TOPIC V - Gas Cycles

The Brayton (Joule) Cycle (Lecture 3/4)

Power from gas turbines.

Contents

7. The (Simple Reversible) Brayton Cycle
8. Variations to the Brayton Cycle
   - entropy generation ☹
   - heat recovery ☺

Objectives

Identify specific processes in Brayton – isentropic expansion, heat exchange.

7) The Brayton (Joule) cycle

Power generation and marine propulsion.

Three stages

- air compressed
- fuel injection plus combustion
- exhaust gases drive turbine.

Turbine "bootstrapped" to compressor

Gas exits at atmospheric pressure

Air standard cycle - heat input replaces combustion

(Fictitious) heat output closes cycle

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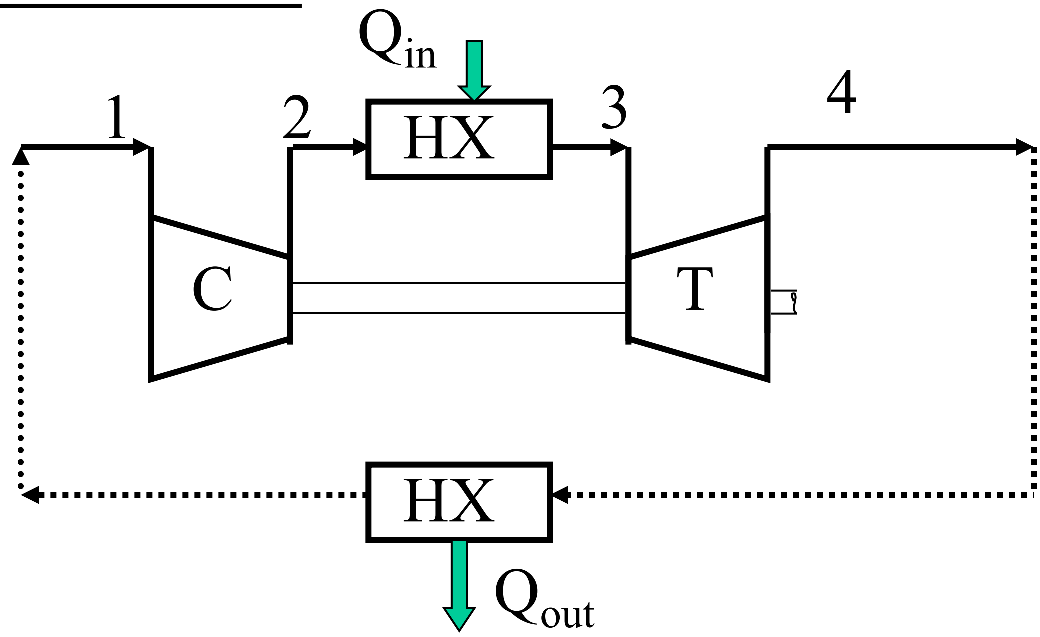
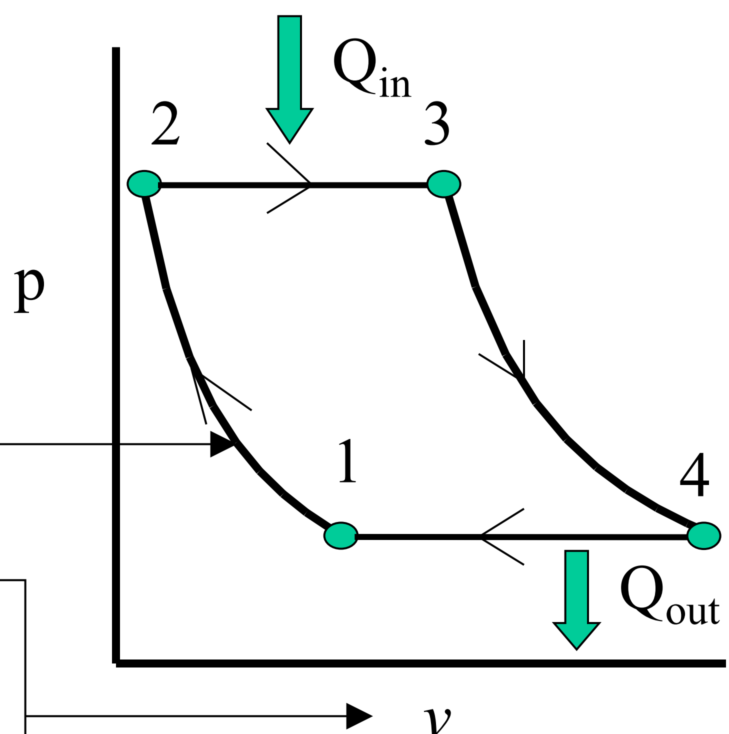
Reversible Version



