Chapter .5 - Theory of the Single-Cell action Turbine

5-1-Principle and definition (General)

Turbine stages can be classified as action (impulse) stage (R=0) or reaction stage (R>0). (**see fig.5-1**)
Impulse blades are used successfully at high pressures in steam turbines.

5-2-Speed triangle: (see fig.5-3)

The triangle of speeds at the entry and exit of the rotor is given by **figure 5-3**

5-3-Mass work: In the case of action

turbines the stage is considered axial we therefore have: $U_1 = U_2$, the work received on the shaft per unit of mass of fluid (>0) given by 1st principle and Euler by: $W_T = h_{01} - h_{02} = U(C_{1u} - C_{2u}) = \frac{C_1^2 - C_2^2}{2} - \frac{W_1^2 - W_2^2}{2}$

5-4-H-S diagram of actual operation: (figure 5-4)

The h-S diagram in the ideal case state 1 and 2 are on the same point on the other hand in the real case if we consider the different losses we differentiate between the turbines at R=0 and with impulse as shown in fig5-4

5-5-Turbine with single-cell action (PULSE BLADE

Assumption: $\boldsymbol{\beta_1 = \beta_2}$, $C_1 = \varphi\, C_{1th}$, $W_2 = \psi W_1$, m=0 (lost output speed)

$$\eta = \frac{\text{energy collected}}{\text{energy spent}} = \frac{2W_T}{C_{1th}^2} = \frac{2U(C_1 cos\alpha_1 - C_2 cos\alpha_2)}{C_{1th}^2} = \frac{2U\Delta C_u}{C_{1th}^2}$$

To determine, we will express $C_2 cos\alpha_2$ as a function of distributor output elements, using speed triangles: $C_2 cos\alpha_2 = \left[U\left(1 + \frac{1}{\psi}\right) - C_1 cos\alpha_1\right]\psi$

$$\Rightarrow \eta = 2\varphi^2 \frac{U}{C_1^2}[C_1 cos\alpha_1(1+\psi) - U(1+\psi)] = 2\varphi^2(1+\psi)\frac{U}{C_1^2}[C_1 cos\alpha_1 - U]$$

With: $\xi = U/C_1$ Hence finally: $\boldsymbol{\eta = 2\varphi^2(1+\psi)\xi[cos\alpha_1 - \xi]}$

$\eta = f(\xi)$ is a parabola, determining ξ optimum corresponding to η optimum.

$$\frac{d\eta}{d\xi} = 0 \;\longrightarrow\; 2\varphi^2(1+\psi)cos\alpha_1 - 2\xi\varphi^2(1+\psi) = 0 \;\longrightarrow\; \xi_{opt} = \frac{cos\alpha_1}{2}$$

Which corresponds to an optimum yield of: $\boldsymbol{\eta_{opt} = \varphi^2 \frac{(1+\psi)}{2} cos^2\alpha_1}$

5-6-Degree of reaction:

■This notion expresses the enthalpy drop produced in the mobile blades in relation to the total drop of the stage (figure 1): $R = \frac{h_1 - h_{2s}}{\Delta h} \approx \frac{h_{1s} - h_{2ss}}{\Delta h} = 1 - \frac{1}{\varphi^2}\frac{C_1^2}{C_d^2} + m\frac{C_2^2}{C_d^2}$,

Note: The degree of reaction determines the shape of the moving blades

5-7-Degree of reaction and shape of the moving blades and the speed triangle:

►For a zero degree of reaction (R = 0), the stage is said to be active;

►In the Ideal case, we then have: $h_{1s} = h_{2s}$ hence $p_2 = p_1$. For an axial stage: $U_1 = U_2$. This results in, $W_{2s} = W_1$. the entry angle β_1 is equal to the exit angle β_2; hence the characteristic shape of the gear triangles and the very cambered blades.

