Engine Cycles

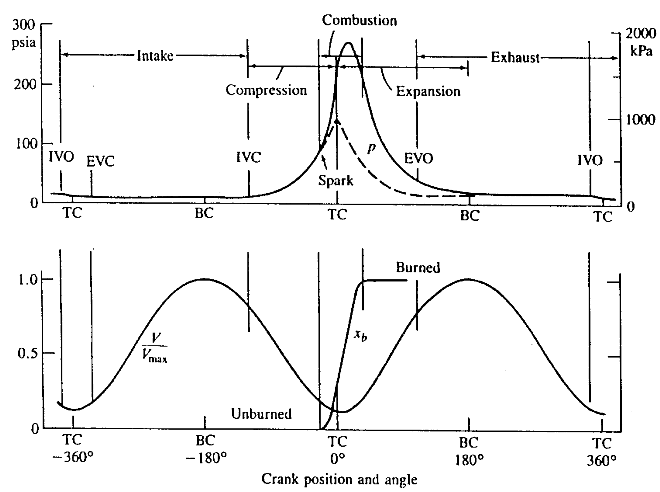


Figure 1-8
Sequence of events in four-stroke spark-ignition engine operating cycle. Cylinder pressure *p* (solid line, firing cycle; dashed line, motored cycle), cylinder volume V/V_{max}, and mass fraction burned x_b are plotted against crank angle.

Pressure-volume diagram

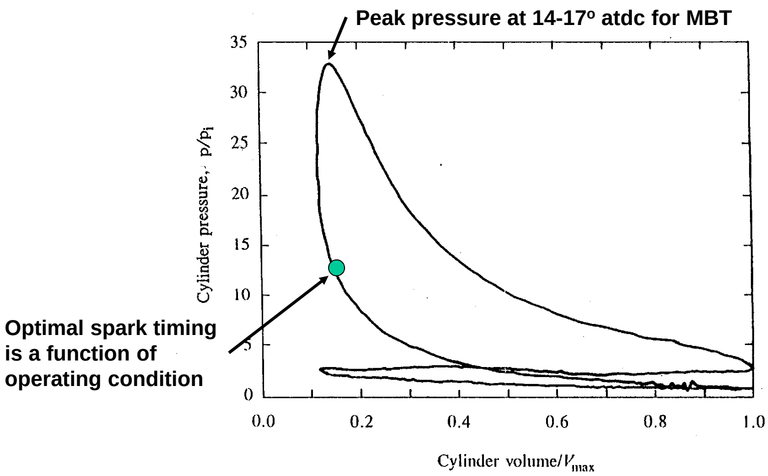


Fig. 5-1 Pressure-volume diagram of firing SI engine; compression ratio=8.4, 3500 rpm, intake pressure = 0.4 bar, Net IMEP = 2.9 bar

Ideal models of engine processes

Table 5.1

Process	Assumptions
Compression (1-2)	1. Adiabatic and reversible (hence isentropic)
Combustion (2-3)	1. Adiabatic 2. Combustion occurs at (*a*) Constant volume (*b*) Constant pressure (*c*) Part at constant volume and part at constant pressure (called limited pressure) 3. Combustion is complete ($\eta_c = 1$)
Expansion (3-4)	1. Adiabatic and reversible (hence isentropic)
Exhaust (4-5-6) and intake (6-7-1)	1. Adiabatic 2. Valve events occur at top- and bottom-center 3. No change in cylinder volume as pressure differences across open valves drop to zero 4. Inlet and exhaust pressures constant 5. Velocity effects negligible

