

Mechanical Energy of Flowing Fluid Elements An Introduction

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Internal Energy & Advertising First Law of Thermodynamics: Extending Work-Energy beyond mechanics

$$\Delta U = \text{Change in Internal Energy } U = \text{"Heat \& work exchange"} = "q - W"$$

What is Mechanical “Engineering” Energy?

- “Form of energy that can be converted to mechanical work completely and directly by an ideal mechanical device like ideal turbine”
(Cengel & Boles: TD)
- We will book keep energy via “control mass”, “control volume”, energy flow across “control surface” but for now, we will look at energy per unit mass

Forms of energy for flowing fluids

$$KE = m \frac{V^2}{2} \quad (\text{kJ}) \quad \text{Kinetic energy}$$

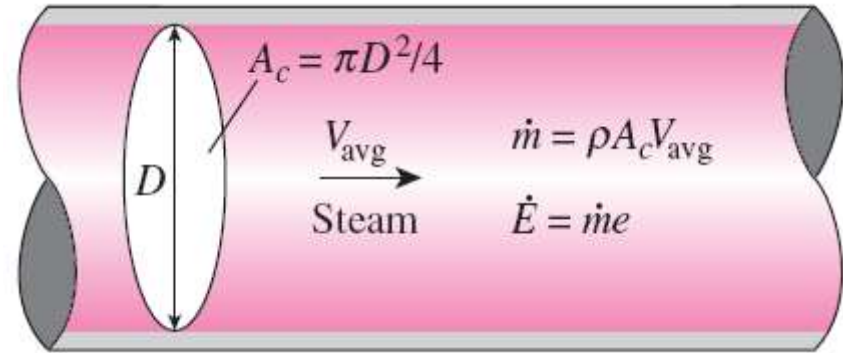
$$ke = \frac{V^2}{2} \quad (\text{kJ/kg}) \quad \text{Kinetic energy per unit mass}$$

$$PE = mgz \quad (\text{kJ}) \quad \text{Potential energy}$$

$$pe = gz \quad (\text{kJ/kg}) \quad \text{Potential energy per unit mass}$$

$$E = U + KE + PE = U + m \frac{V^2}{2} + mgz \quad (\text{kJ}) \quad \text{Total energy of a system}$$

$$e = u + ke + pe = u + \frac{V^2}{2} + gz \quad (\text{kJ/kg}) \quad \text{Energy of a system per unit mass}$$



Mass flow rate

$$\dot{m} = \rho \dot{V} = \rho A_c V_{avg} \quad (\text{kg/s})$$

Energy flow rate

$$\dot{E} = \dot{m}e \quad (\text{kJ/s or kW})$$

Mechanical energy of flowing fluids

$$e_{\text{mech}} = \frac{P}{\rho} + \frac{V^2}{2} + gz$$

Mechanical energy of a flowing fluid per unit mass

$$\dot{E}_{\text{mech}} = \dot{m}e_{\text{mech}} = \dot{m}\left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)$$

Rate of mechanical energy of a flowing fluid

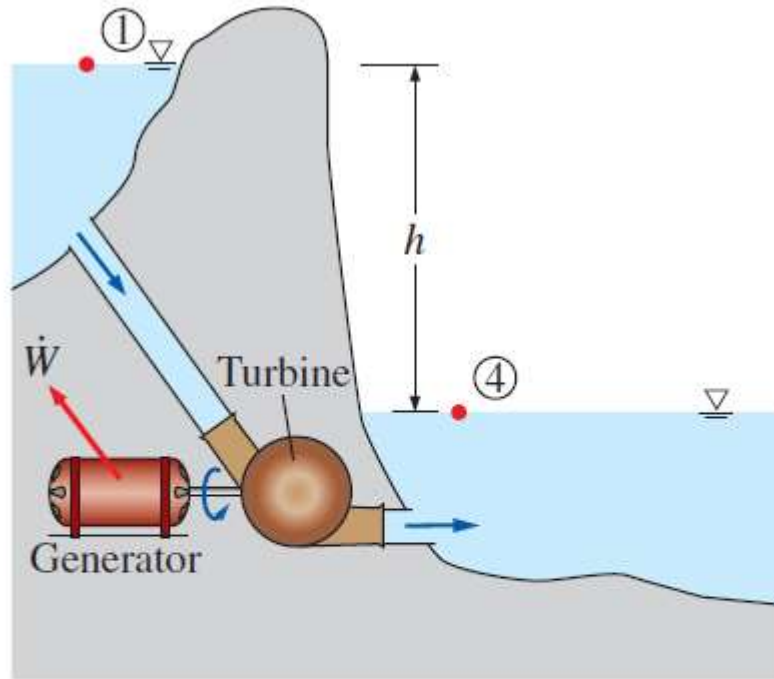
Mechanical energy change of a fluid during incompressible flow per unit mass

$$\Delta e_{\text{mech}} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1) \quad (\text{kJ/kg})$$

Rate of mechanical energy change of a fluid during incompressible flow

$$\Delta \dot{E}_{\text{mech}} = \dot{m}\Delta e_{\text{mech}} = \dot{m}\left(\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right) \quad (\text{kW})$$

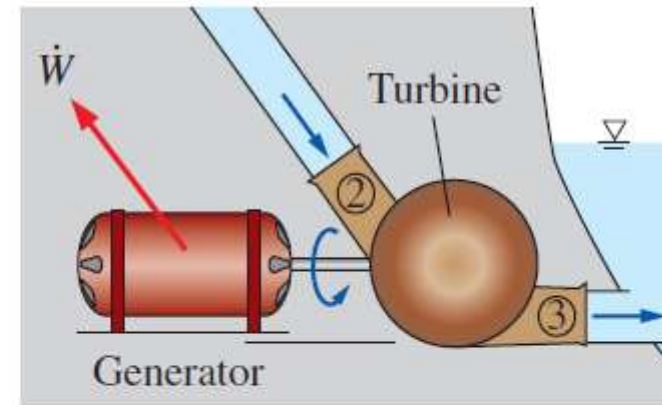
Coupling mechanical energy to work



$$\dot{W}_{\max} = \dot{m} \Delta e_{\text{mech}} = \dot{m} g (z_1 - z_4) = \dot{m} g h$$

since $P_1 \approx P_4 = P_{\text{atm}}$ and $V_1 = V_4 \approx 0$

(a)



$$\dot{W}_{\max} = \dot{m} \Delta e_{\text{mech}} = \dot{m} \frac{P_2 - P_3}{\rho} = \dot{m} \frac{\Delta P}{\rho}$$

since $V_2 \approx V_3$ and $z_2 = z_3$

(b)