Reaction

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Reaction is defined as the ratio of static enthalpy drop in a rotor to overall static enthalpy drop in the stage.

$$R = \frac{\Delta h_{ROTOR}}{\Delta h_{STAGE}}$$

For incompressible flow & isentropic process we can express reaction as ratio of pressure drop in rotor to total pressure drop across the stage.

$$R = \frac{\Delta h_{ROTOR}}{\Delta h_{STAGE}} \approx \frac{\Delta p_{ROTOR}}{\Delta p_{STAGE}}$$

1st & 2nd laws of thermodynamics gives

- $dQ - \delta W = dU$, $dQ = dU + PdV$, $dQ = dH - VdP$.
- $dQ = TdS$ *from second law leads to* $TdS = dH - VdP$
- *For isentropic process* $\boldsymbol{dH = VdP}$ *or* $\boldsymbol{\Delta h = \Delta P/\rho}$

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In rotor relative stagnation enthalpy is constant

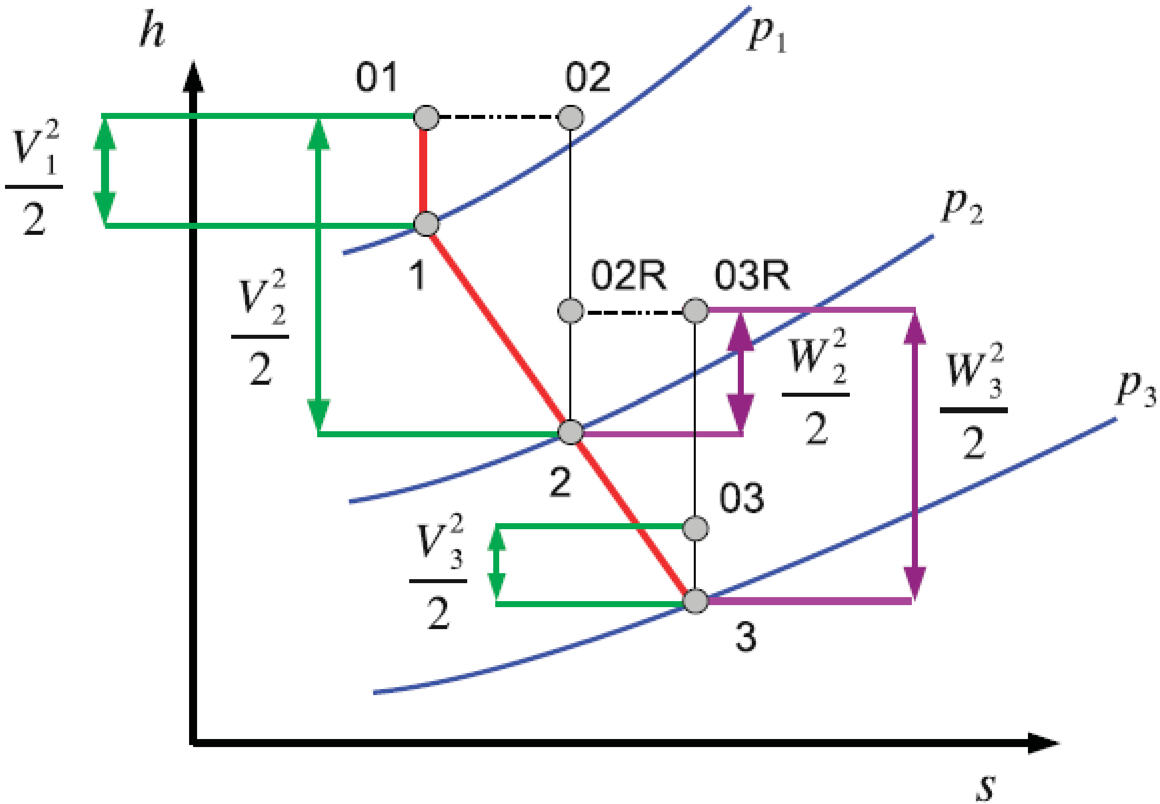
$$h_1 + \frac{w_1^2}{2} = h_2 + \frac{w_2^2}{2}$$

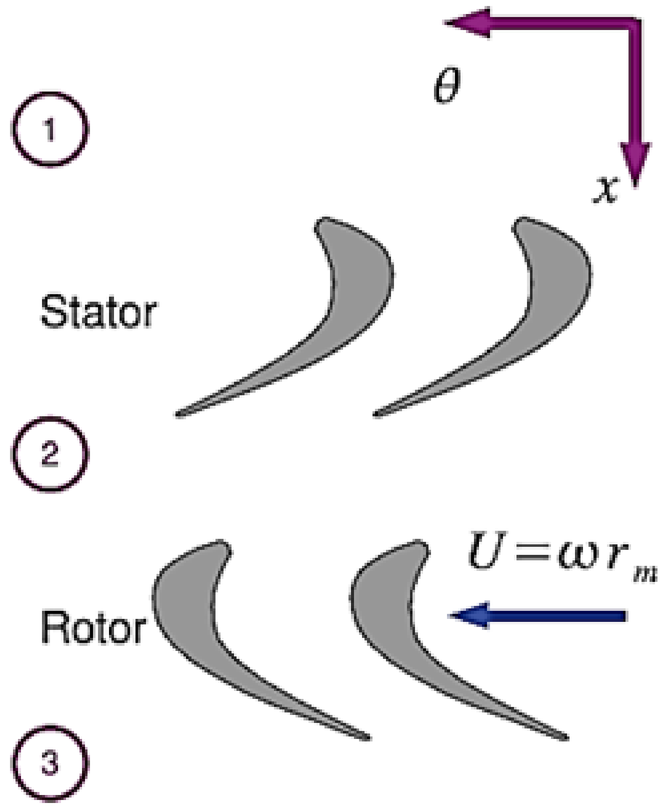
$$R = \frac{\Delta h_{ROTOR}}{\Delta h_{STAGE}} = \frac{0.5(w_1^2 - w_2^2)}{W_{actual}}$$