Compressor increases air pressure r_p times

$$r_p = p_2/p_1$$



Easier to think about specific vol.

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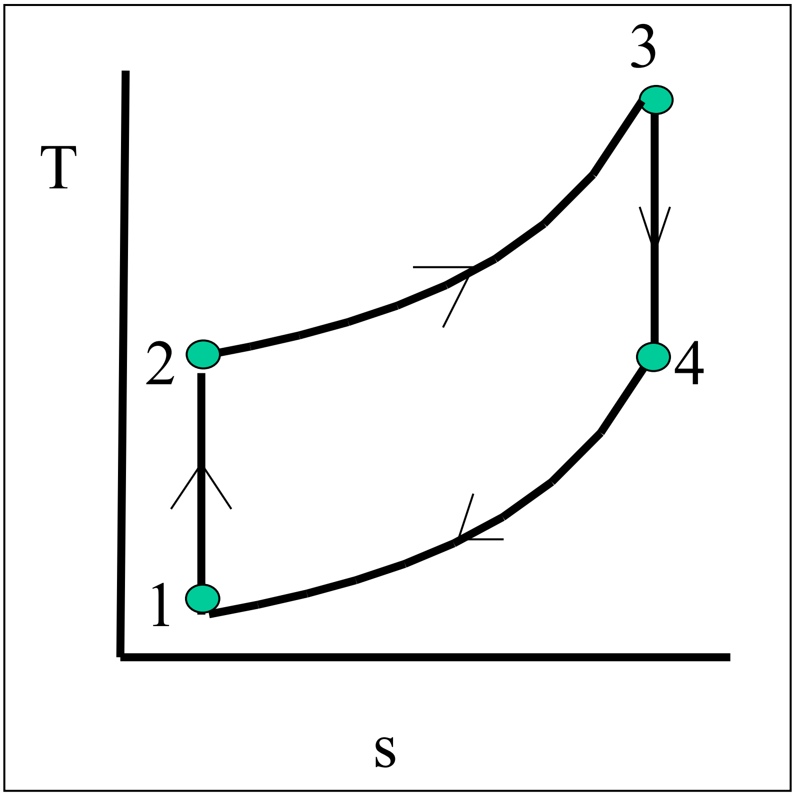


SFEE-> heating/ cooling. No KE, PE change.

$$\dot{Q}_{in} = \dot{m} c_p \left(T_3 - T_2\right) \quad (16)$$

$$\dot{Q}_{out} = \dot{m} c_p \left(T_4 - T_1\right) \quad (17)$$

$$\eta = 1 - \frac{\dot{Q}_{out}}{\dot{Q}_{in}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \quad (18)$$

Isentropic relationships (temp. & pres ratios),

$$T_1 = T_2 \big/ {r_p}^{\gamma-1/\gamma} \qquad T_4 = T_3 \big/ {r_p}^{\gamma-1/\gamma} \qquad (19, 20)$$

