Problema semana 11

① $P_{t3,f}$; $T_{t3,f}$

$\Rightarrow$ Ec. Acoplamiento: $\boxed{\dot{W}_T = \dot{W}_{b,f} + \dot{W}_{b,o}}$; $\eta_b = \dfrac{\Delta P_t/\rho_e}{\Delta h}$

$$\eta_{mec} \cdot \dot{m}_f \cdot C_{pf}\left(T_{t2_f} - T_{t3_f}\right) = \left[\frac{\dot{m}_f}{\eta_b}\left(\frac{\Delta P_{t,f}}{\rho_f}\right) + \frac{\dot{m}_o}{\eta_b}\left(\frac{\Delta P_{t,o}}{\rho_o}\right)\right]$$

Datos: $\eta_{mec}, \eta_b, \rho_f, \rho_o, \Delta P_{t,f}, \Delta P_{t,o}, T_{2t,f}$; $\boxed{T_{2t_f} = 325\ K}$

Divido : $\dot{m}_F$ y despejo $T_{3t,f}$

$$\left[T_{3t} = T_{2t} - \left[\frac{1}{\eta_b \eta_{mec} C_{pf}}\left(\frac{O}{F}\left(\frac{\Delta P_{t,o}}{\rho_o}\right) + \left(\frac{\Delta P_{t,f}}{\rho_f}\right)\right)\right] = 311,7\ K\right]$$

$$\left[C_{pf} = \frac{R_f \gamma_f}{\gamma_f - 1} = 19004\ J/kg\,K\right]$$

$\Rightarrow$ Ec. Rendimiento turbina: $\eta_t = \dfrac{1 - T_{3t_f}/T_{2t_f}}{1 - \left(P_{3t_f}/P_{2t_f}\right)^{\frac{\gamma-1}{\gamma}}}$

$$\left[P_{2t_f} = 0,85\ P_{1t_f} = 0,85\ \Delta P_{tf} = 6,8 \cdot 10^6\ Pa\right]$$

Despejo $\left[P_{3t_f} = \left[1 - \left(\dfrac{1 - (T_{3tf}/T_{2tf})}{\eta_t}\right)\right]^{\frac{\gamma}{\gamma-1}} \cdot P_{2tf} = 5,12 \cdot 10^6\ Pa\right]$

② T_c C^*

$\left.\begin{array}{l}\left[T_{iny,f} = T_{t3,f} = 311,7\ K\right] \\ \left[T_{iny,o} = T_{t1,o} = 100\ K\right]\end{array}\right\}$ Cálculo T_e: La temperatura de los reactivos será una intermedia entre la del fuel y la del oxidante. El calor que libere el fuel será el mismo que absorve el oxidante.

$Q = \dot{m} c_p \Delta T \rightarrow \quad \dot{m}_F C_{pF}\left(T_e - T_{in,f}\right) = \dot{m}_o C_{po}\left(T_e - T_{in,o}\right)$

$\left[\dfrac{\dot{m}_o}{\dot{m}_F} = 6\right]$; $\left[C_{po} = \dfrac{R_o \gamma_o}{\gamma_o - 1} = 1187,65\ J/kg \cdot K\right] \Rightarrow \boxed{T_e = 126,98\ K}$

$\Rightarrow$ Cálculo de los $\bar{C}_{pR}$ y $\bar{C}_{pP}$

Dado que $\left(\frac{O}{F}\right)_{st} = 8 > \left(\frac{O}{F}\right) \Rightarrow$ Exceso de H_2.

Por tanto: $\quad O_2 + H_2 \longrightarrow H_2O + H_2$

Ajustando la reacción usando las masas molares.

$\frac{6}{32} O_2 + \frac{1}{2} H_2 \longrightarrow$ Multiplicamos por 16 para quitar denominadores.

$3 O_2 + 8 H_2 \longrightarrow 6 H_2O + 2 H_2$

$\boxed{\dot{m}\bar{C}_{pR} = \dot{m}_O \bar{C}_{pO} + \dot{m}_F \bar{C}_{pF}} \Rightarrow \bar{C}_{pR} = \frac{6}{7} C_{pO} + \frac{1}{7} C_{pF}$

Ponderamos con masa (kg) porque el C_p está en J/kg·K.

$\boxed{\bar{C}_{pR} = 3732{,}8 \text{ J/kg K}}$

$\boxed{\bar{C}_{pP} = \frac{\dot{m}_{H_2O}}{\dot{m}} C_{pH_2O} + \frac{\dot{m}_{H_2}}{\dot{m}} C_{pH_2} = \frac{27}{28} C_{pH_2O} + \frac{1}{28} C_{pH_2} = 2714{,}84 \text{ J/kg·K}}$

$\Rightarrow \dot{m}_{ox} \dot{Q}_{comb/ox} = \dot{m} \left[\bar{C}_{pP} (T_c - T_{ref}) + \bar{C}_{pR} (T_c - T_{ref}) \right]$

Dado que hay exceso de fuel. Se consume todo el oxidante. Sino habría que calcular cuanto oxidante reacciona porque el "Q" nos lo dan por unidad de gasto de oxidante.

