Now that we can apply energy balances to open systems, we can begin to look at engineering devices. We'll spend the next few days looking at the Galloway turbojet engine used on F80 military jet planes.

Most gas turbine engines consist of the following components:

1. Inlet air
2. Compressor
3. Diffuser
4. Combustor
5. Turbine
6. Afterburner
7. Nozzle

We will use what we've learned to analyze this system piece by piece...
Diffuser: The purpose of a diffuser is to convert a high velocity, low pressure flow into a low velocity, high pressure flow.

For Goblin II

Inlet

\[ m = 250 \text{ kg/s} \]

\[ V_{in} = 350 \text{ mph} \]

\[ T_{in} = 75^\circ \text{ F} \]

\[ P_{in} = 2.2 \text{ atm} \]

\[ V_{in} = 300 \text{ mph} \]

Assuming ideal with constant heat capacity,

1. Inlet diameter of Diffuser

2. Temperature leaving diffuser

Mass balance (Rate):

\[ \dot{m}_{n} = \dot{m}_{in} + \dot{c}_{n} \]

\[ \dot{m}_{n} = 25.0 \text{ kg/s} \]

How do we relate to \( A_{n} \)?

\[ \dot{m}_{n} = \frac{V_{n} A_{n}}{2} \cdot \frac{\rho_{n}}{\rho_{in}} \]

\[ P_{n} = \frac{P_{in}}{\rho_{in}} = \frac{8314 \text{ atm}}{28.37 \text{ atm}} \Rightarrow P_{n} = 287.1 \text{ atm} \]

\[ \dot{c}_{n} = \frac{P_{in} \cdot 3.21}{P_{n} \cdot 7500} \Rightarrow \dot{c}_{n} = 278.3 \text{ kg/s} \]

\[ V_{n} = 1.065 \text{ m/s} \]

\[ \dot{m}_{n} = \frac{1}{2} \pi D_{n}^{2} \cdot (156.5 \text{ m/s}) = 25 \text{ kg/s} \]

\[ D_{n} = 0.4654 \text{ m} \]

B) Temperature of air leaving the diffuser

Energy Balance:

\[ E_{n} = E_{in} + \frac{\dot{c}_{n}^{2}}{2} \]

\[ C_{v} + u_{n}^{2} + m_{n} v_{n}^{2} + \frac{v_{n}^{2}}{\gamma} \Rightarrow C_{v} + \frac{v_{n}^{2}}{2} \Rightarrow \dot{m}_{n} \left( \frac{v_{n}^{2}}{2} \right) = \dot{m}_{n} \left( \frac{v_{n}^{2}}{2} \right) \]

Assumptions: 1) Steady-state

2) No Energy loss

3) No Flow work

4) Adiabatic

5) Ideal gases, constant C_v, \( C_v = C_p \left( \frac{5}{2} - T \right) \)

\[ \dot{m}_{n} \frac{v_{n}^{2}}{2} = k_{p} \left( \frac{5}{2} - T_{n} \right) \]

\[ \dot{m}_{n} \frac{v_{n}^{2}}{2} = k_{p} \left( \frac{5}{2} - T_{n} \right) \]
Compressor: The purpose of a compressor is to use work to increase the pressure of a fluid.

1) Determine the volumetric flow rate

\[ T_2 = \frac{1}{2} C_\text{r} \left( \frac{V_1}{2} + T \right) \]

\[ T_2 = 290.3 \text{ k} \]

\[ P_2 = 2200 \text{ kPa} \]

\[ V_2 = 0 \]

\[ M_2 = 25 \text{ kg/s} \]

\[ \dot{V}_2 = \frac{R T_3}{P_3} \]

\[ \frac{P_3}{P} = \frac{P_3}{P_{\text{rath}}} \Rightarrow P_3 = P_{\text{rath}} \]

\[ \dot{V}_3 = \frac{287.15 (800.2 \text{ k})}{5.25 (229000 \text{ kPa})} \Rightarrow \dot{V}_3 = 1187 \text{ m}^3/\text{s} \]

\[ \dot{W}_3 = 25 \text{ kg/s} (1187 \text{ m}^3/\text{s}) \Rightarrow \dot{W}_3 = 29.67 \text{ kW} \]

D) Find the power required by the compressor

Energy Balance

\[ \dot{E}_\text{in} = \dot{E}_\text{out} + \Delta \dot{E} = 0 \]

\[ \Delta \dot{E} = \dot{W}_n + \dot{M}_2 h_{\text{v}} \left( \frac{V_2}{V_1} \right) \]

\[ \dot{W}_n = \dot{M}_2 \left( h_{\text{f}} - h_{\text{v}} \right) \]

General equation for a compressor

Assumptions

DSS

\[ \dot{W}_n = \dot{M}_2 \left( h_{\text{f}} - h_{\text{v}} \right) \to 25 \text{ kg/s} \left( 105.5 \text{ k} (800.2 \text{ k} - 290 \text{ k}) \right) \Rightarrow \dot{W}_n = 527200 \text{ kW} \]
The purpose of a combustor is to add heat to a flow of fluid. Sometimes just the heat is specified and sometimes rate of fuel's heating value of fuel is specified. Usually, they are large combustion chambers that are open at either end. This means they are isobaric.

c.) Find the heat transfer that must be added to the combustor.

\[ T_f = 1393 \text{K} \]

Assumptions:
1) Steady State
2) TE, KE negligible
3) No shaft or PV work
4) Ideal, constant \( C_p \)

Mass Balance:
\[ \dot{m}_i = \dot{m}_{out}, \quad M_i = M_{out} \]

Energy Balance:
\[ \dot{E}_i = \dot{E}_{out} + \dot{Q} \]

\[ \dot{Q}_{in} = M_i (C_p, T_f - T_i) \]

General equation for combustion with above assumptions:

\[ Q_{in} = 25 \times 6 \times (185 \div 2 - 503 \div 2) = 25,400 \text{W} \]

Nothing out of pattern? No.

Problem solving steps: Included

1. Make a drawing. Note the known properties, state information.
2. Choose the system to solve for important specifications with feasible assumptions.
3. Apply mass balance with assumptions to simplify.
4. Apply energy balance with assumptions to simplify.
5. Apply fluid tables, ideal constant or not.
6. Solve resulting set of equations.