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Département de Génie Mécanique
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TD N 02 : Cycle de Brayton

Module : **Conversion d'énergie**
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Exercice 01.

$T_1 = 25°C = 298\ K$
$T_3 = 577°C = 850\ K$
$P_1 = P_4 = 1\ bar$
$P_2 = P_3 = 10\ bar$
$\dot{m} = 54\ kg/s$

1. La puissance produite par la centrale
   a. Les températures du cycle

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_4 = T_3 \times \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} = 850 \times \left(\frac{1}{10}\right)^{\frac{1,4-1}{1,4}} \Rightarrow T_4 = \mathbf{440,3\ K}$$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_2 = \frac{T_1}{\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}} = \frac{298}{\left(\frac{1}{10}\right)^{\frac{1,4-1}{1,4}}} \Rightarrow T_2 = \mathbf{575,33\ K}$$

   b. Les quantités de chaleurs échangées par le cycle

$$\dot{Q}_c = \dot{m}C_p\Delta T = \dot{m}C_p(T_3 - T_2) = 54 \times 1(850 - 575,33) = 14832,18\ kW = 14,832\ MW$$

$$\dot{Q}_f = \dot{m}C_p\Delta T = \dot{m}C_p(T_4 - T_1) = 54 \times 1(440,3 - 298) = 7684,2\ kW = 7,684\ MW$$

   c. La puissance produite par la centrale

$$\dot{W}_{net} = \dot{Q}_c - \dot{Q}_f = 14,832 - 7,684 = 7,148\ MW$$

2. Le rendement du cycle :

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_c} = \frac{7,148}{14,832} = \mathbf{0,4819 = 48,19}\ \%$$

Exercice 02.

$T_1 = 32°C = 305\ K$
$T_3 = 967°C = 1240\ K$
$r_p = 12$
$\dot{m} = 50\ kg/s$

1. La puissance utilisée pour entraîner le compresseur.

Avec le tableau A-17,
T_1= 305 K $\Rightarrow P_{r1} = 1,4686, h_1 = 305,22\ kJ/kg$

$$\left(\frac{P_{r2}}{P_{r1}}\right) = \left(\frac{P_2}{P_1}\right) = r_p \Rightarrow P_{r2} = r_p \times P_{r1} = 12 \times 1,4686 = 17,6232$$

Avec le tableau A-17, $P_{r2} = 17,6232$
Et l'interpolation linéaire
$x_a = P_{ra} = 17,30$ $\quad y_a = T_a = 610\ K$
$x_2 = P_{r2} = 17,62$ $\quad y_2 = T_2 = ?$

$x_b = P_{rb} = 18{,}36$ $\quad y_b = T_b = 620\ K$

$$\boldsymbol{T_2} = T_a + (T_b - T_a) \times \frac{P_{r2} - P_{ra}}{P_{rb} - P_{ra}} = 610 + (620 - 610) \times \frac{17{,}62 - 17{,}30}{18{,}36 - 17{,}30} = \boldsymbol{613{,}05\ K}$$

$$\boldsymbol{T_2 = 613{,}05\ K}$$

Et l'interpolation linéaire

$x_a = P_{ra} = 17{,}30$ $\quad y_a = h_a = 617{,}53\ kJ/kg$

$x_2 = P_{r2} = 17{,}62$ $\quad y_2 = h_2 = ?$

$x_b = P_{rb} = 18{,}36$ $\quad y_b = h_b = 628{,}07\ kJ/kg$

$$\boldsymbol{h_2} = h_a + (h_b - h_a) \times \frac{P_{r2} - P_{ra}}{P_{rb} - P_{ra}} = 617{,}53 + (628{,}07 - 617{,}53) \times \frac{17{,}62 - 17{,}30}{18{,}36 - 17{,}30} = \boldsymbol{620{,}74\ kJ/kg}$$

$$\boldsymbol{h_2 = 620{,}74\ kJ/kg}$$

$$\dot{W}_{comp} = \dot{m}(h_2 - h_1) = 50(620{,}74 - 305{,}22) = \boldsymbol{15776\ kW = 15{,}776\ MW}$$

2. La puissance produite par la turbine.

Avec le tableau A-17,

T_3= 1240 K $\Rightarrow P_{r3} = 272{,}3, h_3 = 1324{,}93$ kJ/kg

$$\left(\frac{P_{r4}}{P_{r3}}\right) = \left(\frac{P_4}{P_3}\right) = \frac{1}{r_p} \Rightarrow P_{r4} = \frac{P_{r3}}{r_p} = \frac{272{,}3}{12} = 22{,}7$$

Avec le tableau A-17, $P_{r4} = 22{,}7$

Et l'interpolation linéaire

$x_a = P_{ra} = 21{,}86$ $\quad y_a = h_a = 659{,}84\ kJ/kg$

$x_2 = P_{r4} = 22{,}7$ $\quad y_2 = h_4 = ?$

$x_b = P_{rb} = 23{,}13$ $\quad y_b = h_b = 670{,}47\ kJ/kg$

$$\boldsymbol{h_4} = h_a + (h_b - h_a) \times \frac{P_{r4} - P_{ra}}{P_{rb} - P_{ra}} = 659{,}84 + (670{,}47 - 659{,}84) \times \frac{22{,}7 - 21{,}86}{23{,}13 - 21{,}86} = \boldsymbol{666{,}80\ kJ/kg}$$

$$\boldsymbol{h_4 = 688{,}80\ kJ/kg}$$

$$\dot{W}_{turbine} = \dot{m}(h_3 - h_4) = 50(1324{,}94 - 688{,}80) = \boldsymbol{32907\ kW = 32{,}91\ MW}$$

