

## C.01.01.Z1 – Biblioteca Simplificada de Gás Ideal

Aplicação em FTHA – Finite Time Heat Addition Otto Engine Model

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<https://github.com/CNThermSci/AplThermSci>

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## Equação de Estado (EoS): Comportamento $P - T - v$

$$\begin{array}{ll} P v = R T & P \bar{v} = \bar{R} T \quad \rightarrow \\ P = \frac{R T}{v} & P = \frac{\bar{R} T}{\bar{v}} \quad \rightarrow \\ T = \frac{P v}{R} & T = \frac{P \bar{v}}{\bar{R}} \quad \rightarrow \\ v = \frac{R T}{P} & \bar{v} = \frac{\bar{R} T}{P} \quad \therefore \end{array}$$

Cada equação com forma nas bases **mássica**, e **molar**, com  $R = \bar{R}/M$  — armazenar  $\bar{R}$  e  $M$ !



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## Modelo de $\bar{c}_p(T)$ Polinomial:

$$\begin{array}{ll} \bar{c}_p(T) = \sum_{i=1}^4 a_i T^{i-1}, & T_{min} \leq T \leq T_{max} \quad \rightarrow \\ \bar{c}_p(T) = a_1 + a_2 T + a_3 T^2 + a_4 T^3, & T_{min} \leq T \leq T_{max} \quad \rightarrow \\ \bar{c}_v(T) = \bar{c}_p(T) - \bar{R} = \sum_{i=1}^4 b_i T^{i-1}, & T_{min} \leq T \leq T_{max} \quad \rightarrow \\ b_1 = a_1 - \bar{R}, & b_{i>1} = a_{i>1} \quad \therefore \end{array}$$

Armazenar  $a_i$ ,  $T_{min}$  e  $T_{max}$  e saber as conversões (i)  $a_i \rightarrow b_i$  e (ii)  $\bar{c}_{p,v}(T) \rightarrow c_{p,v}(T)$ .



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## Modelo de $\bar{c}_p(T)$ Polinomial: $\bar{u}(T)$

$$\begin{array}{ll} \bar{u}(T) = \int_{T_{ref}}^T \bar{c}_v(T) dT = \int_{T_{ref}}^T \sum_{i=1}^4 b_i T^{i-1} dT, & T_{min} \leq T \leq T_{max} \quad \rightarrow \\ \bar{u}(T) = \left( b_1 T + \frac{b_2 T^2}{2} + \frac{b_3 T^3}{3} + \frac{b_4 T^4}{4} \right)_{T_{ref}}^T, & T_{min} \leq T \leq T_{max} \quad \therefore \end{array}$$

- Armazenar  $T_{ref}$ .
- Compor **eficientemente** a soma de produtos, e
- Saber as conversões  $\bar{u}(T) \rightarrow u(T)$ .



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## Modelo de $\bar{c}_p(T)$ Polinomial: $\bar{h}(T) = \bar{u}(T) + \bar{R}T$

$$\bar{h}(T) = \int_{T_{ref}}^T \bar{c}_p(T) dT + \bar{R}T_{ref} = \int_{T_{ref}}^T \sum_{i=1}^4 a_i T^{i-1} dT + \bar{R}T_{ref}, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{h}(T) = \left( a_1 T + \frac{a_2 T^2}{2} + \frac{a_3 T^3}{3} + \frac{a_4 T^4}{4} \right)_{T_{ref}}^T + \bar{R}T_{ref}, \quad T_{min} \leq T \leq T_{max} \quad \therefore$$

- Compor eficientemente a soma de produtos, e
- Saber as conversões  $\bar{h}(T) \rightarrow h(T)$ .

## Modelo de $\bar{c}_p(T)$ Polinomial: $\bar{s}^\circ(T)$

$$\bar{s}^\circ(T) = \int_0^T \frac{\bar{c}_p(T)}{T} dT = \int_0^{T_{ref}} \frac{\bar{c}_p(T)}{T} dT + \int_{T_{ref}}^T \frac{\bar{c}_p(T)}{T} dT, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{s}^\circ(T) = \bar{s}_{ref}^\circ + \int_{T_{ref}}^T \sum_{i=1}^4 a_i T^{i-2} dT \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{s}^\circ(T) = \bar{s}_{ref}^\circ + \left( a_1 \ln(T) + a_2 T + \frac{a_3 T^2}{2} + \frac{a_4 T^3}{3} \right)_{T_{ref}}^T, \quad T_{min} \leq T \leq T_{max} \quad \therefore$$

- Armazenar  $\bar{s}_{ref}^\circ$ , compor eficientemente a soma de produtos, e
- Saber as conversões  $\bar{s}^\circ(T) \rightarrow s^\circ(T)$ .

## Modelo de $\bar{c}_p(T)$ Polinomial: $P_r(T)$ e $v_r(T)$

$$\left( \frac{P_2}{P_1} \right)_s = \frac{P_{r2}}{P_{r1}} \quad \left( \frac{v_2}{v_1} \right)_s = \frac{v_{r2}}{v_{r1}} \quad \rightarrow$$

$$P_r(T) \equiv e^{\bar{s}^\circ(T)/\bar{R}} \quad P_r(T) = e^{s^\circ(T)/R}$$

$$v_r(T) \equiv \frac{T}{P_r(T)}.$$

- Sem requisitos adicionais de armazenamento!
- Sem conversões de base!

## Padrões nos Cálculos:

$$\bar{c}_p(T) = a_1 + a_2 T + a_3 T^2 + a_4 T^3, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{c}_v(T) = b_1 + b_2 T + b_3 T^2 + b_4 T^3, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{u}(T) = \left( b_1 T + \frac{b_2 T^2}{2} + \frac{b_3 T^3}{3} + \frac{b_4 T^4}{4} \right)_{T_{ref}}^T, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{h}(T) = \left( a_1 T + \frac{a_2 T^2}{2} + \frac{a_3 T^3}{3} + \frac{a_4 T^4}{4} \right)_{T_{ref}}^T + \bar{R}T_{ref}, \quad T_{min} \leq T \leq T_{max} \quad \rightarrow$$

$$\bar{s}^\circ(T) = \left( a_1 \ln(T) + a_2 T + \frac{a_3 T^2}{2} + \frac{a_4 T^3}{3} \right)_{T_{ref}}^T + \bar{s}_{ref}^\circ, \quad T_{min} \leq T \leq T_{max} \quad \therefore$$

- Verificação de limites;
- Coef./func. próprios; e
- Produtos matriciais.

```
1 # Universal gas constant
2  $\bar{R}()$  = 8.314472 # ± 0.000015 # kJ/kmol·K
3
4 # Standard Tref
5 Tref() = 298.15 # K
6
7 # IG (Ideal Gas) structure: values for each gas instance
8 struct IG
9     MW                # Molecular "Weight", kg/kmol
10    CP::Ntuple{4}      # Exactly 4  $\bar{c}_p(T)$  coefficients
11    Tmin               # T_min, K
12    Tmax               # T_max, K
13    sref               #  $\bar{s}^\circ_{ref}$ , kJ/kmol·K
14 end
```

