ENERGY PRINCIPLE

First Law of Thermodynamics

For a given system

$$\Delta E = Q - W$$

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

Where:

$Q = Heat\ transferred\ to\ the\ system\ (poistive\ sign)$

$W = Work\ transferred\ out\ of\ the\ system\ (negative\ sign)$

E = (Internal Energy, Kinetic Energy, Potential Energy)

$$E = U + K.E + P.E$$

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$$\dot{Q} - \dot{W} = \frac{d}{dt}\int_{cv}(u + e_K + e_P)\rho dQ + \int_{cs}(u + e_K + e_P)\rho V \bullet dA$$

Mass flow rate

$$e_K = \frac{(1/2)mv^2}{m} = \frac{v^2}{2}$$

$$e_P = \frac{mgz}{m} = gz$$

$$\dot{Q} - \dot{W} = \frac{d}{dt}\int_{cv}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{cs}(u + \frac{v^2}{2} + gz)\rho V \bullet dA$$

$$The\ Work\ \dot{W} = \dot{W}_f + \dot{W}_s$$

$$\dot{W}_s = Shaft\ Work$$

$$\dot{W}_f = Flow\ Work$$

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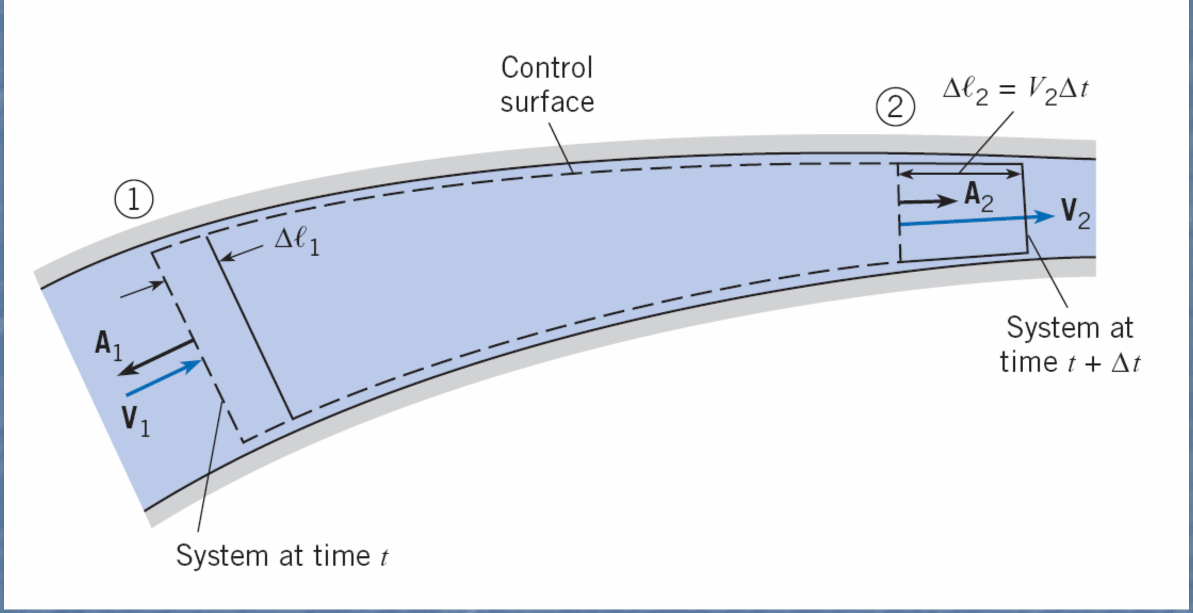
Flow Work



The flow of work done by the system at station (2) is given by

$$W_{f2} = F \times \Delta l_2 = (p_2 A_2) \times v_2 \Delta t$$

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$$\dot{W}_{f2} = (p_2 A_2) \times v_2 = p_2 v \bullet A$$

The flow of work by the system at station (1) is given by

$$W_{f1} = F \times \Delta l_1 = (p_1 A_1) \times V_1 \Delta t$$

$$\dot{W}_{f1} = (p_1 A_1) \times V_1 = p_1 V \bullet A$$

In general form, the work done by the system for a constant velocity

$$\dot{W}_f = \sum_{CS} pV \bullet A$$

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In general form, the work done by the system for a variable velocity

$$\dot{W}_f = \int_{CS} pV \bullet dA = \int_{CS} \frac{p}{\rho}\left(\rho V \bullet dA\right)$$

Shaft Work $(\dot{W}_s)$

Consider Eqn.

$$\dot{Q} - \dot{W} = \frac{d}{dt}\int_{cv}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{cs}(u + \frac{v^2}{2} + gz)\rho V \bullet dA$$

$$\dot{Q} - \dot{W}_s - \dot{W}_f = \frac{d}{dt}\int_{cv}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{cs}(u + \frac{v^2}{2} + gz)\rho V \bullet dA$$

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$$\dot{W}_f = \int_{CS} pV \bullet dA = \int_{CS} \frac{p}{\rho}(\rho V \bullet dA)$$

$$\dot{Q} - \dot{W}_s - \int_{CS} \frac{p}{\rho}(\rho v \bullet dA) = \frac{d}{dt}\int_{cv}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{cs}(u + \frac{v^2}{2} + gz)\rho V \bullet dA$$

$$\dot{Q} - \dot{W}_s = \frac{d}{dt}\int_{CV}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{CS}(u + \frac{v^2}{2} + gz)\rho V \bullet dA + \int_{CS} \frac{p}{\rho}(\rho V \bullet dA)$$

$$\dot{Q} - \dot{W}_s = \frac{d}{dt}\int_{CV}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{CS}(u + \frac{p}{\rho}) + \frac{v^2}{2} + gz)\rho V \bullet dA$$

$$\text{The term enthalpy} = h = \left(u + \frac{p}{\rho}\right)$$

$$\dot{Q} - \dot{W}_s = \frac{d}{dt}\int_{CV}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{CS}(h + \frac{v^2}{2} + gz)\rho V \bullet dA$$

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Steady Flow Energy Equation

For steady flow, the flow accumulation equal zero and if the **velocity distribution is constant**, then

the Eqn. $\dot{Q} - \dot{W}_s = \frac{d}{dt}\int_{CV}(u + \frac{v^2}{2} + gz)\rho dQ + \int_{CS}(h + \frac{v^2}{2} + gz)\rho V \bullet dA$ becomes

$$\dot{Q} - \dot{W}_S = \sum_{CS} \dot{m}_{out}\left(\frac{V^2}{2} + gz + h\right)_{out} - \sum_{CS} \dot{m}_{in}\left(\frac{V^2}{2} + gz + h\right)_{in}$$

END OF LECTURE (1)