$$w_{actal} = U(V_{2\theta} - V_{1\theta})\ compressor\ for\ rotor$$

$$w_{actal} = U(V_{3\theta} - V_{2\theta})\ turbine\ for\ rotor$$

Reaction in a Turbine





Rothalpy in Rotors

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Defining relative stagnation enthalpy as follows

$$h_{0rel} = h + \frac{W^2}{2}$$

$$LHS = h_1 + \frac{V_1^2}{2} - UV_{1\theta} = h_1 + \frac{W_1^2}{2} - \frac{U_1^2}{2}$$

If blade speed is same through turbine, relative stagnation enthalpy will be constant through rotor blade.

$$h_{0rel1} - \frac{U_1^2}{2} = h_{0rel2} - \frac{U_2^2}{2}$$

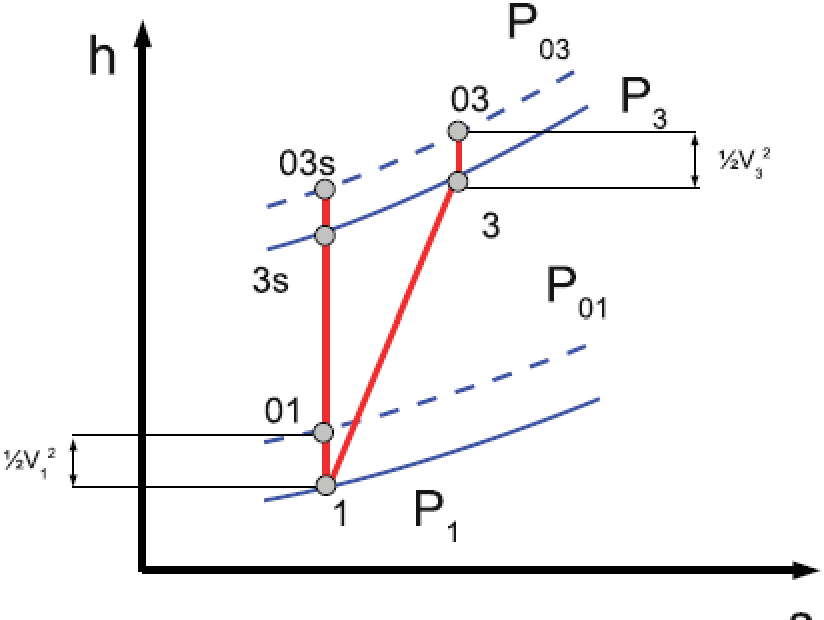
An axial compressor has a rotor blade row where the inlet velocity is 150 m/s and is in the axial direction. The blade speed is 180 m/s and the relative outlet angle is $-30°$ to the axial. The axial velocity is constant across the row.

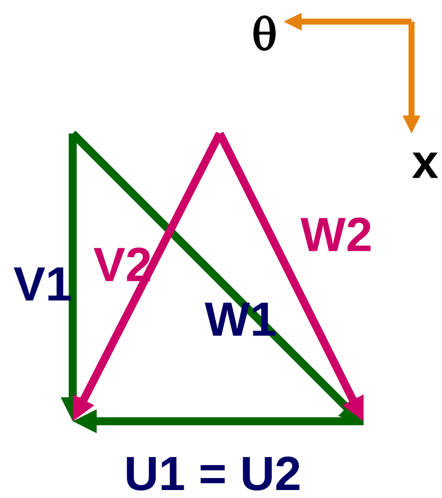
These rotor blades are followed by a set of stator blades to form a complete stage. The stators turn the flow back to the axial direction and the axial velocity is constant across the whole stage. If the total-to-total efficiency is 90%, calculate the total pressure at outlet from the stage. Assume air properties with inlet stagnation conditions of 20° and 1.0 *bar*. *Answer:* 1.187 *bar*

Given: $V_1 = 150$ m/s; $U = 180$ m/s; $\beta_2 = -30°$; $V_{1x} = V_{2x} = V_3$;

$\eta_{ic} = 0.9$; $P_1 = 1.0$ bar; $T_1 = 20°C$

To Find: $P_{03} = ?$





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Q. 2 Calculate the reaction of stage in previous question?

Ans 0.74

3. The flow at exit from a turbine stator row has a velocity of 100 m/s at an angle (α_2) of 70° to the axial direction. The rotor row is moving with a velocity of 50 m/s. At exit from the rotor row the relative flow angle (β_3) is $-60°$. The axial velocity is constant across the row. Calculate the power output for a flow rate of $4\,kg/s$. Calculate the total pressure drop across the stage if the efficiency is 90 % and the fluid density is constant at $1.2\,kg/m^3$. Calculate also the static pressure drop. What is the stage reaction? *Answers:* $20.6\,kW$, $6.88\,kPa$, $6.93\,kPa$,0.154

Lecture 9

Review of Dimensional Analysis & Similitude

Dimensionless Parameters for Turbomachinery