ESO201A

Lecture#20

(Class Lecture)

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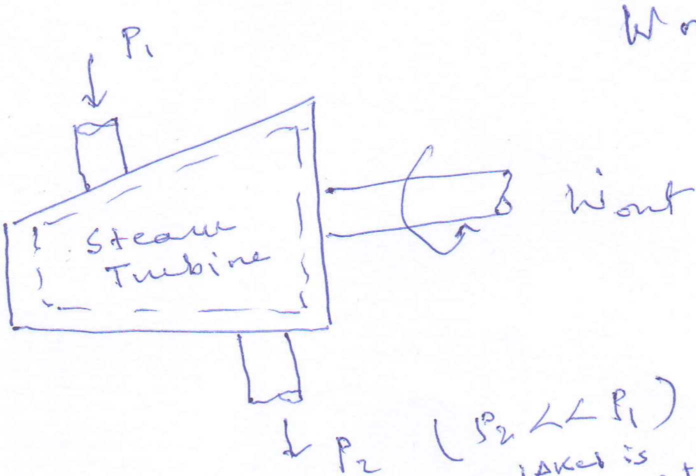
By

Dr. P.S. Ghoshdastidar

Turbines and Compressors

Turbine

(Steam, gas or hydroelectric power plants)



P_2 ($P_2 << P_1$)

Work producing devices.

Work done by the system.

$\dot{Q} = 0$ (Well insulated)

$\Delta pe = 0$

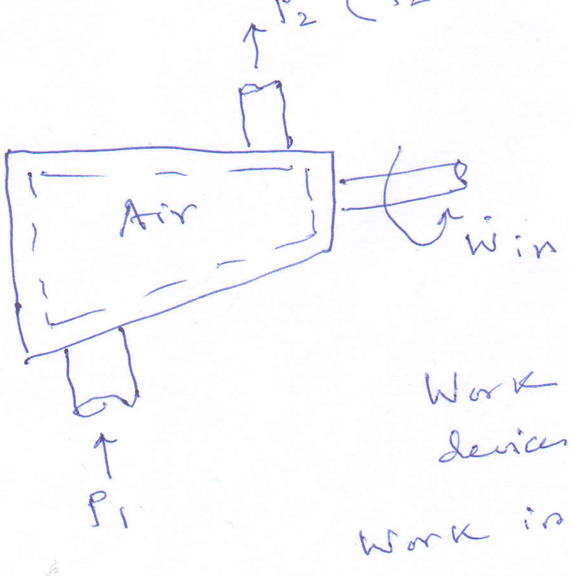
$\Delta ke \neq 0$

$|\Delta ke|$ is small w.r.t. $|\Delta h|$.

As the fluid passes through the turbine, work is done against the blades, which are attached to the shaft. As a result, the shaft rotates, and the turbine produces work.

Compressor, Pump, fan

P_2 ($P_2 >> P_1$)



$\Delta ke = 0$ except for fans.

$\Delta pe = 0$

$\dot{Q}$ is usually zero or small.

Work done on the system.

Compressor → High pressure increase in gas

Pump → Handles liquids.

Fan → Increases the pressure of a gas slightly and is mainly used to mobilize a gas.

Work consuming devices.

Work is supplied to these devices from an external source through a rotating shaft.

Example Problem #1

Air at 100 kPa and 280K is compressed steadily to 600 kPa and 400 K. The mass flow rate of air is 0.02 kg/s, and a heat loss of 16 kJ/kg occurs during the process. Assuming the changes in kinetic and potential energies are negligible, determine the necessary power input to the compressor. $P_{cr} = 3.77$ MPa, $T_{cr} = 132.5$ K. See Fig. 1.

Solution

Assumptions

1. Steady-flow process and hence $\Delta m_{cv} = 0$ and $\Delta E_{cv} = 0$.

2. Air is treated as an ideal gas since $P << P_{cr}$ and $T >> T_{cr}$.

3. $\Delta ke = 0$, $\Delta pe = 0$.

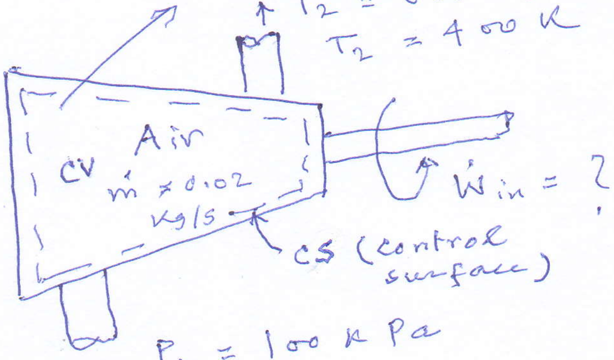


Fig. 1

The compressor is taken as the system which is a control volume since the mass crosses the system boundary.

The energy balance:

$$\dot{E}_{in} - \dot{E}_{out} = \overset{0\ (\text{steady})}{\cancel{dE_{system}/dt}} = 0 \qquad (1)$$

$$\Rightarrow \quad \dot{E}_{in} = \dot{E}_{out}$$

$$\Rightarrow \quad \dot{W}_{in} + \dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta ke = 0,\ \Delta pe = 0)$$

$$\Rightarrow \quad \dot{W}_{in} = \dot{Q}_{out} + \dot{m}(h_2 - h_1)$$

$$= \dot{m}q_{out} + \dot{m}(h_2 - h_1) \qquad (2)$$

The enthalpy of an ideal gas depends on temperature only, and the enthalpies of the air at the specified temperatures are determined from the air table (Table A-17) to be

$$h_1 = h_{@280\,K} = 280.13 \text{ KJ/kg}$$

$$h_2 = h_{@400\,K} = 400.98 \text{ KJ/kg}$$

Substituting the above in eq. (2), we get

$$\dot{W}_{in} = \dot{m}\, q_{out} + \dot{m}\,(h_2 - h_1)$$

$$= (0.02)(16) + (0.02)(400.98 - 280.13)$$

$$= 0.32 + 2.417$$

$$= 2.737 \text{ KW}$$

$$\approx \boxed{2.74 \text{ KW}}$$

Conclusions

The mechanical energy input to the compressor results in a rise in enthalpy of air and heat loss from the compressor.