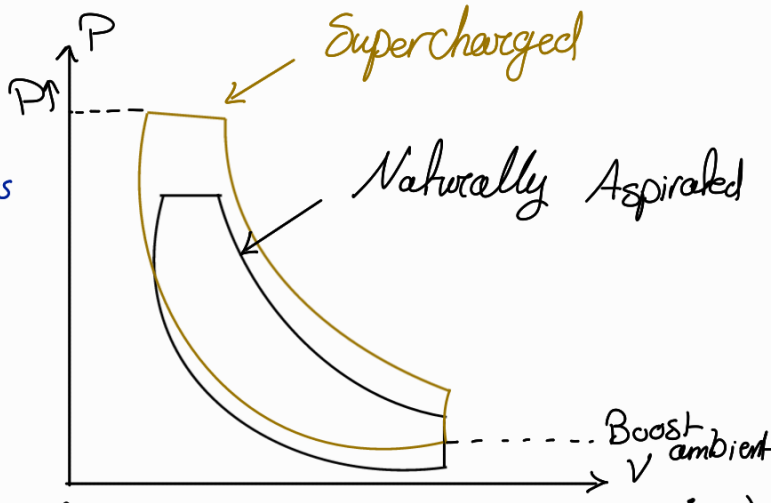
Chapter 7: Supercharging and Turbocharging

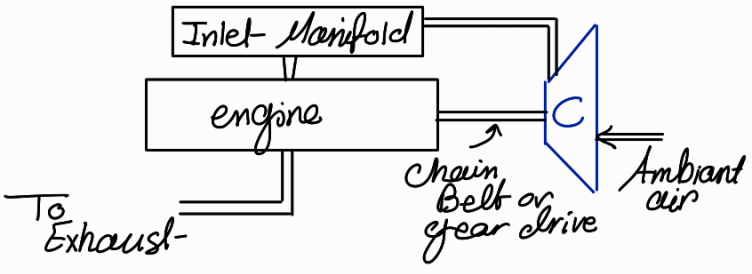
Supercharging

- Air or Air/fuel mixture introduction to an engine cylinder at a greater density (Compressed so smaller volume)
- More burned fuel
- Higher Power output
  → No efficiency improvements
- Area under PV is larger



Mechanical Supercharging

- Compressor is driven from the crankshaft ($\dot{W}_i >>> \dot{W}_c$)
  Indicated comp
- it doesn't need time to introduce power ⟹ proportional to engine speed

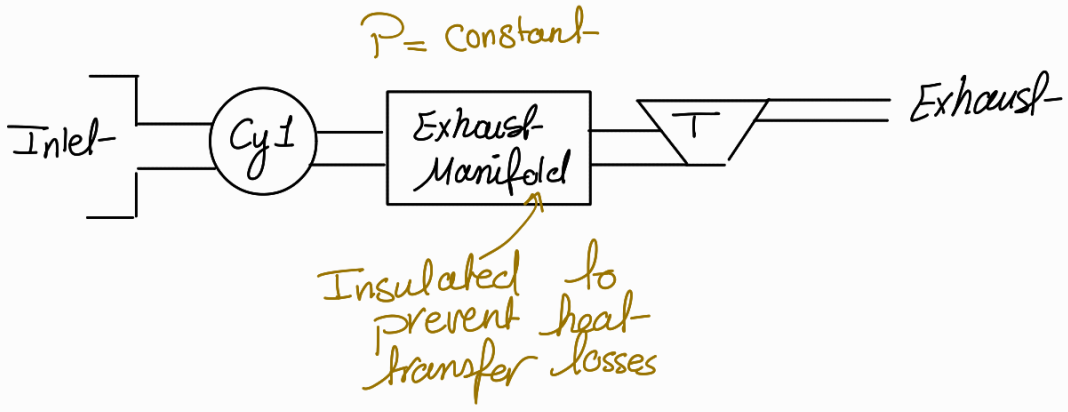


Turbocharging

- Hot exhaust air of the engine drives the compressor
- Needs time to produce power → E.G has low kinetic energy
- Shaft runs at a high speed → Cooling is needed

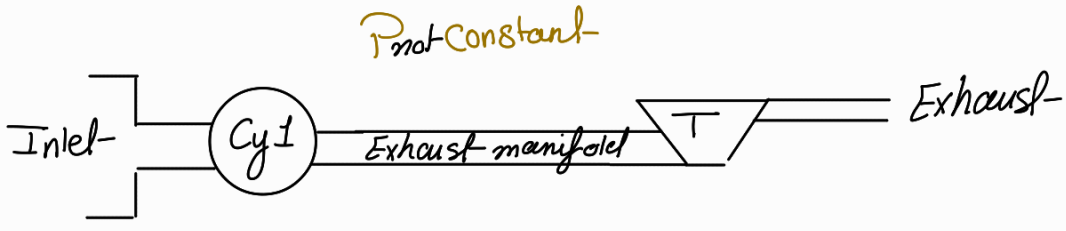
Constant pressure turbocharging

- A chamber is used to store exhaust gases from different Cylinders → Constant pressure



Pulse turbocharging

- Narrow tube is used, it is pressurized and boosted up to to form pressure pulse or wave
- Uses high P & T of E.G



