# MECHANICAL ENGINEERING SCIENCE (UE25ME141A/B)

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- Hydraulic machines are the devices that convert hydraulic energy into mechanical energy. Or mechanical energy into hydraulic energy.
- Hydraulic turbines are the basic prime movers which convert the hydraulic energy (in the form of pressure/kinetic energy) into mechanical energy.
- Pressure energy is developed due to head of water in the form of potential energy and kinetic energy is developed due to mass flow of water with some velocity.
- The shaft of hydraulic turbine rotates due to impact/ reaction force of water on hydraulic blades; the shaft of the turbine is coupled with generator which produces electrical energy.
- Pump converts mechanical energy into hydraulic energy (pressure energy).

- Fluid energy (like the energy in moving water, steam, or air) can be converted into mechanical energy through devices called **turbines** or **impellers**.

- This process harnesses the **kinetic energy** (energy of motion) and/or **pressure energy** of the fluid and transforms it into useful mechanical work, such as rotating a shaft.

**Examples:**

i. **Hydroelectric turbines:** Convert energy from flowing water into mechanical rotation that generates electricity.

ii. **Steam turbines:** Convert energy from high-pressure steam into mechanical work.

iii. **Wind turbines:** Convert kinetic energy of wind into mechanical rotation.

# MECHANICAL ENERGY AND EFFICIENCY

- Many fluid systems are designed to transport a fluid from one location to another at a specified flow rate, velocity, and elevation difference, and the system may generate mechanical work in a turbine or it may consume mechanical work in a pump or fan during this process.

- These systems do not involve the conversion of nuclear, chemical, or thermal energy to mechanical energy. Also, they do not involve heat transfer in any significant amount, and they operate essentially at constant temperature.

- Such systems can be analyzed conveniently by considering only the mechanical forms of energy and the frictional effects that cause the mechanical energy to be lost (i.e., to be converted to thermal energy that usually cannot be used for any useful purpose).

- The **mechanical energy** is defined as the form of energy that can be converted to mechanical work completely and directly by an ideal mechanical device such as an ideal turbine.

Mechanical energy is a useful concept for flows that do not involve significant heat transfer or energy conversion, such as the flow of gasoline from an underground tank into a car.

- Kinetic and potential energies are the familiar forms of mechanical energy. Thermal energy is not mechanical energy, however, since it cannot be converted to work directly and completely (the second law of thermodynamics).

- The mechanical energy of a flowing fluid can be expressed on a unit-mass basis as

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

where $P/\rho$ is the flow energy, $V^2/2$ is the kinetic energy, and gz is the potential energy of the fluid, all per unit mass. Then the mechanical energy change of a fluid during incompressible flow becomes

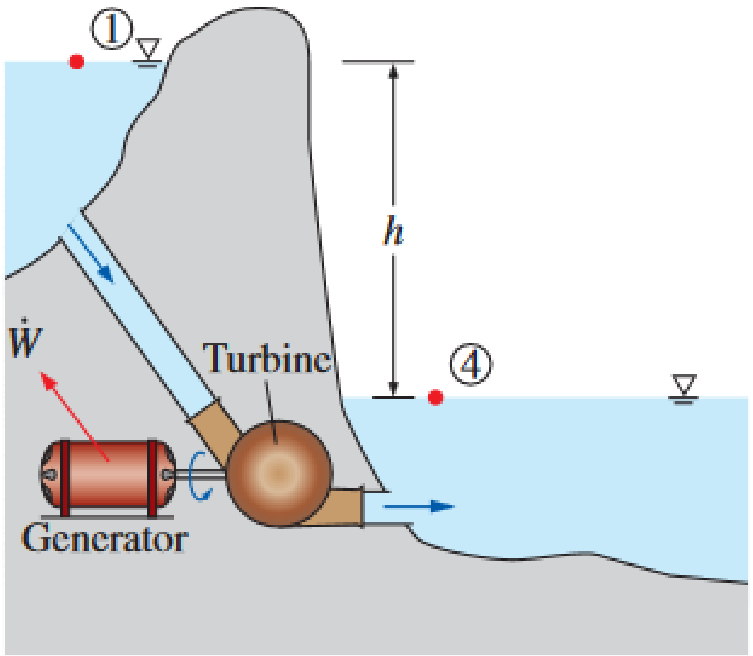
$$\Delta e_{\text{mech}} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1) \qquad \text{(kJ/kg)}$$

## MECHANICAL ENERGY AND EFFICIENCY

- Therefore, the mechanical energy of a fluid does not change during flow if its pressure, density, velocity, and elevation remain constant.

