt}$$

Now, we can calculate the pressure derivative by differentiating the ideal gas relation :

$$V \cdot \frac{dp}{dt} = -p \cdot \frac{dV}{dt} + m \cdot R \cdot \frac{dT}{dt} + R \cdot T \cdot \dot{m}$$

Where pressure variation (dP) is a function of volume variation (dV) , mass inflow and outflows $(\dot{m})$ and temperature variation (dT) . The mass flow and volume variation are given as input from attached submodels.

Fortran 77 call prototype

```
external pn2vol2
double precision dtemp, dpress, temp, press, sdm, mgas, sdh
double precision vvolt, volt, kth, sth, extemp
call pn2vol2(dtemp, dpress, temp, press, sdm, mgas, sdh, vvolt,
             volt, kth, sth, extemp)
```

C call prototype

```
extern void pn2vol2_
(
#ifdef _NO_PROTO
    double *dtemp, double *dpress, double *temp, double *press,
    double *sdm, double *mgas, double *sdh, double *vvolt,
    double *volt, double *kth, double *sth, double *extemp
#endif
)
pn2vol2_(dtemp, dpress, temp, press, sdm, mgas, sdh, &vvolt, &volt,
         kth, sth, extemp)
```

Arguments

Inputs

- **temp**, temperature into the chamber [K]
- **press**, pressure into the chamber [PaA] (>0)
- **sdm**, sum of input mass flows [kg/s]
- **mgas**, mass of gas [kg] (>0)

- ***sdh***, sum of enthalpy flows [kg/s]
- ***vvolt***, total derivative volume [m³/s]
- ***volt***, total volume [m³] (>0)
- ***kth***, thermal exchange coefficient [J/m²/K/s]
- ***sth***, thermal exchange area [m²]
- ***extemp***, external temperature [K]

Outputs

- ***dpress***, pressure derivative [PaA/s]
- ***dtemp***, temperature derivative [K/s]