Lesione 29 - Internal Combustion Engines (ICEs)

Definitions

Periodic linear - moving piston which moves between bottom and top dead center.

Stroke → distance between dead centers

Engine Displacement → volume swept in stroke

Bore → cylinder diameter.

Top part of volume is combustion chamber.

Classification

- Start of Combustion
  - Spark Ignition (accensione comandata)
  - Compression Ignition
- Working Cycle Length
  - Four-stroke engine
  - Two-stroke engine

The stroke after ignition (3) to expansion (4) is the only power stroke, meaning it's the only stroke in which power is generated.

Intake stroke → Compression Stroke → Power stroke → Exhaust Stroke

2-stroke → no valve since the intake and exhaust are not unique strokes but things that occur as we move between dead points.
- → We discharge some uncombusted fresh mixture, so they can have significant losses of efficiency.
- → Typically, noisier, more pollutant and less efficient

2-stroke vs. 4-stroke

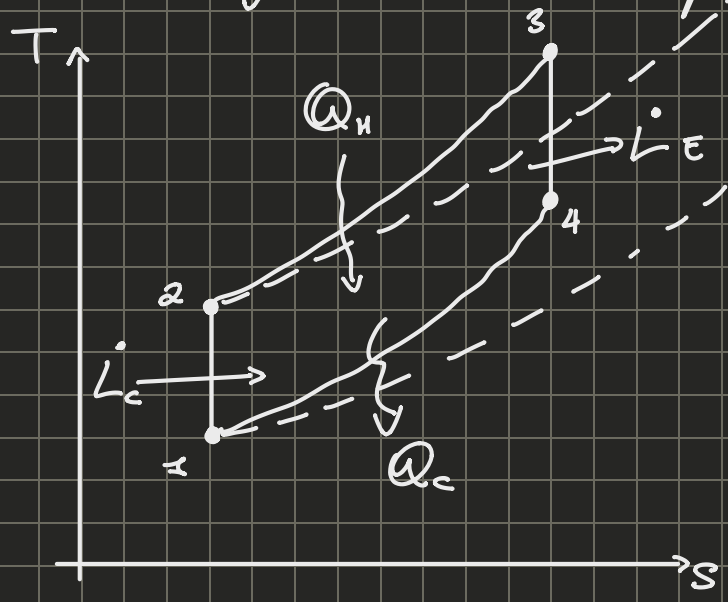
Advantages: of 2-stroke
- higher power per unit displaced volume
- Possible simpler structure
- More uniform torque

Disadvantages:
- Lower overall efficiency
- Bad replacement of burner fuel
- Higher thermal stresses

Thermodynamics of ICEs

There are two main cycles we can realise:

Otto Cycle ⇒ 2 isoentropic + 2 isocoric



$c_p = c_v + R \Rightarrow c_p > c_v \Rightarrow$ Isocoric line will increase T more at parity of q.

Energy Balance (closed system):

$$l + q = \Delta u$$

$$l - l_w = -\int P dv$$

isocoric

Inside a V transformation with no ... 9:25 I forgot, $l = 0$

If the ignition is istantaneously it occurs while the piston is fixed, this means that it's isocoric since there is no change in volume at the moment.

A spark ignition engines a good candidate to be represented by the Otto cycle.

3 → 4 is also an infinitely fast drop in pressure if we assume $a \to \infty$.

↳ speed of sound

↳ Also since it's instantaneous it is also isochoric.

$$\eta_o = 1 - \frac{|\dot{Q}_c|}{\dot{Q}_H} = 1 - \frac{\dot{m} c_c q_c}{\dot{m} q_H} = 1 - \frac{|q_c|}{q_H} = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

H: $\ell = 0$, $q_H = c_v (T_3 - T_2)$

C: $\ell = 0$, $q_c = c_v (T_1 - T_4)$

In reality c_v changes because it reacted and T then changed. but we consider a perfect gas.

$$= 1 - \frac{T_1}{T_2} \cdot \frac{T_4/T_1 - 1}{T_3/T_2 - 1}$$

$$\eta_o = 1 - \frac{T_1}{T_2} = 1 - \beta^{\frac{1-\gamma}{\gamma}}$$

same as η_{JB}

$$\beta = \frac{P_2}{P_1}$$

In these machines β is not directly controlled. It's easier to control the change in specific volume.