►In the real case, with losses, the pressure $p_2 = p_1$, but the enthalpies are different, the difference $h_2 - h_1$ represents the loss in the moving blades, then: $W_1 \neq W_{2s}$ and $\beta_1 \neq \beta_2$ but the shape of the triangles of speeds remains the same.

► When the degree of reaction increases, the angle β_1 increases and the blade becomes less cambered.

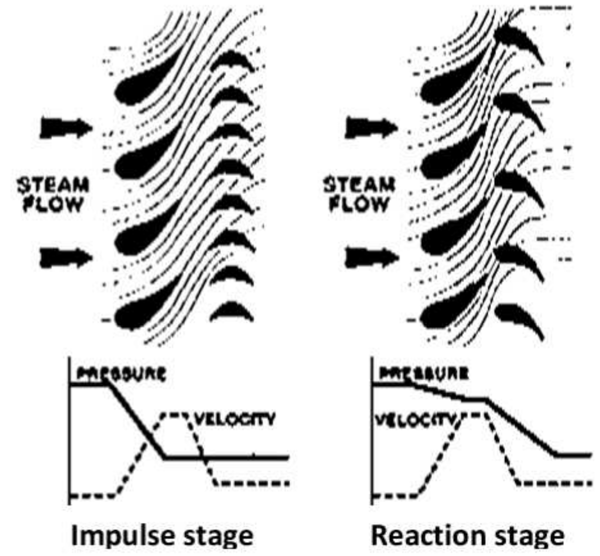

Fig.5.1- Stage of an impulse and reaction turbine

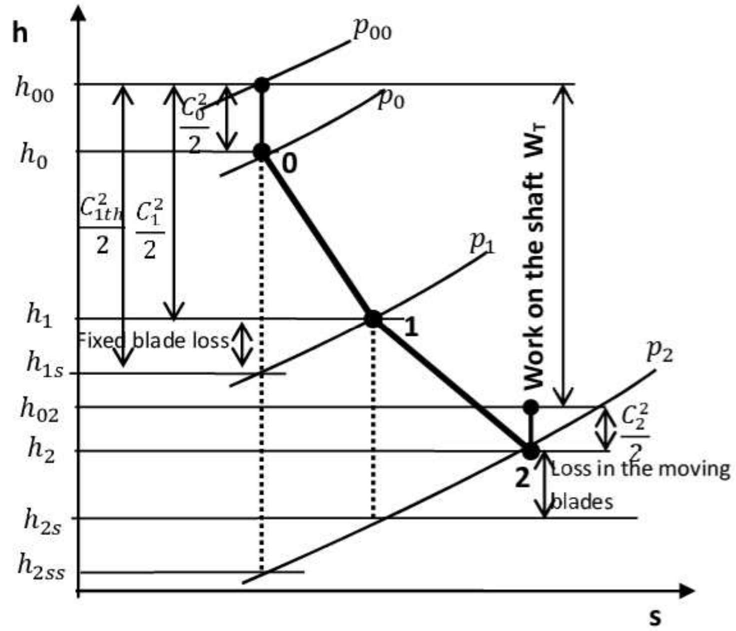