Different ideal cycles

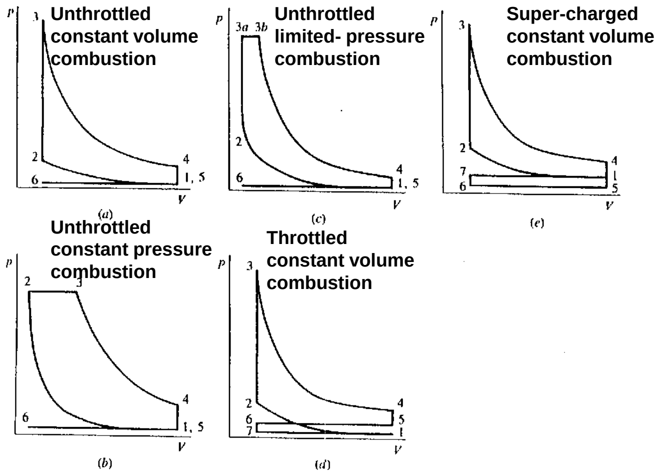


Fig 5.2 Pressure-volume diagrams of ideal cycles

Ideal constant volume combustion cycle fuel conversion efficiency

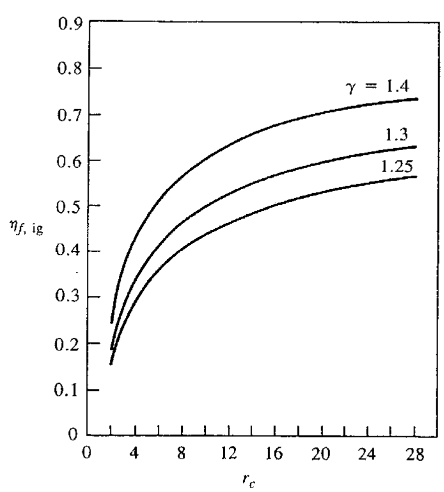
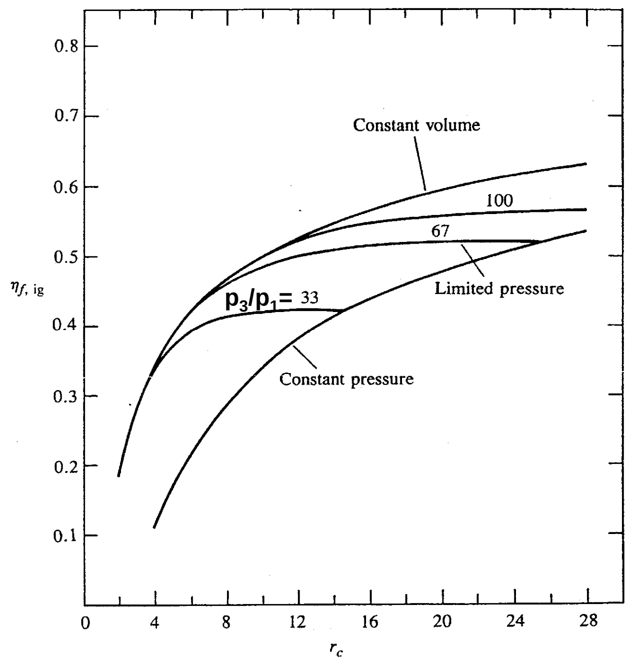


Fig. 5-5

Ideal efficiency

$$\eta_{f,ig} = 1 - \frac{1}{r_c^{\gamma-1}}$$

γ = specific heat ratio



Comparison of fuel conversion efficiency

Fig. 5-7 Fuel conversion efficiency as a function of compression ratio for constant-volume, constant-pressure, and limited pressure ideal gas cycles.

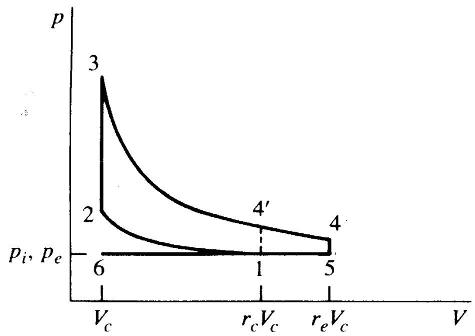
Factors affecting fuel conversion efficiency

These ideal engine cycle analysis results show that expansion ratio r_c and gas composition (through γ the ratio of specific heats) both affect the cycle's fuel conversion efficiency because:

1. **The expansion ratio (which may or may not equal to the compression ratio) determines how much work is extracted over the expansion stroke.**
2. **The higher the value of γ the more the temperature falls during expansion, the larger the energy change and hence the larger the expansion stroke work.**
3. **The compression stroke work is of order one-sixth of the expansion stroke work so expansion stroke work effects dominate.**

Miller cycle

- Late intake valve closing
  - Effective compression ratio is less than expansion ratio
- Advantages
  - Lower compression temperature
    - Better knock tolerance
    - Lower NOx emission



- Drawback
  - Reduced trapped charge mass: loss in max power
  - Compensated for by turbo-charging or hybrid operation

Effects of compression ratio

- Theoretical efficiency η_f increases with CR
- SI engine CR limited by knocking to 12 (13 with direct injection
- Practical η_f values decreases at high CR
  - ~~Heat transfer effect~~
  - Crevice effect
  - Dissociation effect
  - Friction
- Other considerations for diesel engines
  - Peak pressure
  - NOx emissions
  - Startability

Practical diesel engines have CR between 14 and 22

Effect of compression ratio on fuel conversion efficiency

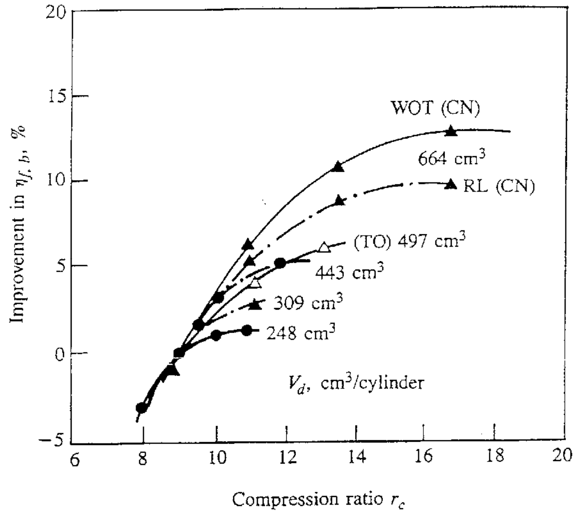


FIGURE 15-14
Relative brake fuel conversion efficiency improvement with increasing compression ratio of spark-ignition engines of different displaced volume per cylinder at part throttle (except top curve at WOT).[19] RL road load. CN,[17] TO.[10]

2.61 Internal Combustion Engines
Spring 2017