3. Le rendement de la centrale.

$$\dot{Q}_c = \dot{m}(h_3 - h_2) = 50(1324{,}94 - 620{,}74) = \boldsymbol{35210\ kW = 35{,}21\ MW}$$

$$\dot{W}_{net} = \dot{W}_{turbine} - \dot{W}_{comp} = 32{,}91 - 15{,}776 = \boldsymbol{17{,}134\ MW}$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_c} = \frac{17{,}134}{35{,}21} = \boldsymbol{0{,}4866 = 48{,}66}\ \%$$

Exercice 03.

$T_1 = 32°C = 305$ K

$T_3 = 1007°C = 1280$ K

$r_p = 14$

$\eta_{is,comp} = 0{,}82$

$\eta_{is,turb} = 0{,}86$

Avec le tableau A-17,

T_1= 305 K $\Rightarrow P_{r1} = 1{,}4686, h_1 = 305{,}22$ kJ/kg

$$\left(\frac{P_{r2}}{P_{r1}}\right) = \left(\frac{P_2}{P_1}\right) = r_p \Rightarrow P_{r2} = r_p \times P_{r1} = 14 \times 1{,}4686 = \mathbf{20{,}5604}$$

Avec le tableau A-17, $P_{r2} = 20{,}5604$

Et l'interpolation linéaire

$x_a = P_{ra} = 19{,}84$ $\quad y_a = h_a = 638{,}63\ kJ/kg$

$x_2 = P_{r2} = 20{,}56$ $\quad y_2 = h_{2s} = ?$

$x_b = P_{rb} = 20{,}64$ $\quad y_b = h_b = 649{,}22\ kJ/kg$

$$\boldsymbol{h_{2s}} = h_a + (h_b - h_a) \times \frac{P_{r2} - P_{ra}}{P_{rb} - P_{ra}} = 638{,}63 + (649{,}22 - 638{,}63) \times \frac{20{,}56 - 19{,}84}{20{,}64 - 19{,}84} = \mathbf{648{,}16\ kJ/kg}$$

$$\boldsymbol{h_{2s} = 648{,}16\ kJ/kg}$$

Avec le tableau A-17,

T_3= 1280 K $\Rightarrow P_{r3} = 310{,}4, h_3 = 1372{,}24$ kJ/kg

$$\left(\frac{P_{r4}}{P_{r3}}\right) = \left(\frac{P_4}{P_3}\right) = \frac{1}{r_p} \Rightarrow P_{r4} = \frac{P_{r3}}{r_p} = \frac{310{,}4}{14} = \mathbf{22{,}17}$$

Avec le tableau A-17, $P_{r4} = 22{,}17$

Et l'interpolation linéaire

$x_a = P_{ra} = 21{,}86$ $\quad y_a = h_a = 659{,}84\ kJ/kg$

$x_2 = P_{r4} = 22{,}17$ $\quad y_4 = h_{4s} = ?$

$x_b = P_{rb} = 23{,}13$ $\quad y_b = h_b = 670{,}47\ kJ/kg$

$$\boldsymbol{h_{4s}} = h_a + (h_b - h_a) \times \frac{P_{r4} - P_{ra}}{P_{rb} - P_{ra}} = 659{,}84 + (670{,}47 - 659{,}84) \times \frac{22{,}17 - 21{,}86}{23{,}13 - 21{,}86} = \mathbf{662{,}43\ kJ/kg}$$

$$\boldsymbol{h_{4s} = 662{,}43\ kJ/kg}$$

$$W_{iso,comp} = (h_{2s} - h_1) = (648{,}16 - 305{,}22) = \mathbf{342{,}94\ kJ/kg}$$

$$\eta_{is,comp} = \frac{W_{iso,comp}}{W_{actuel,comp}} \Rightarrow W_{actuel,comp} = \frac{W_{iso,comp}}{\eta_{is,comp}} = \frac{342{,}94}{0{,}82} = \mathbf{418{,}22\ kJ/kg}$$

$$W_{iso,turb} = (h_3 - h_{4s}) = (1372{,}24 - 662{,}43) = \mathbf{709{,}81\ kJ/kg}$$

$$\eta_{is,turb} = \frac{W_{actuel,turb}}{W_{iso,turb}} \Rightarrow W_{actuel,turb} = W_{iso,turb} \times \eta_{is,turb} = 709{,}81 \times 0{,}86 = \mathbf{610{,}43\ kJ/kg}$$

$$W_{actuel,net} = W_{actuel,turb} - W_{actuel,comp} = 610{,}43 - 418{,}22 = \mathbf{192{,}22\ kJ/kg}$$

$$\dot{W}_{actuel,net} = \dot{m} \times W_{actuel,net} \Rightarrow \dot{m} = \frac{\dot{W}_{actuel,net}}{W_{actuel,net}} = \frac{50000}{192{,}22} = \mathbf{260{,}12\ kg/s}$$