ESO 201A: Thermodynamics

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Gas Power Cycle: part 1

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Learning Objectives

- Evaluate the performance of gas power cycles for which the working fluid remains a gas throughout the entire cycle.
- Develop simplifying assumptions applicable to gas power cycles.
- Review the operation of reciprocating engines.
- Analyze both closed and open gas power cycles.
- Solve problems based on the Otto, Diesel, and Brayton cycles.

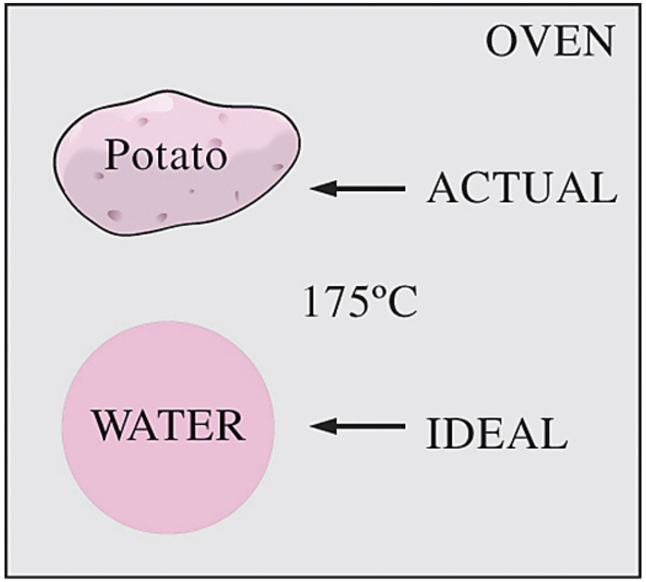
Thermodynamic cycles

Thermodynamic cycles

Basic Considerations in the Analysis of Power Cycles

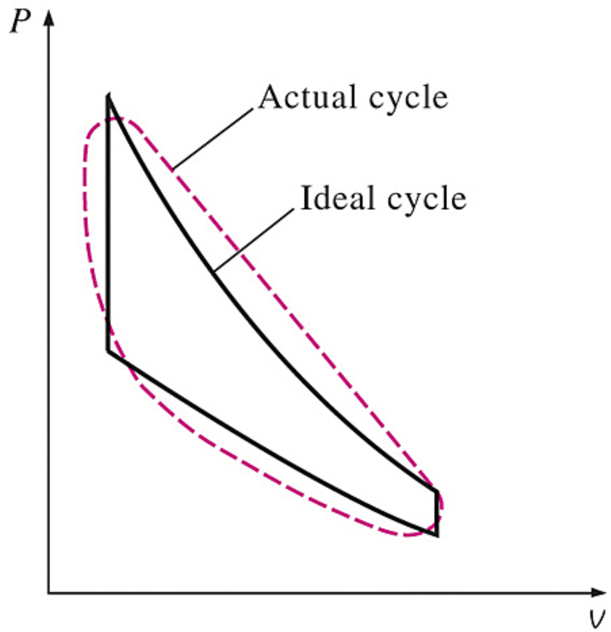
Overview

- Most power producing devices operate on cycles
- In general, these cycles are difficult to analyze
- To make the analysis feasible, idealizations are utilized



Ideal Cycle

- A cycle that resembles an actual cycle closely but is made up totally of internally reversible processes



Basic Considerations in the Analysis of Power Cycles

Thermal Efficiency

- The ratio of net work produced by the engine to the total heat input

$$\boxed{\eta_{\text{th}} = \frac{W_{\text{net, out}}}{Q_{\text{in}}}}$$

- The Carnot cycle has the highest efficiency of all heat engines operating between the same temperature levels, i.e., no cycle can be more efficient than the Carnot cycle
- Ideal cycles are internally reversible, but unlike the Carnot cycle, they are not necessarily externally reversible
- As a result, ideal cycles may involve heat transfer through a finite temperature difference