Fig.5.5- (h,s) diagram of a reaction turbine stage

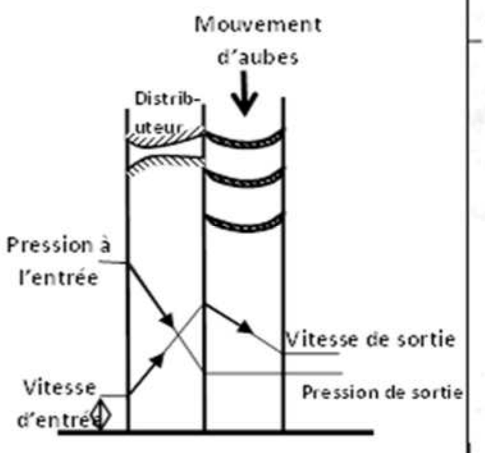

Fig.5-2-Diagramme de pression et vitesse pour une turbine à impulsion

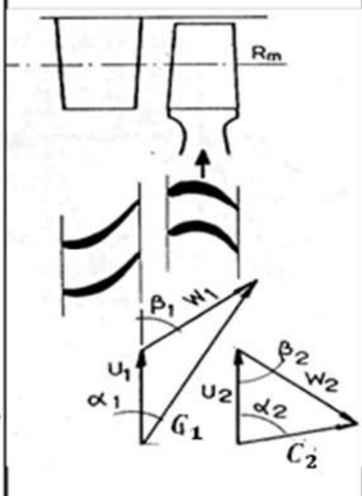

Fig.5.3-Triangle des vitesses d'un étage d'une turbine a action monocellulaire

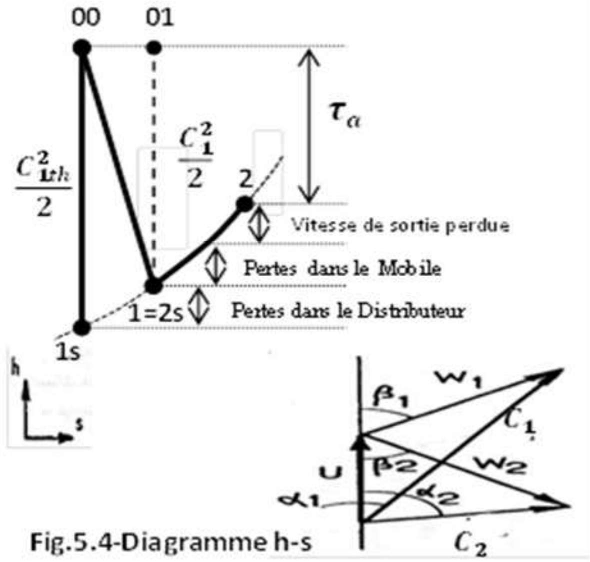

Fig.5.4-Diagramme h-s réel d'une turbine à action

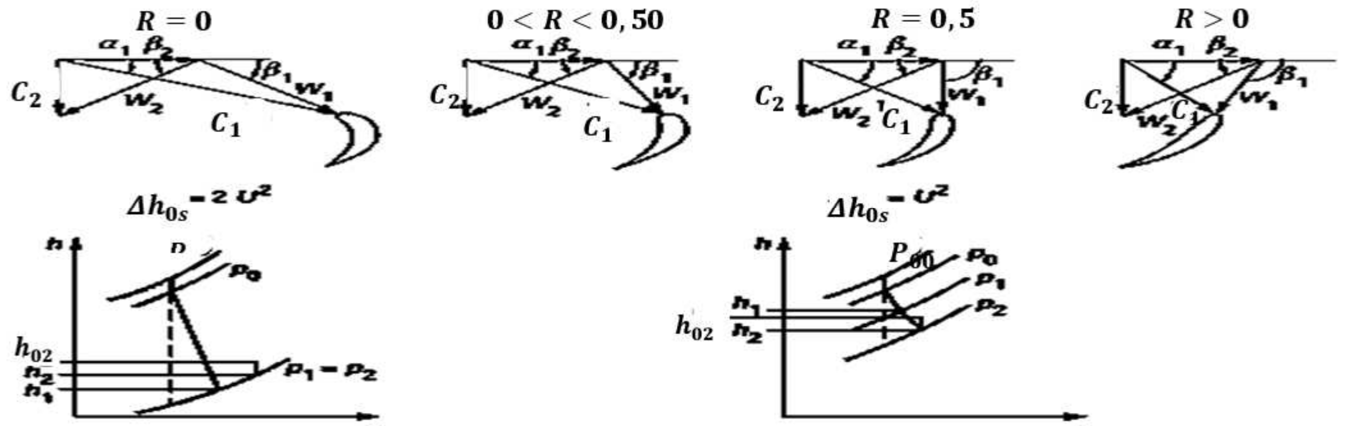

Fig.5.6- Influence of the degree of reaction on the shape of the blades