TOPIC III - Energy Balances

Steady Flow Applications (Lecture 4/4)

Contents

8 – Nozzles and diffusers

9 - Turbines and compressors

10 - Throttling valves

Objectives

Understand what equipment does. Problem solve by selecting appropriate terms in SFEE.

TOPIC III - Energy Balances

Steady Flow Applications (Lecture 4/4)

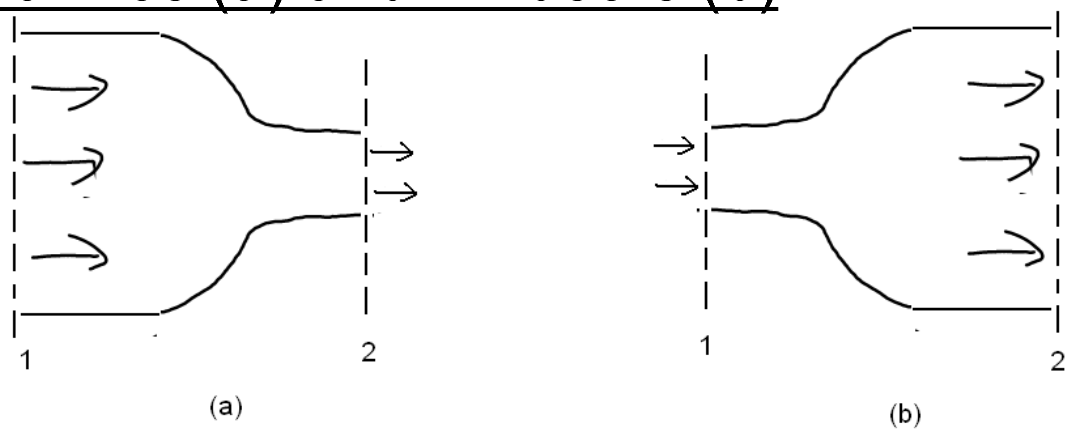
7 SFEE

Recall - Steady Flow Energy Equation (SFEE) balances inputs and outputs – terms for kinetic energy, potential energy, enthalpy (= internal energy + flow work)

$$\boxed{\dot{Q} + \dot{W} = \dot{m}[(h_2 + \frac{1}{2}c_2^2 + g\,z_2) - (h_1 + \frac{1}{2}c_1^2 + g\,z_1)]} \tag{8}$$

For ideal gases $h_2 - h_1 \approx c_p\,(T_2 - T_1)$

8 Nozzles (a) and Diffusers (b)



Accelerate (nozzle) or decelerate gas (diffuser). Assume no work or heat transfer.

Relate mass flow to cross sectional area,

$$\dot{m} = \rho\, A\, C$$

In subsonic flow, increased A reduces C

Example, diffuser (b) with c_1 = 200 m s^{-1} , T_1 = 10°C, c_2 ~ 0.

TOPIC III - Energy Balances

Steady Flow Applications (Lecture 4/4)

Eliminate terms in SFEE

$$\cancel{\dot{Q}} + \cancel{\dot{W}} = \dot{m}[(h_2 + \cancel{\tfrac{1}{2} c_2^2} + \cancel{g z_2}) - (h_1 + \tfrac{1}{2} c_1^2 + \cancel{g z_1})]$$

Rearrange

$$h_2 = h_1 + \frac{c_1^2}{2}$$

If $c_2 \approx 0$ m s^{-1}, and h = c_p (T – T_o),

$$T_2 = T_1 + \frac{c_1^2}{2\,c_p}$$

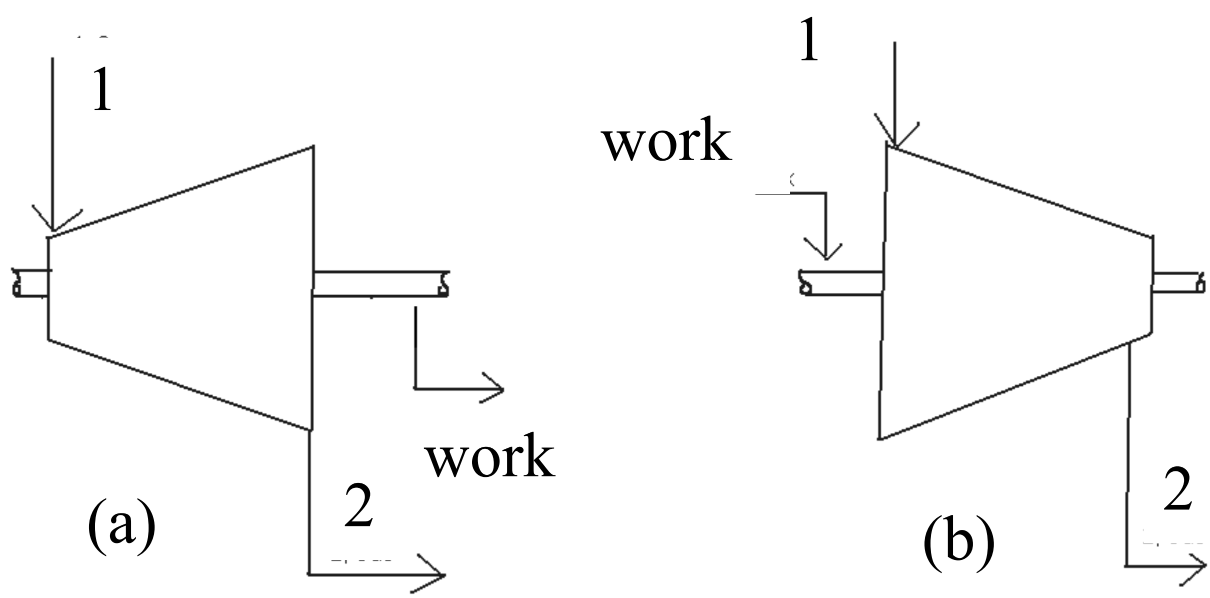
$$T_2 = 10°\text{C} + \frac{200^2\ \text{m}^2\ \text{s}^{-2}}{(2 * 1.005\ \text{kJ kg}^{-1}\ \text{K}^{-1} * 1000\ \text{J kJ}^{-1})}$$