$\frac{\dot{\ }}{\dot{m}_F} \rightarrow \quad Q_{comb/ox} \frac{O}{F} = \left(1 + \frac{O}{F}\right) \left[\bar{C}_{pP} (T_c - T_{ref}) + \bar{C}_{pR} (T_c - T_{ref}) \right]$

$\boxed{T_c = 2904{,}32 \text{ K}}$

$C^* = \frac{\sqrt{R T_c}}{\Gamma(\gamma)}$; $\quad \boxed{\bar{R}_P = \frac{27}{28} R_{H_2O} + \frac{27}{28} R_{H_2} = 593{,}875 \text{ J/kg·K}}$

$\boxed{\Gamma(\gamma) = 0{,}6636}$

$\boxed{C^* = 1979{,}1 \text{ m/s}}$

3 P_c : $\dot{m}_{b.c}$. $\dot{m}_{b.d}$

$$\boxed{P_c = P_{iny} - \frac{1}{2}\rho_l \cdot V_{in}^2} \qquad (I)$$

$$\boxed{\dot{m}_{ox} = \rho_l V_{in} C_D A_{iny}} \qquad (II)$$

$$\boxed{P_c = \frac{\dot{m} C^*}{A_g}} \qquad (III)$$

$$\left[\dot{m} \equiv \dot{m}_{ox} \cdot \frac{\dot{m}}{\dot{m}_{ox}} = \dot{m}_{ox} \frac{\dot{m}/\dot{m}_F}{\dot{m}_{ox}/\dot{m}_F}\right] \rightarrow \boxed{\dot{m} = \dot{m}_{ox}\left(\frac{1+O/F}{O/F}\right)} \qquad (IV)$$

$$\boxed{\dot{m} = \dot{m}_F + \dot{m}_{ox}} \qquad (V)$$

5 Ec. y 5 incógnitas $\{P_c, V_{iny}, \dot{m}, \dot{m}_{ox}, \dot{m}_F\}$

$(IV) \rightarrow (II) = (IV)'$

$$\dot{m} = \left(\frac{1+O/F}{O/F}\right) \rho_{ox} V_{iny} C_D A \quad ; \left(\frac{1+O/F}{O/F} = \frac{7}{6}\right)$$

$(IV)' \rightarrow (III) = (III)'$

$$P_c = \frac{(7/6)\rho_{ox} V_{iny} C_D A_{iny} C^*}{A_g}$$

$(III)' \rightarrow (I)$

$$\left(\frac{1}{2}\rho_{ox}\right) V^2 + \left(\frac{7}{6}\rho \frac{C_D A_{iny}}{A_g} \cdot C^*\right) V - P_{iny} = 0 \quad ; (P_{iny} = \Delta P_{b.c})$$

$$\boxed{V_{iny} = 39{,}59 \text{ m/s}}$$

$$\left[P_c = P_{iny} - \frac{1}{2}\rho_{ox} V_{iny}^2 = 3{,}106 \text{ MPa}\right]$$

$$\boxed{\dot{m} = 28{,}96 \text{ kg/s}}$$

$$\boxed{\dot{m}_{ox} = 24{,}82 \text{ kg/s}}$$

$$\boxed{\dot{m}_F = 4{,}14 \text{ kg/s}}$$

(4) (E), (I_{sp})

$$\varepsilon = 30 \rightarrow \frac{P_s}{P_c} \rightarrow C_E \begin{cases} E \\ I_{sp} \end{cases}$$

$P_{amb} = 38{,}25$ KPa
$T_{amb} = 239{,}4$ K

$$\varepsilon = \frac{\Gamma(\gamma)}{\left(\frac{P_s}{P_c}\right)^{\frac{1}{\gamma}} \sqrt{\frac{2\gamma}{\gamma-1}\left(1-\left(\frac{P_s}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right)}} \Rightarrow \boxed{\frac{P_s}{P_c} = 0{,}002244}$$

$$C_E = \Gamma(\gamma)\sqrt{\frac{2\gamma}{\gamma-1}\left(1-\left(\frac{P_s}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right)} + \varepsilon\left(\frac{P_s}{P_c} - \frac{P_{amb}}{P_c}\right) \Rightarrow \boxed{C_E = 1{,}42}$$

$$\boxed{E = C_E \cdot P_c \cdot A_g = 81{,}377 \text{ KN}}$$

$$I_{sp} = C^* C_E = 2810{,}3 \text{ m/s} \longrightarrow \boxed{I_{sp} = 286{,}5 \text{ s}}$$

(5) (A_{det})

En primer lugar comprobamos si hay desprendimiento en la salida. Ya que si no hay, no puede haber en ningún punto de la tobera. Calculo la P_{amb}^* para la cual puede ~~haber~~ desprendimiento a la salida.

$$P_{det} = P_s = P_c\left(\frac{P_s}{P_c}\right) = 6970 \text{ Pa}$$

$$M_{det} = M_s \rightarrow \left(\frac{P_c}{P_s}\right) = \left(1+\frac{\gamma-1}{2}M_s^2\right)^{\frac{\gamma}{\gamma-1}} \Rightarrow \boxed{M_s = 4{,}47}$$

$$P_{amb}^* = \frac{P_s \cdot 3 \cdot M_s}{\pi} = 29751{,}7 \text{ Pa} < P_{amb} \Rightarrow$$ Si, hay desprendimiento

Con la $P_{amb} = 38{,}25$ KPa calculo $\underline{M_{det}}$ y $\underline{P_{det}}$.

$$\left\{\begin{aligned} \frac{P_{det}}{P_{amb}} &= \frac{\pi}{3 M_{det}} \\ \frac{P_c}{P_{det}} &= \left(1+\frac{\gamma-1}{2}M_{det}^2\right)^{\frac{\gamma}{\gamma-1}} \end{aligned}\right\} \Rightarrow \boxed{\begin{aligned} P_{det} &= 9368{,}3 \text{ Pa} \\ M_{det} &= 4{,}27 \end{aligned}}$$

$$\boxed{\varepsilon^* = f\left(\gamma, \frac{P_{det}}{P_c}\right) = 24{,}109} \rightarrow \boxed{A_{sdet} = 0{,}4448 \text{ m}^2}$$