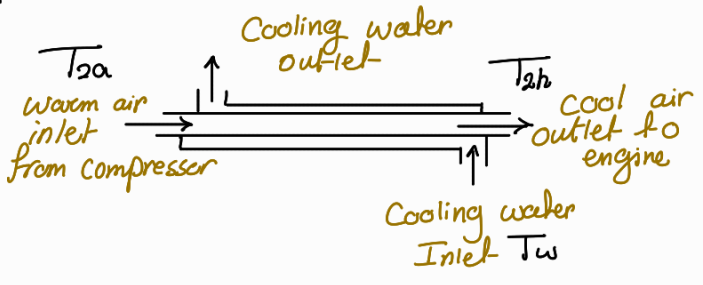
Charge cooling

- Temperature rises with air compression

Inlet manifold $T \downarrow \longrightarrow P_{air} \uparrow \longrightarrow$ Air mass in cylinders $\uparrow \longrightarrow$ Fuel Burnt $\uparrow$ output power $\uparrow$

- A heat-exchanger (Intercooler or after cooler) is used for cooling
- Placed between engine & compressor
- Efficiveness ε:

$$\varepsilon = \frac{T_{2a} - T_{2h}}{T_{2a} - T_w}$$



Turbocharging Systems

1- Variable Geometry

- Consists of a turbine housing, variable angle vanes and an adjusting ring
- For Diesel engine
- Vanes open and closes

Low speed → Vanes close → Restricts $\dot{m}_{Ea}$ → $\omega \uparrow$ → $P \uparrow$

High Speed → Vanes open → Maximize $\dot{m}_{Ea}$ → Avoids turbo over-Speed → Maintains required boost pressure

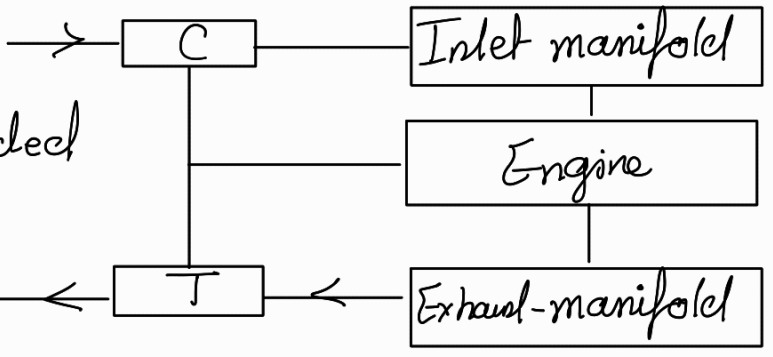
2- Compound engines

- At low engine speeds, the crank shaft is used to help the turbocharger

Disadvantages:

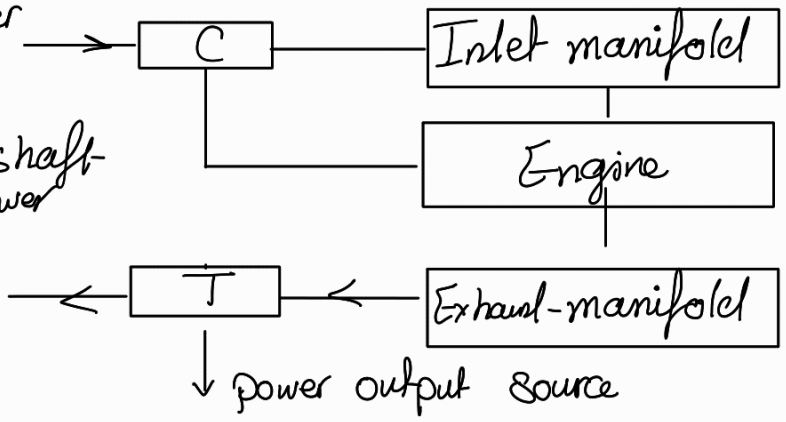
i - Gear Box is needed so heavier

ii - Fixed gear ratio limits the turbine Speed → variable gear ratio is used → Mechanical Difficulties



3. Gas generator power plant

- Compressor is driven by crankshaft
- Turbine output power compensates for power loss



Turbocharger Thermodynamics

$$Q - W = m\left[(h_2 + K_2 + PE_2) - (h_1 + KE_1 + PE_1)\right]$$

$$Q - W = m\, cp(T_2 - T_1)$$

- Compressor Isentropic efficiency

$$\eta = \frac{h_{2s} - h_1}{h_2 - h_1} = \frac{T_{2s} - T_1}{T_2 - T_1} = \frac{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\frac{T_2}{T_1} - 1}$$

($\gamma = 1.4$)

- Turbine Isentropic efficiency

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4s}} = \frac{T_3 - T_4}{T_3 - T_{4s}} = \frac{1 - \frac{T_4}{T_3}}{1 - \left(\frac{P_4}{P_3}\right)^{\frac{0.4}{1.4}}}$$

Turbocharger Mechanical

$$\eta_m = \frac{(m_a) \times C_{pa}(T_2 - T_1)}{(m_a + m_f) \times C_{pa}(T_3 - T_4)}$$

m_a

A/F

* In supercharging: pumping loop is positive

Effect of supercharging

1. Output power ↑ $\Longrightarrow$ P_{intake} ↑ $\Longrightarrow$ residue gases compressed $\Longrightarrow$ more charge

2. Fuel consumption ↓ : $S.f.c \downarrow = \frac{\dot{m}_f}{b.p} \uparrow$

3. η_m ↑ : P_{intake} ↑ $\Longrightarrow$ gas load ↑ $\Rightarrow$ heavier compounds $\Longrightarrow$ F.P ↑ but less than ↑ in output Power so η ↑