Basic Considerations in the Analysis of Power Cycles

Common Idealizations and Simplifications

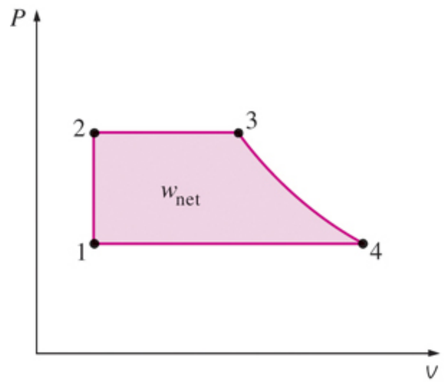
- The following idealizations and simplifications are commonly employed in the analysis of power cycles

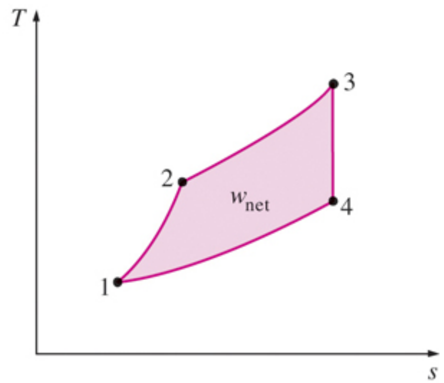
1. The cycle does not involve any friction. Therefore, the working fluid does not experience any pressure drop as it flows in pipes or devices
2. All expansion and compression processes take place in a quasi-equilibrium manner
3. The pipes connecting the various components of a system are all well insulated, and heat transfer through them is negligible

Basic Considerations in the Analysis of Power Cycles

Property Diagrams

- In the analysis of cycles, property diagrams such as the *P-v* and *T-s* diagrams serve as valuable aids
- On both the *P-v* and *T-s* diagrams, the area enclosed by the process curves of a cycle represents the net work produced during the cycle, which is equivalent to the net heat transfer for that cycle
- On a *T-s* diagram:
  - o Heat addition → proceeds in the direction of increasing entropy
  - o Heat rejection → proceeds in the direction of decreasing entropy
  - o Isentropic → constant entropy

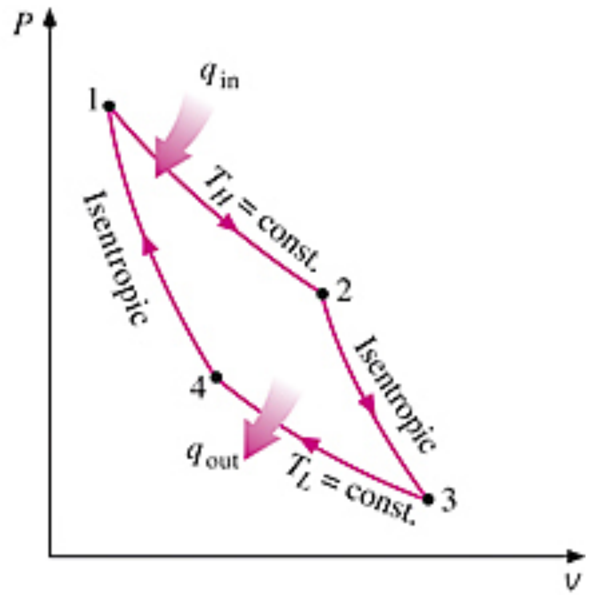




The Carnot Cycle and its Value in Engineering

Carnot Cycle

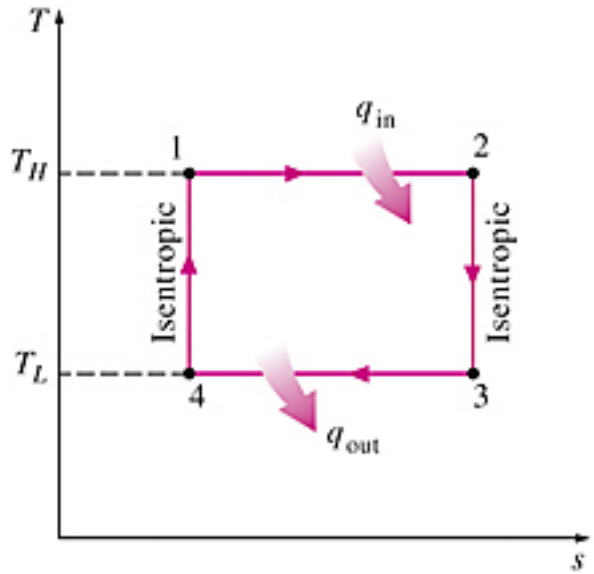
- The Carnot cycle is composed of four totally reversible processes
  1. Isothermal heat addition
  2. Isentropic expansion
  3. Isothermal heat rejection
  4. Isentropic compression



