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MC-Tema-9.pdf

Ejercicios Libro Mot. Cohete

3° Motores Cohete

Grado en Ingeniería Aeroespacial

Escuela Técnica Superior de Ingeniería Aeronáutica y del Espacio
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Problema 9.1.

1º) MCPL

$$N_2H_4(l) \longrightarrow \frac{4}{3}(1-x)\,NH_3(g) + \frac{1}{3}(1+2x)\,N_2(g) + 2x\,H_2(g)$$

2º) $\varepsilon = 40$

3º) Se descompone 40% NH_3 al ingresar en la tobera

4º) $T_e = T_{ref} = 298{,}15\ K$

5º) Datos

$$C_{p,NH_3} = 57\ \frac{J}{mol\cdot K}\ ;\ C_{p,H_2} = 28\ \frac{J}{mol\cdot K}\ ;\ \Delta h^\circ_{f,N_2H_4} = 50{,}63\ \frac{kJ}{mol}$$

$$\Delta h^\circ_{f,NH_3} = -45{,}90\ \frac{kJ}{mol}\ ;\ M_N = 14\ \frac{g}{mol}\ ;\ M_H = 1\ \frac{g}{mol}$$

¿I_{sp} en vacío ?

$\varepsilon = 40 \rightarrow \frac{P_s}{P_c} =$

Descomposición NH_3 (Amoníaco)

$$NH_3 \longrightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$$

Descomposición N_2H_4 (Hidracina) $x = 1 \rightarrow$ Estq.

$$N_2H_4 \longrightarrow \cancel{\text{basura}} + \cancel{N_2} + 2\,H_2 \quad \text{Est.}$$

Solo se descompone 40% NH_3 $\rightarrow x = 0{,}4$

$$\boxed{N_2H_4 \longrightarrow \frac{4}{5}NH_3 + \frac{3}{5}N_2 + \frac{4}{5}H_2}$$

Como $I_{sp} = c^* C_E \rightarrow c^* = \frac{\sqrt{RT_c}}{\Gamma(\gamma)}$ Hay que sacar T_c y γ

$\sum \Delta H_{react} = \sum \Delta H_{prod}$ Adiabáticas

$$\Delta_f h^\circ_{N_2H_4} = \frac{4}{5}\left(\Delta_f h^\circ_{NH_3} + C_{p,NH_3}\Delta T\right) + \frac{3}{5}\left(\Delta_f h^\circ_{N_2} + C_{p,N_2}\Delta T\right) + \frac{4}{5}\left(\Delta_f h^\circ_{H_2} + C_{p,H_2}\Delta T\right)$$

($\Delta_f h^\circ_{N_2} = 0$, $\Delta_f h^\circ_{H_2} = 0$)

$$\Delta_f h_{N_2H_4} = \Delta T\left(\frac{4}{5}C_{p_{NH_3}} + \frac{3}{5}C_{pN_2} + \frac{4}{5}C_{p_{H_2}}\right) + \frac{4}{5}\Delta_f h^\circ_{NH_3}$$

$$\Delta T = \frac{\Delta_f h_{N_2H_4} - \frac{4}{5}\Delta_f h_{NH_3}}{\frac{4}{5}C_{p_{NH_3}} + \frac{3}{5}C_{p,N_2} + \frac{4}{5}C_{p_{H_2}}} = 1015{,}7\ K$$

$$T_c = T_{ref} + \Delta T = \boxed{1314\ K = T_c}$$

$$\bar{C}_p = \frac{\frac{4}{5}C_{p_{NH_3}} + \frac{3}{5}C_{p,N_2} + \frac{4}{5}C_{p,H_2}}{\frac{4}{5} + \frac{3}{5} + \frac{4}{5}} = \boxed{39{,}1\ \frac{J}{mol\cdot K} = \bar{C}_p}$$

$\gamma = \frac{C_p}{C_v} \rightarrow R = C_p - C_v \Rightarrow C_v = C_p - R \rightarrow \gamma = \frac{C_p}{C_p - R}$ ~~$\frac{1}{\gamma} = \frac{1}{\gamma}$~~