Eqns 18, 19, 20 give efficiency,

$$\eta = 1 - \frac{1}{{r_p}^{\gamma-1/\gamma}} \qquad (21)$$

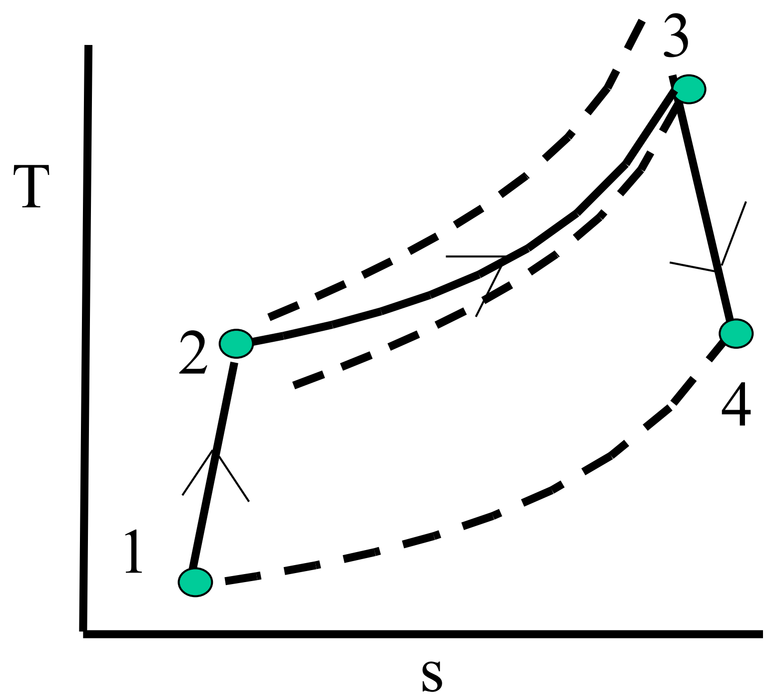
work ratio = net work / turbine work

8. Variations to the Brayton Cycle

Irreversible processes ☹

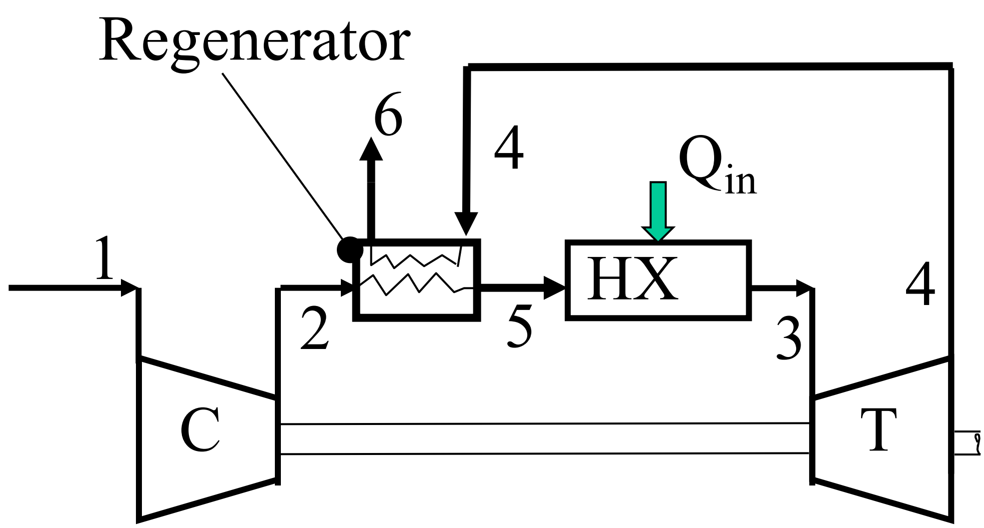
Entropy generation in comp/ turbine.

Pressure drop in combustor



Towards Ericsson (Remove Irreversibility) ☺

- Recover enthalpy from turbine exhaust. Must have T4 > T2



- Concept of renenerator effectiveness,

$$T_5 \le T_4 \quad (T_5 = T_4 \ \text{at best}) \qquad (22)$$

$$e = \frac{\text{Heat transfer}}{\text{Max heat transfer}} = \frac{m\,c_p\left(T_5 - T_2\right)}{m\,c_p\left(T_4 - T_2\right)} = \frac{T_5 - T_2}{T_4 - T_2}$$

Other options

Compressors with intercooling

- Closer to isothermal operation at TL
- Demands less work input (topic 4)
- Approaches Ericcson cycle

Turbines with reheating

- Closer to isothermal operation at TH
- Gives more work output
- Approaches Ericcson cycle

Conclusions

Simplest Brayton = Comp + HX + Turbine

Calculate process by process, Eq 21 as check

Compressors/ turbines need isentropic efficiency

Heat recovery - effectiveness applies. Must have T(turbine exit) > T(compressor exit)