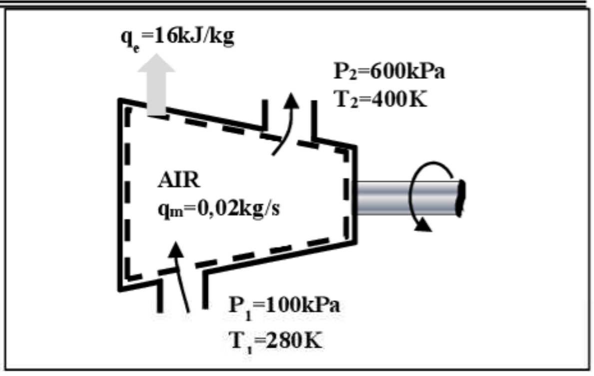
Université Med BOUDIAF M'Sila
Faculté de Technologies
Département de Génie mécanique

Série TD N°3 de Turbomachines II : L 3^eme^ A Energétique *Resp-Module :Mr Bouaouina-L*

Exercise 1 :

A compressor, consisting of a compressor, compresses air (as an ideal gas) in a steady state under the thermodynamic conditions at the inlet and outlet shown in the figure opposite. If, neglecting the variation of kinetic and potential energy between the inlet and outlet of the compressor,
With: Cp = 1005 kJ/(K.kg)
1) Determine the required power for the compressor?



Exercise 2 :

A flow passes through the stator of an axial turbine (see figure opposite). Given:

Fluid characteristics:

T_{01}=800°C, P_{01}=1,7bar, R=287J/kg.K, γ=1,33, C_{1a}=110,2m/s, α_1=0°, P_2=1,36bar, $\xi_s = 0{,}0156$,

Channel geometry:

Radius at the cross-section: r_1=0,65m, r_2=0,65m,
Thickness at the cross-section: B_1=0,162m, B_2=0,200m

Static conditions:

$Cp = 1005 J/kg.°c$, $T_1 = 794{,}75°c$, $P_1 = 1{,}66 bar$, $\rho_1 = 0{,}54 kg/m^3$,
$q_{m1} = 39{,}65 kg/s$ $W_2 = 116{,}97 m/s$

To allow this flow to establish itself:

1°)- Represent the thermodynamic state of the flow (static, stagnation, and isentropic variables) on the h-s diagram, then the velocity triangle at section 2.

2°)- Calculate C2 and T2 (using the conservation of stagnation enthalpy).

3°)- Calculate the adiabatic losses in the turbine stator.

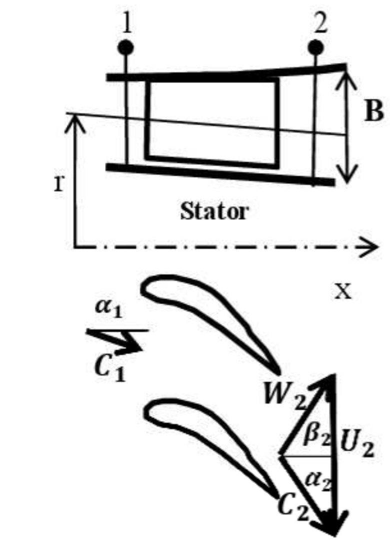


Fig-1.

Exercise 3 :

Following exercise n°4 of the TD2 series on a multi-stage turbine,

Determine:

1°)- The actual technical work done by the turbine?
2°)- The total efficiency of the turbine?
3°)- The static efficiency of the turbine?
4°)- The turbine efficiency if the change in kinetic energy is neglected?
5°)- The relationship between the total efficiency and the static efficiency, and verify it?

Solution to exercise n°1 :

$$\frac{d\cancel{m}_{mvc}}{dt} = \sum_s q_{ms} - \sum_e q_{me} \Rightarrow q_{m1} = q_{m2} = q_m$$

$$\cancel{\frac{dE}{dt}} + \sum_2 q_{m2}\left(h_2 + \cancel{\frac{C_2^2}{2}} + \cancel{gZ_2}\right) - \sum_1 q_{m1}\left(h_1 + \cancel{\frac{C_1^2}{2}} + \cancel{gZ_1}\right) = \dot{Q} + \dot{W}$$

$$\dot{W} = -\dot{Q} + q_m h_2 - q_m h_1$$

$$\dot{W} = -q_m q + q_m(h_2 - h_1)$$

$$h_1 = h_{(280)} = 281{,}4Kj/kg$$

$$h_2 = h_{(400)} = 402Kj/kg$$

$$P = \dot{W} = -q_m q + q_m(h_2 - h_1) = (0{,}02)(16) + (0{,}02)(402 - 281{,}4) = 2{,}73kw$$

Solution to exercise n°2 :

