ESO 201A: Thermodynamics

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Gas Power Cycle: part 3

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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.

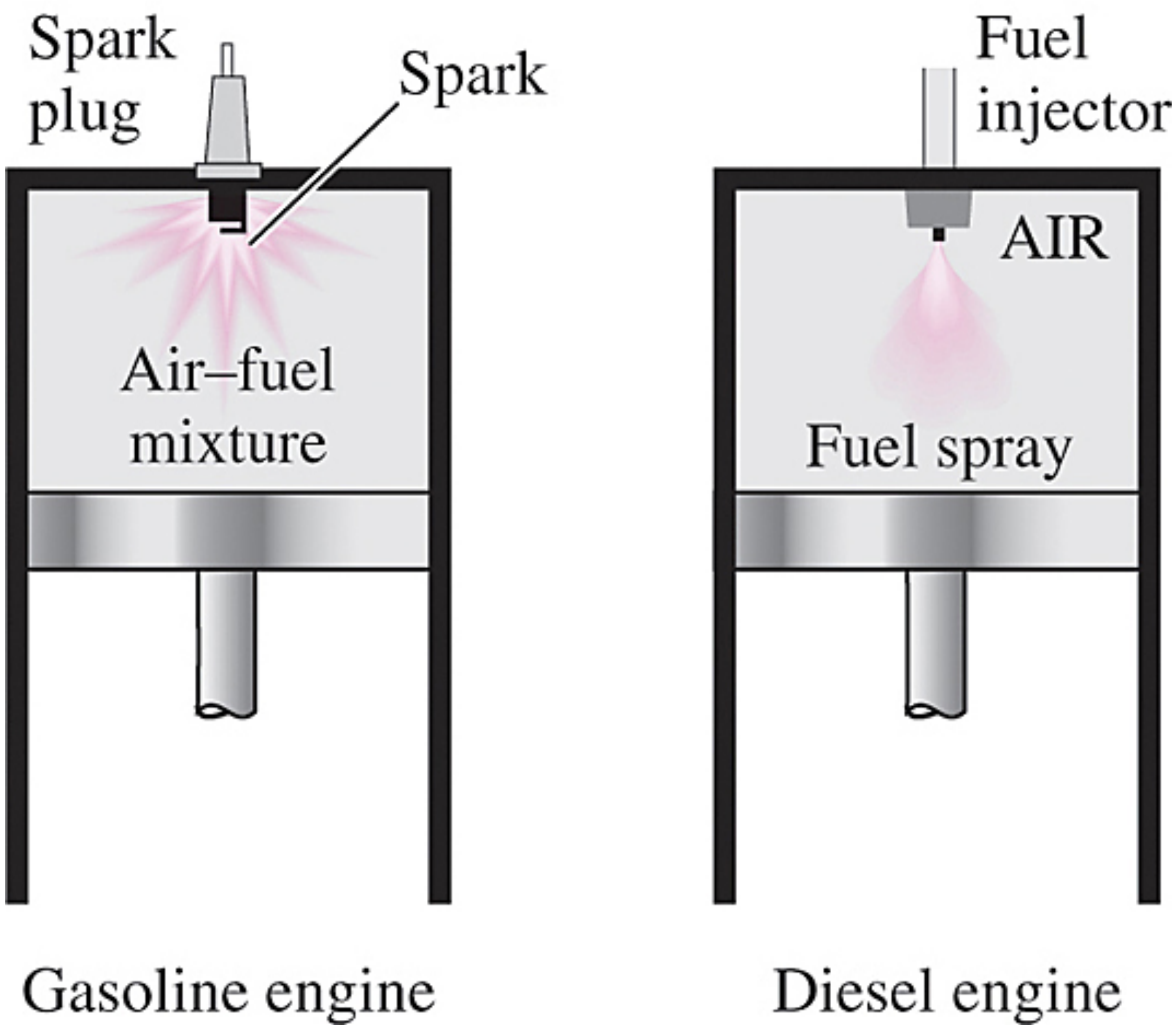
Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

Diesel Cycle

- The Diesel cycle is the ideal cycle for compression-ignition engines
- The combustion process in these engines takes place over a longer interval
- Due to this longer duration, the combustion process in the ideal Diesel cycle is approximated as a constant-pressure heat-addition process
- This is the only process where the Otto and the Diesel cycles differ

