Unit 3
Gas Power Cycles & Internal Combustion Engines

GAS POWER CYCLES

INTRODUCTION

Gas power cycles describe ideal thermodynamic processes used to model real internal combustion engines and gas turbines. These theoretical cycles use air as the working fluid and involve a series of compression, heat addition, expansion, and heat rejection.

AIR STANDARD ASSUMPTIONS

To simplify real engine analysis:

- Air is used as the working fluid and behaves as an ideal gas.
- The combustion process is replaced by external heat addition.
- Exhaust is modelled as heat rejection.
- No chemical reactions are considered.
- The cycle operates in a closed loop with reversible processes.
- Specific heats (C_p and C_v) are considered constant.

Thermal Efficiency

$$\eta = \frac{Net\ Work\ Output}{Heat\ Supplied} = \frac{W_{net}}{Q_{in}}$$

Indicates how much of the input heat is converted to useful work.

- GAS POWER CYCLES
  - OTTO CYCLE
  - DIESEL CYCLE
  - DUAL CYCLE
  - BRAYTON CYCLE

OTTO CYCLE (IDEAL SPARK-IGNITION ENGINE CYCLE)

- Used for petrol engines (SI engines).
- Four steps:
  1. Isentropic Compression
  2. Constant Volume Heat Addition
  3. Isentropic Expansion
  4. Constant Volume Heat Rejection

Efficiency

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$

Where:

- $r = \frac{V_1}{V_2}$ = Compression ratio
- $\gamma = \frac{C_p}{C_v}$

DIESEL CYCLE (IDEAL COMPRESSION-IGNITION CYCLE)

- Used in diesel engines.
- Four steps:
    1. Isentropic Compression
    2. Constant Pressure Heat Addition
    3. Isentropic Expansion
    4. Constant Volume Heat Rejection

Efficiency

$$\eta_{diesel} = 1 - \frac{1}{r^{\gamma-1}} \cdot \left(\frac{\rho^{\gamma-1}}{\gamma(\rho - 1)}\right)$$

Where:

- r = compression ratio
- $\rho = \frac{V_3}{V_2}$ = cut-off ratio

DUAL CYCLE (LIMITED PRESSURE CYCLE)

- A combination of Otto and Diesel cycles.
- Used for modern engines where combustion is neither purely constant volume nor constant pressure.
- Five steps:
    1. Isentropic Compression
    2. Constant Volume Heat Addition
    3. Constant Pressure Heat Addition
    4. Isentropic Expansion
    5. Constant Volume Heat Rejection

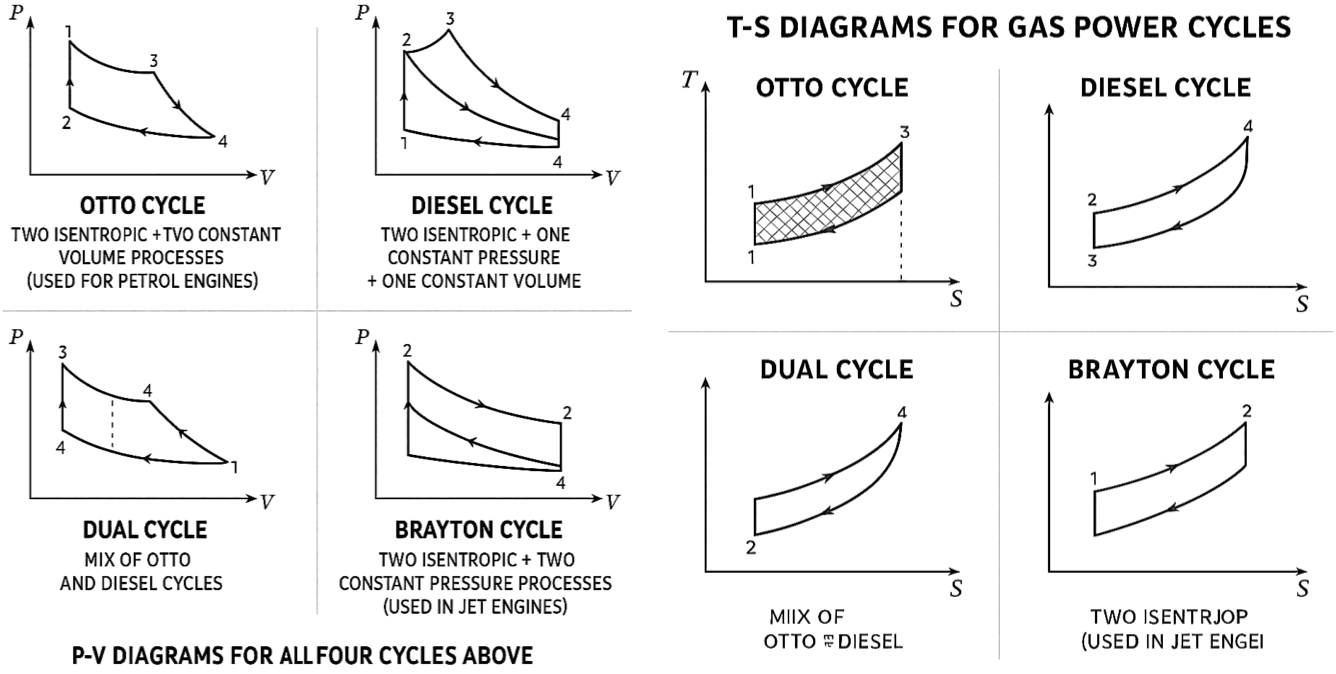
BRAYTON CYCLE (GAS TURBINE CYCLE)

- Used in jet engines and gas turbines.
- Four steps:
    1. Isentropic Compression
    2. Constant Pressure Heat Addition
    3. Isentropic Expansion
    4. Constant Pressure Heat Rejection

Efficiency

$$\eta = 1 - \left(\frac{P_1}{P_2}\right)^{\frac{(\gamma-1)}{\gamma}}$$

- P_1, P_2: Inlet and outlet pressures



INTERNAL COMBUSTION ENGINES

INTRODUCTION

Internal Combustion (IC) Engines are heat engines in which the combustion of fuel occurs inside the engine cylinder. These are widely used in automobiles, aviation, agriculture, and power generation.