T_2 =10°C + 20K = <u>*30°C*</u>

9. Turbines and Compressors

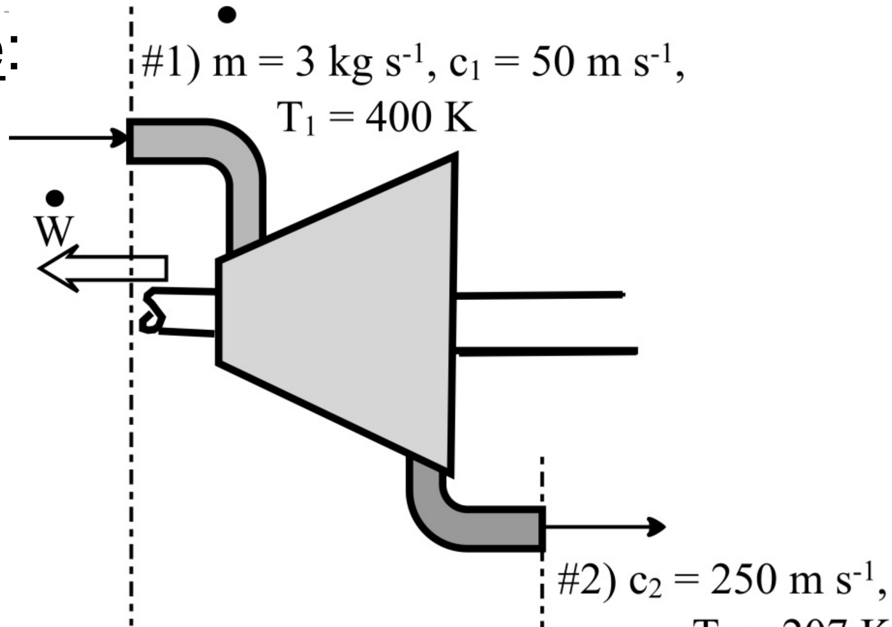
Turbine -> produces useful work from hot, high pressure gas (exits cold, low pressure). Axial, radial, not wind

Compressor -> applies work to raise pressure (higher temperature follows). Turbomachine or piston-cyclinder



(a) turbine and (b) compressor

<u>Example</u>:



Eliminate terms,

$$\cancel{\dot{Q}} + \dot{W} = \dot{m}[(h_2 + \frac{1}{2} c_2^2 + \cancel{g z_2}) - (h_1 + \frac{1}{2} c_1^2 + \cancel{g z_1})]$$

Note that h = c_p (T - T_o)

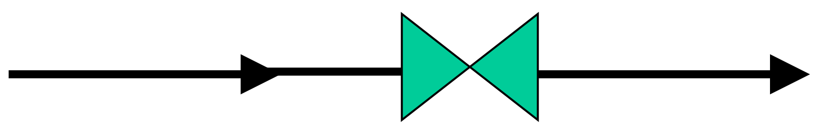
$$\dot{W} = \dot{m}[c_p (T_2 - T_1) + (c_2^2 - c_1^2)/2]$$

$$\dot{W} = 3\times[1.005\times(207-400)+(250^2-50^2)/(2\times1000)=$$

<u>-492 kW</u>

10. Throttling Valves

Reduces pressure. No work or heat transfer. Ignore changes in KE, PE. The expansion is *isenthalpic*



1) High pressure

2) Low pressure

$$h_1 = h_2 \qquad (10)$$

11. Mixing Chambers

Examples in topic notes.

Conclusions:

The SFEE

$$\boxed{\dot{Q} + \dot{W} = \dot{m}[(h_2 + \frac{1}{2}c_2^2 + g z_2) - (h_1 + \frac{1}{2}c_1^2 + g z_1)]}$$

Assumptions

Diffusers/ nozzles, $\dot{Q}, \dot{W} = 0$

Turbines, compressors, $\dot{Q} = 0$

Ideal gases, often useful to write,

$h_2 - h_1 = c_p (T_2 - T_1)$ or $h = c_p (T - T_o)$

Use the multi inlet/ multi outlet form (E9) for (say) two inlets and one outlet (a mixer)