$\boxed{\gamma = 1{,}27} \rightarrow \Gamma(\gamma) = \sqrt{\gamma}\left(\frac{1+\gamma}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}} \Rightarrow \boxed{\Gamma(\gamma) = 0{,}662}$

~~$\frac{P_0}{P_c}$~~

CONT. PROBLEMA 9.1

$$R_g = \frac{R}{\bar{M}} \Rightarrow \bar{M} = \frac{\frac{4}{5}\times 17 + \frac{3}{5}\times 23 + \frac{4}{5}\times 2}{\frac{11}{5}} = 14{,}545 \ \frac{g}{mol}$$

$$\boxed{R = 571{,}6 \ \frac{J}{kg \cdot K}}$$

$$\varepsilon = 40 \rightarrow \frac{P_s}{P_c} = 1{,}587 \times 10^{-3}$$

$$C_E = \Gamma(\gamma)\sqrt{\quad} + \varepsilon \frac{P_s}{P_c} = 1{,}82$$

$$c^* = \frac{\sqrt{R T_c}}{\Gamma(\gamma)} = 1309{,}14 \ m/s$$

$$I_{sp} = c^* C_E$$

$$\boxed{I_{sp} = 2382{,}63 \ m/s = 243 \ s}$$

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Problema 9.2

1º) MCPL → Hidracina monopropul.

2º) Incrementador empuje

$$\frac{\dot{W}}{\dot{m}} = 2 \ \frac{MJ}{kg}$$

3º) En equilibrio solo N_2 ; H_2

4º) $\varepsilon = 90$

5º) Datos:

$$c_{p_{NH_3}} = 57 \ \frac{J}{mol \cdot K} \ ; \ c_{p_{N_2}} = 30 \ \frac{J}{mol \cdot K} \ ; \ c_{p_{H_2}} = 28 \ \frac{J}{mol \cdot K}$$

$$\Delta_f h_{N_2H_4} = 50,63 \ \frac{kJ}{mol} \ ; \ \Delta_f h_{NH_3} = -45,90 \ \frac{kJ}{mol}$$

$$N_2H_4 \longrightarrow N_2 + 2H_2$$

$$\Sigma \Delta H_{react} = \Sigma \Delta H_{prod}$$

$$\Delta_f h^\circ_{N_2H_4} = \cancel{\Delta_f h^\circ_{N_2}}^{\,0} + c_{p_{N_2}} \Delta T + 2\cancel{\Delta_f h^\circ_{H_2}}^{\,0} + 2 c_{p_{H_2}} \Delta T$$

$$\Delta T = \frac{\Delta_f h^\circ_{N_2H_4} - \cancel{\Delta_f h^\circ_{N_2}}^{\,0}}{c_{p_{N_2}} + 2 c_{p_{H_2}}} = 588,72 \rightarrow \boxed{T_c = 886,87 \ K}$$

$$\bar{c}_p = \frac{c_{p_{N_2}} + 2 c_{p_{H_2}}}{1+2} = \boxed{28,67 \ \frac{J}{mol \cdot K} = \bar{c}_p}$$

$$\bar{M} = \frac{2 \times 14 + 2 \times 2}{3} = \boxed{10,67 \ \frac{g}{mol} = \bar{M}}$$

$$\boxed{R = 779,24 \ \frac{J}{kg \, K}}$$

$$\boxed{\gamma = 1,41} \qquad \boxed{\Gamma(\gamma) = 0,686}$$

$$C^* = \frac{\sqrt{RT_{c1}}}{\Gamma(\gamma)} = 1212 \ m/s = C_1^*$$

$$\varepsilon = 90 \rightarrow \frac{P_3}{P_c} = 2{,}839 \times 10^{-4}$$

Suponemos vacío

$$C_E = 1{,}74$$

El incrementador de empuje a media carga $\eta = 0{,}5$

$$\bar{C}_p (T_{c2} - T_{c1}) = 0{,}5 \underbrace{\left(\frac{\dot{W}}{\dot{m}}\right)}_{Q} \rightarrow \boxed{T_{c2} = 1258{,}17 \ K}$$

$$\Delta H = Q$$