$$\frac{V_1}{V_2} = \frac{v_1}{v_2} = r$$

↳ since $\dot{m}$ is the same

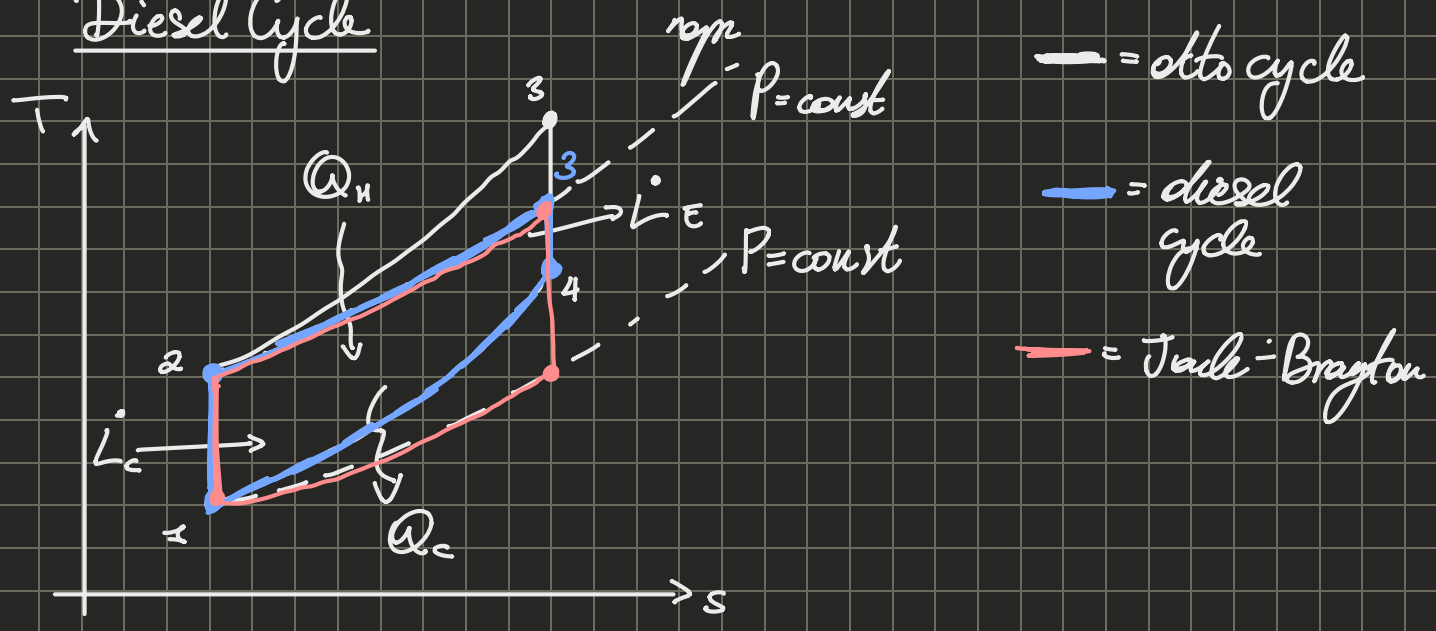
$$P v^\gamma = \text{const} \longrightarrow \frac{P_1}{P_2} = \left(\frac{V_1}{V_2}\right)^\gamma \qquad \frac{V_1}{V_2} = \left(\frac{P_1}{P_2}\right)^{1/\gamma}$$

$r > 1$

$$\Rightarrow \eta_o = 1 - \left(\frac{V_1}{V_2}\right)^{1-\gamma} = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$= 1 - r^{1-\gamma}$$

Diesel Cycle



— = otto cycle

— = diesel cycle

— = Jaule-Brayton

2-3 the combustion occurs along the stroke so the pressure is nearly matched by the change in pressure along the stroke, so the transformation is nearly (so we approximate) adiabatic so we can represent it with in isobaric.

While the area is lower, Q_H is smaller so the efficiency is not necessarily lower.

In JB between 2-3, $q = 0$ because the combustion camber is essentially a duct so we don't have a pressure change other that associated to a duct.

Q_H for JB and Diesel is the same, but the area in JB is bigger, so we can immediately say the efficiency of JB is greater than the diesel cycle.

$$\eta_D < \eta_{JB} = \eta_O \Rightarrow \eta_D > \eta_O$$

Because of what we say before $\eta = 1 - \frac{T_1}{T_2}$

In reality we find that diesel engines (not cycle) are more efficient than engines with spark-ignition-based engines

The difference is because P_2 in diesel is not the same as otto, since we need to increase it a lot to be able to ignite the fluid

$r_D \approx 20$ while $r_O \approx 10$