Rudolph Diesel

Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

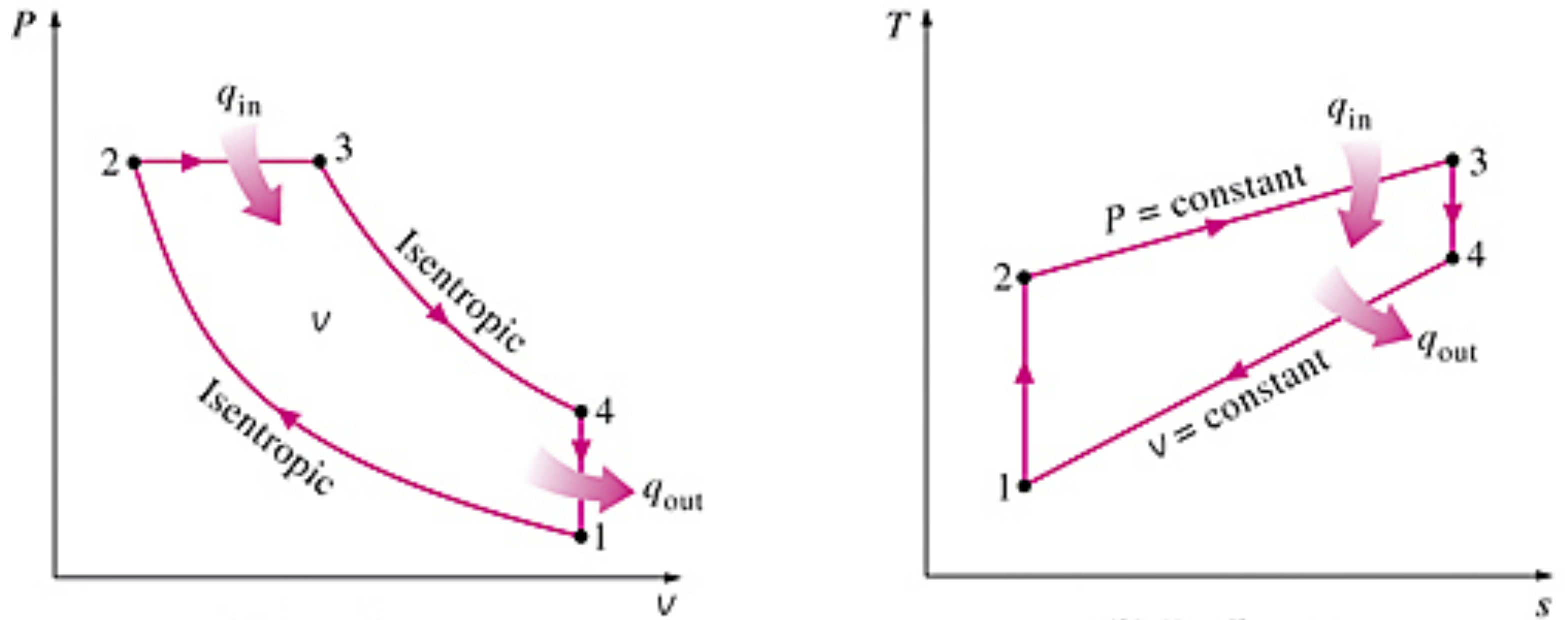


Diesel Cycle (cont.)

- The four processes of the Diesel cycle are as follows

1→2	Isentropic compression
2→3	Constant-pressure heat addition
3→4	Isentropic expansion
4→1	Constant-volume heat rejection

- Here are the *P*-*v* and *T*-*s* diagrams for the Diesel cycle



(*a*) *P*- *v* diagram

(*b*) *T*-*s* diagram

Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

Thermodynamic Analysis

- The Diesel cycle occurs in a closed system
- For the constant pressure process 2→3 we have

$$q_{\text{in}} - w_{b,\,\text{out}} = u_3 - u_2$$

$$q_{\text{in}} = u_3 - u_2 + P\left(v_3 - v_2\right)$$

$$q_{\text{in}} = h_3 - h_2 = c_p\left(T_3 - T_2\right)$$

- Process 4→1 is the same as for the Otto cycle

$$-q_{\text{out}} = u_1 - u_4 = c_v\left(T_1 - T_4\right)$$

$$q_{\text{out}} = c_v\left(T_4 - T_1\right)$$

Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

Thermal Efficiency

- The thermal efficiency of the ideal Diesel cycle under the cold-air-standard assumptions becomes

$$\eta_{\text{th, Diesel}} = \frac{w_{\text{net}}}{q_{\text{in}}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}}$$

$$= 1 - \frac{c_v\left(T_4 - T_1\right)}{c_p\left(T_3 - T_2\right)}$$

$$= 1 - \frac{1}{k}\frac{\left(T_4 - T_1\right)}{\left(T_3 - T_2\right)}$$

$$= 1 - \frac{1}{k}\frac{T_1\left(T_4/T_1 - 1\right)}{T_2\left(T_3/T_2 - 1\right)}$$

Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

Thermal Efficiency (cont.)