CLASSIFICATION OF IC ENGINES

- **By Fuel**: Petrol, Diesel, CNG, Biofuel
- **By Ignition**:
  - SI (Spark Ignition)
  - CI (Compression Ignition)
- **By Stroke**:
  - Two-stroke
  - Four-stroke
- **By Cooling System**:
  - Air-cooled
  - Water-cooled
- **By Application**:
  - Automobiles, Aircrafts, Marine, Generator Sets

TERMINOLOGY

- **Bore**: Diameter of cylinder.
- **Stroke**: Distance travelled by piston.
- **TDC (Top Dead Centre)**: Highest piston position.
- **BDC (Bottom Dead Centre)**: Lowest piston position.
- **Swept Volume**: Volume displaced by piston.
- **Clearance Volume**: Space above piston at TDC.

- **Compression Ratio**:

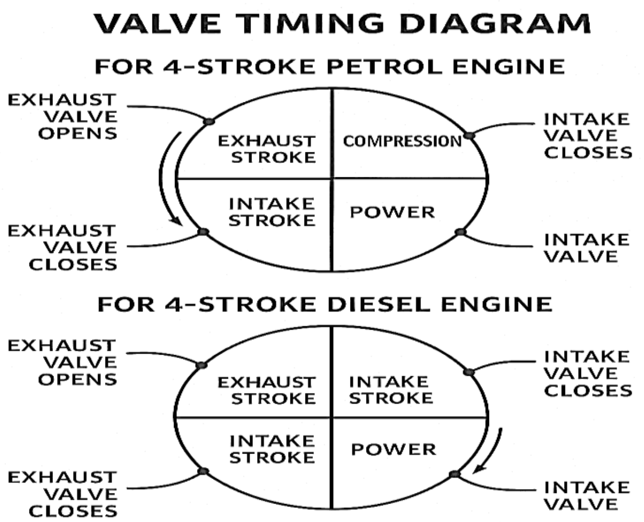
$$r = \frac{V_{total}}{V_{clearence}}$$

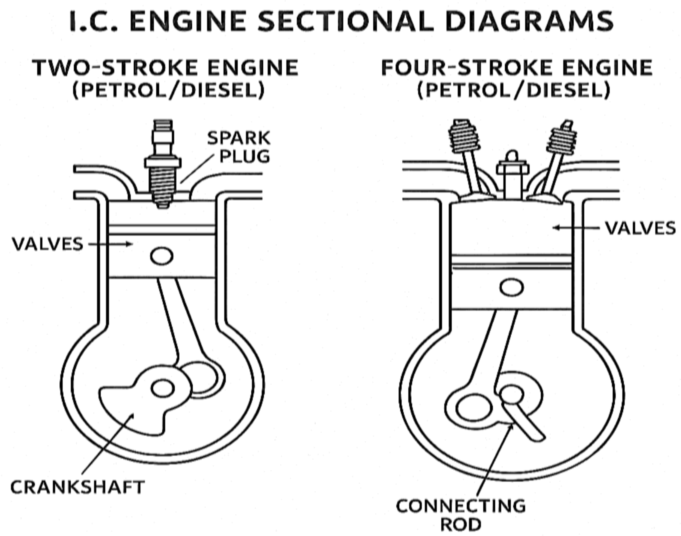
FOUR-STROKE PETROL ENGINE (SI ENGINE)

1. **Suction Stroke**: Air-fuel mixture enters the cylinder.
2. **Compression Stroke**: Mixture is compressed.
3. **Power Stroke**: Spark plug ignites mixture; expansion occurs.
4. **Exhaust Stroke**: Burnt gases are expelled.

FOUR-STROKE DIESEL ENGINE (CI ENGINE)

1. **Suction Stroke**: Air enters cylinder.
2. **Compression Stroke**: Air is compressed to high temperature.
3. **Power Stroke**: Fuel is injected and self-ignites.
4. **Exhaust Stroke**: Burnt gases are removed.





TWO-STROKE ENGINE

- Power stroke in every revolution.
- Simpler construction.
- Intake and exhaust occur through ports.
- High power-to-weight ratio.
- Poorer fuel efficiency and more emissions.

COMPARISON: PETROL VS DIESEL ENGINE

Feature	Petrol (SI)	Diesel (CI)
Fuel	Petrol	Diesel
Ignition	Spark Plug	Compression
Compression	6:1 to 10:1	14:1 to 22:1
Efficiency	Lower	Higher
Noise	Less	More
Maintenance	Easier	Complex
Applications	Cars, Bikes	Trucks, Buses, Heavy Vehicles

MODERN ENGINE ENHANCEMENTS

- **Turbocharging**: Uses exhaust gases to boost intake.
- **CRDI**: Common Rail Direct Injection in diesel engines.
- **Fuel Injection**: Increases mileage and reduces emissions.
- **Hybrid Engines**: Combine IC engines with electric motors.