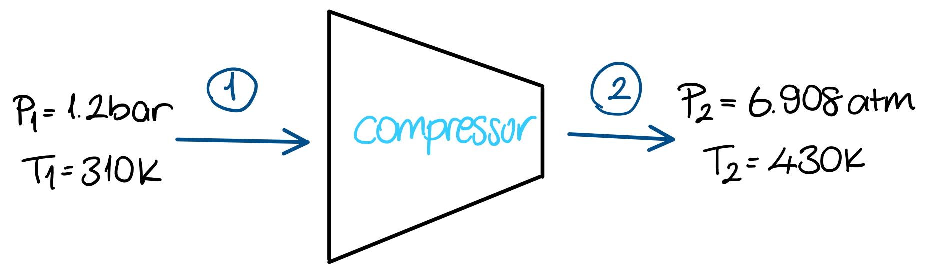
28 Mart 2025 Cuma 08:37

∗ Helium enters a compressor at 1.2bar and 310K. It leaves the compressor at 6.908 atm and 430K. During the compression process, 20kJ/kg of heat transfer takes place. If the mass flow rate is 90kg/min, then calculate the compressor power. (KE and PE are negligible)



90kg/min = 90/60 kg/s = 1.5kg/s

$\dot{E}_1 = \dot{E}_2$

$\dot{m}h_1 + \dot{W} = \dot{m}h_2 + \dot{Q}$

for ideal gases:

$\Delta U = mc_v\Delta T$

$\Delta H = mc_p\Delta T$

$h = c_pT$

$\Delta U = mc_v\Delta T$

$\Delta H = mc_p\Delta T$

$H_2 - H_1 = mc_p\Delta T$

$h_2 - h_1 = c_p(T_2 - T_1)$

q = 20kJ/kg

$\dot{Q} = q\cdot\dot{m}$

$= 20\cdot(1.5) = 30$kW

from table

$1.5 \times 5.1926 \times 310 + \dot{W} = 1.5 \times 5.1926 \times 430 + 30$

$\dot{W} = 964.66$ kW

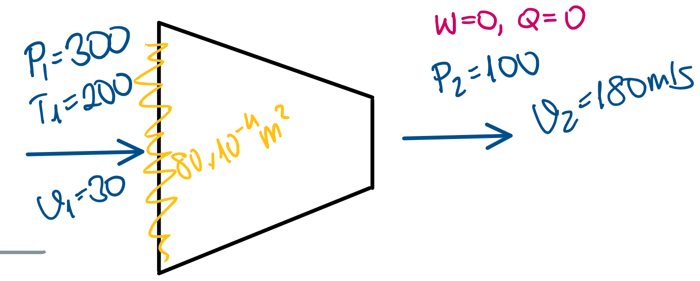
∗ Air enters an adiabatic nozzle at 300kPa and 200°C with a velocity of 30m/s. It leaves at 100kPa with 180m/s velocity. The inlet area of the nozzle is $80cm^2$. Calculate:

NO HEAT TRANSFER!

a) air mass flow rate.

b) exit temperature of air.

c) exit area of the nozzle.



a)

$\dot{m}_1 = \dot{m}_2 = \dot{m} = \rho_1 . A_1 . V_1$

$\dot{m} = \rho\dot{V}$

$\dot{V} = V.A$

$\rho_1 = \frac{P_1}{RT_1} = \frac{300kPa}{0.287 \times 473 K} = 2.209\ kg/m^3 = \rho_1$

$\dot{m} = 2.209 \times 30 \times 80\times10^{-4} = 0.53$ kg/s

b) $P_2 = \rho_2 R T_2$ can't use this (2 unknowns) ⇒

? ?

from Table: $c_p = 1.005$ kJ/kg

$\dot{E}_1 = \dot{E}_2$

$\dot{m}h_1 + \frac{1}{2}\dot{m}V_1^2 = \dot{m}h_2 + \frac{1}{2}\dot{m}V_2^2$

$1.005 \times 473.15 + \frac{30^2}{2} \times 10^{-3} = 1.005 \times T_2 + \frac{1}{2}180^2 \times 10^{-3}$

kJ/kg, J/kg, kilo, kJ/K, J/kg, kilo

$(h = c_pT)$

$T_2 = 457.478$ K

c) $\dot{m} = \rho_2 V_2 A_2$, $P_2 = \rho_2 R T_2$

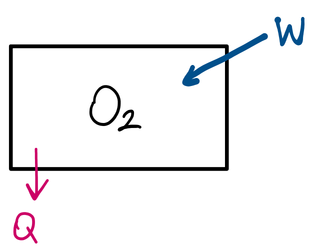
$100 = \rho_2 \cdot 0.287 \cdot 457.478$

$\dot{m} = 0.762 \times 180 \times A_2$

$A_2 = 3.86 \times 10^{-3} m^2$

$= 38.6 cm^2$

∗ A rigid tank contains O_2 at 100kPa and 27°C. A fan is operated and the pressure is increased up to 140kPa. During the state change 20kJ of heat transfer is observed. Calculate the work for this process. The volume of the tank is 300L. ($R = 0.26 \frac{kJ}{kgK}$, $c_p = 0.9218 \frac{kJ}{kg.K}$)



$Q - W = \Delta U = mc_v\Delta T$

$Pv = mRT \rightsquigarrow 100 \times 0.3 = m\ 0.26 \cdot 300.15$

m = 0.385 kg

→ MAYER'S RELATION:

$c_p - c_v = R$

$\rightarrow c_v = 0.9218 - 0.26 = 0.6618 \frac{kJ}{kgK}$

$T_2 = ?$ isochoric change of state (constant volume)

$\frac{P}{T} = \frac{mR}{V}$ const.

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{100}{300.15} = \frac{140}{T_2}$

$T_2 = 420.21$ K

$\Delta U = 0.385 \times 0.6618 (420.21 - 300.15) = 30.59$ kJ

$Q - W = \Delta U$

$-20 - W = 30.59$

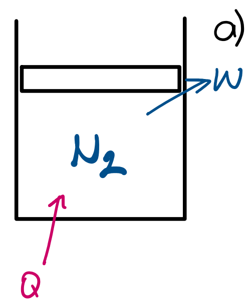
$W = -50.59$

∗ A piston cylinder device contains nitrogen at 130kPa and 120°C. The initial volume is given as 70L. Nitrogen gas temperature is increased up to 200°C at constant pressure. Calculate the:

a) work during the process.

b) heat transfer.

($R = 0.2968 \frac{kJ}{kgK}$, $c_p = 1.039 \frac{kJ}{kgK}$)



a) Isobaric change of state ($P_1 = P_2$ = constant)

$W = P(V_2 - V_1)$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightsquigarrow \frac{70}{393.15} = \frac{V_2}{473.15}$

$W = 130(0.0842 - 0.07)$

$= 1.846$ kJ

$V_2 = 84.24$ L

$= 0.0842 m^3$

b) $Q - W = \Delta U = mc_v\Delta T$

$\frac{P_1V_1}{RT_1} = m \rightsquigarrow \frac{130(0.07)}{0.2968(393.15)} = 0.1046$ kg

$(c_p - R)$

$\Delta U = 0.1046 (1.039 - 0.2968)(200 - 120)$

$\Delta U = 6.21$ kJ

$Q - W = \Delta U \rightsquigarrow Q - 1.846 = 6.21$

$Q = 8.056$ kJ