- We now define the cutoff ratio r_c as the ratio of the cylinder volumes after and before the combustion process

$$r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2}$$

- Utilizing the above definition and the isentropic ideal-gas relations for process 1→2 and 3→4, the thermal efficiency relation reduces to

$$\boxed{\eta_{\text{th, Diesel}} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]}$$

- The efficiency of a Diesel cycle differs from that of an Otto cycle only by the term in the brackets, which is always greater than 1
- The result indicates that

$$\eta_{\text{th, Otto}} > \eta_{\text{th, Diesel}}$$

- As the cutoff ratio decreases, the efficiency increases

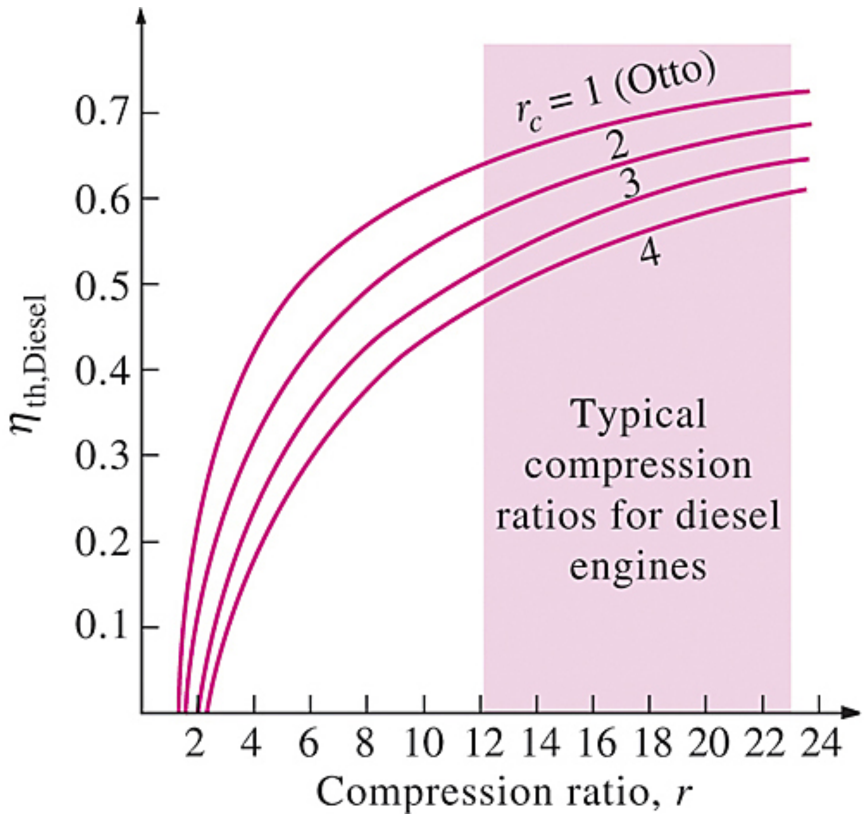
Diesel Cycle: The Ideal Cycle for Compression-Ignition Engines

Thermal Efficiency (cont.)

- In the limiting case that $r_c = 1$, the efficiencies of the Otto and Diesel cycles become identical

$$\text{As} \quad r_c \to 1, \quad \eta_{\text{th, Diesel}} \to \eta_{\text{th, Otto}}$$

- The dependence of the thermal efficiency on the compression ratio r and the cutoff ratio r_c is shown to the right
- In practice, Diesel engines can operate at much higher compression ratios than spark-ignition engines, and therefore, often times are much more efficient than spark-ignition engines



Problem

An air standard Diesel cycle has a compression ratio of 16 and a cutoff ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27 ^oC. Accounting for the variation of specific heats with temperature, determine

(a) The temperature after the heat-addition process.

(b) The thermal efficiency.

(c) The mean effective pressure.

Next lecture

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