Thermal Efficiency

- The Carnot cycle is the most efficient cycle that can be operated between a heat source at temperature T_H and a sink at temperature T_L
- The thermal efficiency of the Carnot cycle is

$$\boxed{\eta_{\text{th, rev}} = 1 - \frac{T_L}{T_H}}$$



The Carnot Cycle and its Value in Engineering

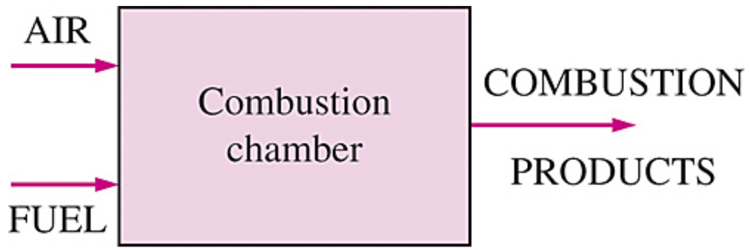
Value of Carnot Cycle

- Reversible isothermal heat transfer is very difficult to achieve in reality
- It is not practical to build an engine that would operate on a cycle that closely approximates the Carnot cycle
- The value of the Carnot cycle comes from it being a standard against which actual and ideal cycles can be compared
- The thermal efficiency relation conveys an important message that is equally applicable to both ideal and actual cycles

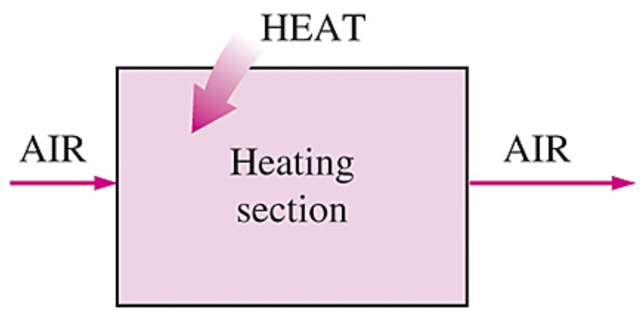
Thermal efficiency increases with an increase in the average temperature at which heat is supplied to the system or with a decrease in the average temperature at which heat is rejected from the system

$$\boxed{\eta_{\text{th, rev}} = 1 - \frac{T_L}{T_H}}$$

Air-Standard Assumptions



(*a*) Actual



(*b*) Ideal

The combustion process is replaced by a heat-addition process in ideal cycles.

Overview

- In gas power cycles, the working fluid remains a gas throughout the entire cycle
- In all gas cycles, energy is provided by burning a fuel within the system boundary
- The composition of the working fluid changes from air and fuel to combustion products during the course of a cycle
- Considering that air is predominately nitrogen that undergoes hardly any chemical reactions in a combustion chamber, the working fluid closely resembles air at all times

Air-Standard Assumptions

Approximations

- To simplify the analysis, we utilize the following approximations, known as the *air-standard assumptions*
  1. The working fluid is air, which continuously circulates in a closed loop and always behaves as an ideal gas
  2. All of the processes that make up the cycle are internally reversible
  3. The combustion process is replaced by a heat-addition process from an external source
  4. The exhaust process is replaced by a heat rejection process that restores the working fluid to its initial state

Cold-air-standard Assumption

- Assumption that the air has constant specific heats whose values are determined at room temperature (25 ^{o}C)

Air-standard Cycle

- A cycle for which the air-standard assumptions are applicable

Next lecture

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