Example

Steam enters a nozzle 1 MPa and 350°C with velocity of 30 m/s. The pressure and temperature at the exit are 0.3 Mpa and 200°C. There is no significant heat transfer to surroundings and a negligible change in potential energy. Determine the nozzle isentropic efficiency.

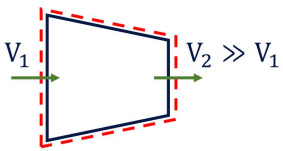
$P_1 = 1\ MPa$

$T_1 = 350°C$

$V_1 = 30\ m/s$

$P_2 = 0.3\ MPa$

$T_2 = 200°C$



steady, adiabatic, no work

$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \dot{m}_{in}\left(h + \frac{1}{2}V^2 + gz\right)_{in} - \dot{m}_{out}\left(h + \frac{1}{2}V^2 + gz\right)_{out}$$

$$\left(h_1 + \frac{1}{2}V_1^2\right)_{in} = \left(h_2 + \frac{1}{2}V_2^2\right)_{out}$$

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

Actual

$P_1, T_1 \rightarrow$ Table A-6 $\rightarrow h_1 = 3158.2\ [kJ/kg]$

$P_2, T_2 \rightarrow$ Table A-6 $\rightarrow h_2 = 2865.9\ [kJ/kg]$

$$\frac{1}{2}V_{2a}^2 = 3158.2\ [kJ/kg] - 2865.9\ [kJ/kg] + \frac{1}{2}(30)^2\left[\frac{m^2}{s^2}\right]\left(\frac{1\ kN \cdot m}{1000\ kg \cdot m/s^2 \cdot m}\right)$$

$$= 292.75\ [kJ/kg]$$

$0.45\ kJ/kg$

Isentropic

$P_1, T_1 \rightarrow$ Table A-6 $\rightarrow s_1 = 7.3029\ [kJ/kg]$

Isentropic $\therefore s_2 = s_1$

$P_2, s_2 \rightarrow$ Table A-6 $\rightarrow$

$s_x @ 7.0792 \rightarrow h_x = 2761.2$

$s_2 @ 7.3029 \rightarrow h_2 = ?$

$s_y @ 7.3132 \rightarrow h_y = 2865.9$

Interpolate

$$\frac{h_2 - h_x}{s_2 - s_x} = \frac{h_y - h_x}{s_y - s_x}$$

$$h_2 = \frac{h_y - h_x}{s_y - s_x}(s_2 - s_x) + h_x = 2861.29\ [kJ/kg]$$

$$\frac{1}{2}V_{2s}^2 = h_1 - h_2 + \frac{V_1^2}{2}$$

$$= 3158.2\ [kJ/kg] - 2861\ [kJ/kg] + 0.45\ [kJ/kg] = 297.65\ [kJ/kg]$$

$$\eta_N = \frac{V_{2s}^2}{V_{2a}^2} = \frac{292.75\ [kJ/kg]}{297.65\ [kJ/kg]} = \boxed{98.35\ \%}$$

∴ Irreversible losses due to friction between fluids and walls, or with layers of fluid