Derive volumetric coefficient of thermal expansion

Research from “Constructal solar chimney configuration” by Koonsrisuk

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| --- | --- | --- | --- | --- | --- | --- |
| Temp deg C | Density kg/m^3 | Cp (kJ/kg.K) | K (W/m.K) | Viscosity x10^-6 (m^2/s) | Expansion coeff x10^-3 (1/K) | Prandtl # |
| -50 | 1.534 | 1.005 | 0.0204 | 9.55 | 4.51 | 0.725 |
| 0 | 1.293 | 1.005 | 0.0243 | 13.30 | 3.67 | 0.715 |
| 20 | 1.205 | 1.005 | 0.0257 | 15.11 | 3.43 | 0.713 |
| 40 | 1.127 | 1.005 | 0.0271 | 16.97 | 3.20 | 0.711 |
| 60 | 1.067 | 1.009 | 0.0285 | 18.90 | 3.00 | 0.709 |
| 80 | 1.000 | 1.009 | 0.0299 | 20.94 | 2.83 | 0.708 |
| 100 | 0.946 | 1.009 | 0.0314 | 23.06 | 2.68 | 0.703 |
| 120 | 0.898 | 1.013 | 0.0328 | 25.23 | 2.55 | 0.70 |
| 140 | 0.854 | 1.013 | 0.0343 | 27.55 | 2.43 | 0.695 |
| 160 | 0.815 | 1.017 | 0.0358 | 29.85 | 2.32 | 0.69 |
| 180 | 0.779 | 1.022 | 0.0372 | 32.29 | 2.21 | 0.69 |

Source: http://www.engineeringtoolbox.com/air-properties-d\_156.html

Units clarification: at 40 deg C, = 3.2 x 10^-3 K^-1

Volumetric coefficient of thermal expansion has units of 1/K

v is v0 and is from inlet, state 0 is the starting point of the expansion. In Koonsrisuk paper they choose average air density for (between state 1 and 0) and do not specify what temperature corresponds to. We don’t know the density at state 1 yet, so this method seems to be flawed.)

What if want to take the integral approach?

if was constant,

if ,

Need a polynomial fit of data points between and

Finding pressure drop, as temp increases pressure decreases, pressure gradient causes mass flow in

(Approximation less than or equal 1% error, for , this is far less than the % change of the beta value, meaning should get a solution using an integral approach)

Q: Why can’t I use ideal gas law? Instead of ?

A: Because both density and pressure are unknown at state 2, but we could calculate pressure from ideal gas law, after using to calculate density at state 1, rather than calculating using static fluid pressure equation (), but this does not take into account the pressure gradient created by having a chimney full of air at temperature

Integral approach (want to see error compared to just using constant corresponding to )

Using data at 20 increments from 0 to 180 we create a polynomial best fit line of order 3 with matlab function polyfit()

(note: T is in units of Kelvin)

Our complete integral approach pressure drop equation with no approximations

Q: When comparing this to constant approach, , what error can we expect given a temperature range

A: when comparing vs from a starting point of 20 we found at a introduced an error of 2%, and introduced an error of 7%,

Comment: these errors may or may not seem significant as we continue our analysis

Comment: the way we are calculating pressure change is assuming air is acting like a fluid and not a gas? Because don’t assume any density change in column of air

Viscosity: