ME 410 Day 15

Topics

- Properties of Gas Mixtures - Theory
- EES Implementation of Gas Mixture Properties
- Class Example
- Another Example: Isentropic Compression
- Discussion

1. Properties of Mixtures of Ideal Gases

An important thing to remember is that the specific properties may be given on a basis of

- property / mole of mixture
- property / mass of mixture
- property / mass of air (sometimes)

It's important to keep this straight. The properties we will deal with are:

- $\tilde{u}$ internal energy/mole u internal energy / mass
- $\tilde{h}$ enthalpy /mole h enthalpy / mass
- $\tilde{s}$ entropy/mole s entropy / mass
- $\tilde{c}_p$ constant pressure specific heat (molar basis)
- c_p constant pressure specific heat (mass basis)
- $\tilde{c}_v$ constant volume specific heat (molar basis)
- c_v constant volume specific heat (mass basis)

Let x_i represent the mass fraction and y_i represent the mole fraction of a component gas in a mixture.

The following is a very quick review of some of the thermodynamics equations related to ideal gas mixtures.

Then to calculate the specific properties for the mixture

$$u = \sum x_i \, u_i \qquad \tilde{u} = \sum y_i \, \tilde{u}_i$$

$$h = \sum x_i \, h_i \qquad \tilde{h} = \sum y_i \, \tilde{h}_i$$

$$s = \sum x_i \, s_i \qquad \tilde{s} = \sum y_i \, \tilde{s}_i$$

$$c_p = \sum x_i \, c_{p,i} \qquad \tilde{c}_p = \sum y_i \, \tilde{c}_{p,i}$$

$$c_v = \sum x_i \, c_{v,i} \qquad \tilde{c}_v = \sum y_i \, \tilde{c}_{v,i}$$

The mixture may be said to have an apparent molar mass. Let M_i be the molar mass of a component gas.

$$M = \sum y_i M_i$$

Important: To get the per/mass specific property multiply the corresponding per/mole specific property by M.

Ratio of specific heats.

$$\gamma = \frac{c_p}{c_v} = \frac{\tilde{c}_p}{\tilde{c}_v}$$

Ideal gas law

$$pV = mRT = m\frac{\tilde{R}}{M}T = n\tilde{R}T$$

where $\tilde{R}$ is the universal gas constant and R is the gas constant of the mixture.

We find that the specific heats and the gas constants are related.

$$c_p - c_v = R$$

$$\tilde{c}_p - \tilde{c}_v = \tilde{R}$$

For isentropic processes of a mixture of ideal gases, the polytropic relationship is the same as for ideal gases,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

2. Exercise

Compute the molecular weight, enthalpy(kJ/kg) and entropy (kJ/kg-k) of a gas mixture at P=2000 kPa and T = 1000 K.

Species	y_i
CO_2	0.109
H_2O	0.121
N_2	0.694
CO	0.0283
H_2	0.0455

Please use EES. We will compare notes after about 10-12 minutes. The EES solution will be posted at the website.

Please continue this exercise to calculate γ.

3. Exercise 2 (This is Problem 4.13)

Further Practice in Using EES

A diesel engine has a compression ratio of 22:1. The conditions in the cylinder at the start of compression are p=101.3 kPa and T=325 K. Calculate the pressure and temperature at the end of compression, assuming that compression is isentropic.

- Use EES. Set up a mixture of O_2 (y_1=0.2095) and N_2 (y_2=0.7905). Make the specific volume at the end of the stroke to 1/22 the specific volume at the beginning of the stroke. Equate the entropies. Calculate the work of compression.
- Calculate constant pressure specific heat and constant volume specific heat, and γ at both endpoints.
- Use the average of these two γ's in modeling the compression stroke as a polytropic process. Calculate the work of compression.