- In the absence of any irreversible losses, the mechanical energy change represents the mechanical work supplied to the fluid (if $\Delta e_{mech} > 0$) or extracted from the fluid (if $\Delta e_{mech} < 0$).

- The maximum (ideal) power generated by a turbine, for example, is $W\max = \dot{m}\Delta e_{mech}$




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

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

## MECHANICAL ENERGY AND EFFICIENCY

- The transfer of mechanical energy is usually accomplished by a rotating shaft, and thus mechanical work is often referred to as shaft work.

- A pump or a fan receives shaft work (usually from an electric motor) and transfers it to the fluid as mechanical energy (less frictional losses). A turbine, on the other hand, converts the mechanical energy of a fluid to shaft work.

- Because of irreversibilities such as friction, mechanical energy cannot be converted entirely from one mechanical form to another, and the mechanical efficiency of a device or process is defined as

$$\eta_{\text{mech}} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy input}} = \frac{E_{\text{mech, out}}}{E_{\text{mech, in}}} = 1 - \frac{E_{\text{mech, loss}}}{E_{\text{mech, in}}}$$

- The degree of perfection of the conversion process between the mechanical work supplied or extracted and the mechanical energy of the fluid is expressed by the pump efficiency and turbine efficiency. In rate form, these are defined as

$$\eta_{\text{pump}} = \frac{\text{Mechanical power increase of the fluid}}{\text{Mechanical power input}} = \frac{\Delta \dot{E}_{\text{mech, fluid}}}{\dot{W}_{\text{shaft, in}}}$$

$$\Delta \dot{E}_{\text{mech, fluid}} = \dot{E}_{\text{mech, out}} - \dot{E}_{\text{mech, in}}$$

$$\eta_{\text{turbine}} = \frac{\text{Mechanical power output}}{\text{Mechanical power decrease of the fluid}} = \frac{\dot{W}_{\text{shaft, out}}}{|\Delta \dot{E}_{\text{mech, fluid}}|}$$

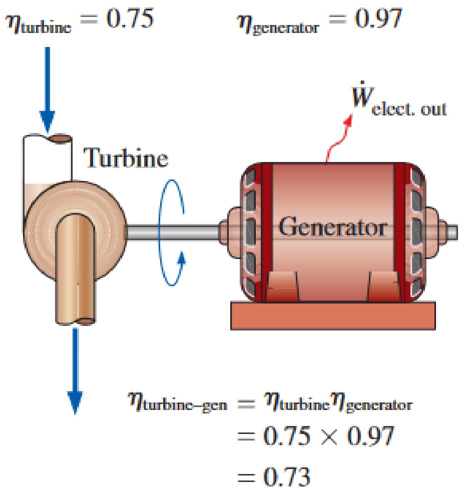
$$|\Delta \dot{E}_{\text{mech, fluid}}| = \dot{E}_{\text{mech, in}} - \dot{E}_{\text{mech, out}}$$

- The mechanical efficiency should not be confused with the motor efficiency and the generator efficiency, which are defined as

*Motor:* $$\eta_{\text{motor}} = \frac{\text{Mechanical power output}}{\text{Electric power input}} = \frac{\dot{W}_{\text{shaft, out}}}{\dot{W}_{\text{elect, in}}}$$

and

*Generator:* $$\eta_{\text{generator}} = \frac{\text{Electric power output}}{\text{Mechanical power input}} = \frac{\dot{W}_{\text{elect, out}}}{\dot{W}_{\text{shaft, in}}}$$




- A pump is usually packaged together with its motor, and a turbine with its generator. Therefore, we are usually interested in the combined or overall efficiency of pump–motor and turbine–generator combinations, which are defined as

$$\eta_{\text{pump-motor}} = \eta_{\text{pump}}\,\eta_{\text{motor}} = \frac{\Delta \dot{E}_{\text{mech, fluid}}}{\dot{W}_{\text{elect, in}}}$$

$$\eta_{\text{turbine-gen}} = \eta_{\text{turbine}}\,\eta_{\text{generator}} = \frac{\dot{W}_{\text{elect, out}}}{|\Delta \dot{E}_{\text{mech, fluid}}|}$$

# THANK YOU

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