Flow at section 2

$$h_{01} = h_{02} \quad \rightarrow \quad C_p T_1 + \frac{C_1^2}{2} = C_p T_2 + \frac{C_2^2}{2}$$

$$C_2 = \sqrt{C_1^2 + 2C_p T_1\left(1 - \frac{T_2}{T_1}\right)} \quad = \sqrt{C_1^2 + 2C_p T_1\left(1 - \frac{T_2}{T_{2s}}\frac{T_{2s}}{T_1}\right)}$$

By definition: $\Delta S = C_p ln\left(\frac{T''}{T'}\right) - Rln\left(\frac{P''}{P'}\right)$

For $T_{01} = T_{02}$: $\quad \Delta S = -Rln\left(\frac{P_{02}}{P_{01}}\right)$

And for $P_2 = P_{2s}$: $\quad \Delta S = C_p ln\left(\frac{T_2}{T_{2s}}\right) = \frac{\gamma}{\gamma-1}R.\,ln\left(\frac{T_2}{T_{2s}}\right)$

The equality of the two: $\Delta S = \Delta S$ donne: $\frac{T_2}{T_{2s}} = \left(\frac{P_{01}}{P_{02}}\right)^{\frac{\gamma-1}{\gamma}}$

The total pressure at the stator outlet is known via the loss coefficient : $\zeta_s = 1 - \frac{P_{02}}{P_{01}}$

Therefore: $P_{02} = P_{01}(1 - \zeta_s)$=1,6736bar

Finally, the velocity: : $\quad C_2 = \sqrt{C_1^2 + 2C_p T_1\left(1 - \left(\frac{P_2}{P_1}\frac{P_{01}}{P_{02}}\right)^{\frac{\gamma-1}{\gamma}}\right)}$ = 353,03m/s

While the total temperature: $T_{02} = T_{01} \Rightarrow T_2 = T_{02} - \frac{C_2^2}{2C_p} = 746{,}13°c$

The adiabatic losses in the stator: $T_{2s} = \frac{T_2}{\left(\frac{P_{01}}{P_{02}}\right)^{\frac{\gamma-1}{\gamma}}} = 1{,}0045°c$

$$\pi_s = h_2 - h_{2s} = C_p(T_2 - T_{2s}) = 3350{,}93\,J$$

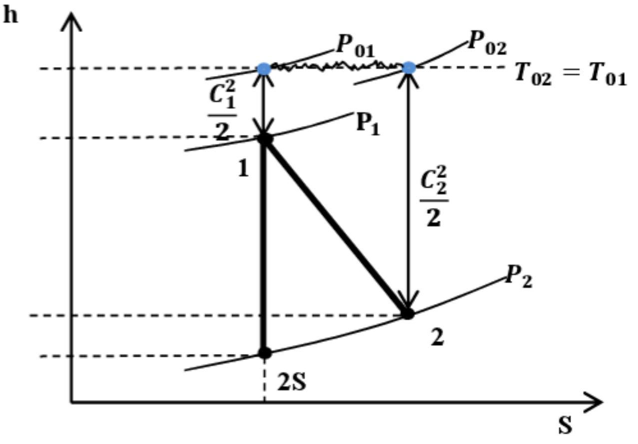


Fig.1-Diagramme h-s pour le Stator

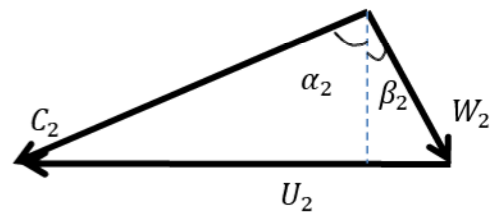


Fig.2-Diagramme des vitesses à la section 2

Solution to exercise n°3 :

1) Specific work developed: $W_T = h_{01} - h_{03} = 3449{,}1 - 2665{,}0 = 784{,}1$ KJ/kg

2) Total efficiency: $\eta_{tt} = \frac{h_{01}-h_{03}}{h_{01}-h_{03s}} = \frac{3449{,}1-2665{,}0}{3449{,}1-2329{,}9} = 0{,}700$

3) Total efficiency at static conditions: $\eta_{ts} = \frac{h_{01}-h_{03}}{h_{01}-h_{3s}} = \frac{3449{,}1-2665{,}0}{3449{,}1-2309{,}9} = 0{,}688$

4) Efficiency if the change in kinetic energy is neglected: $\eta_{tt} = \frac{h_1-h_3}{h_1-h_{3s}} = \frac{3447{,}8-2645{,}0}{3447{,}8-2309{,}9} = 0{,}705$

5) Since a relationship can be found between the two efficiencies:

$$\frac{1}{\eta_{tt}} = \frac{1}{\eta_{ts}} - \frac{C_3^2}{2W_T} = 1{,}42789 \implies \eta_{tt} = 0{,}700$$ (this can be verified)