1.1 Tractor Engines

Tractor engines form the core power source for agricultural machinery. Unlike automotive engines, tractor engines are designed to deliver **high torque at low speeds**, enabling them to pull implements and carry heavy loads effectively.

Key Features:

- **Diesel powered**: Nearly all modern tractors use diesel engines because of their **higher torque output**, **better fuel efficiency**, and **durability**.
- **Engine Power Range**: Typically from **15 HP to over 100 HP** depending on the application. For example:
    - Mini tractors: 15–30 HP
    - Utility tractors: 31–60 HP
    - Heavy-duty tractors: 60–100+ HP
- **Cooling Systems**: Water-cooled (common), air-cooled (in mini tractors), and oil-cooled systems.
- **Rugged Construction**: Cast iron engine blocks, reinforced pistons and crankshafts, and deep cylinder liners for extended life.

Applications:

Tractor engines must support **PTO (Power Take-Off) shafts**, **hydraulic systems**, and **tractional operations**. Therefore, they are expected to perform in dusty, muddy, or rocky terrains under varying loads.

1.2 Engine Operation

The engine in a tractor performs the conversion of **chemical energy (diesel)** into **mechanical energy** via combustion inside the cylinders. These engines follow the

internal combustion engine (ICE) principle, more specifically **compression ignition (CI)**.

Stages of Engine Operation:

1. **Intake Stroke**: Air is drawn into the cylinder through the open intake valve.
2. **Compression Stroke**: The piston moves upward, compressing the air to a high pressure and temperature.
3. **Power Stroke**: Diesel is injected. The high temperature causes the fuel to auto-ignite, creating an explosion that forces the piston down.
4. **Exhaust Stroke**: The burnt gases are expelled through the open exhaust valve.

Tractor engines use **mechanical or electronic governors** to regulate engine speed automatically in response to load variations, ensuring efficient field performance.

1.3 Working Principle of Diesel Engine

Diesel engines work on the **compression ignition principle**. Unlike spark ignition engines (e.g., petrol), diesel engines **do not use spark plugs**.

Detailed Explanation:

- Only **air** is drawn into the cylinder.
- The piston compresses the air, raising its temperature to around **600–800°C**.
- Diesel fuel is injected into the hot compressed air using a **fuel injector at high pressure** (1500–2000 bar).
- The fuel auto-ignites, creating a rapid expansion of gases that forces the piston downward.

Advantages of Diesel Engines:

- Higher thermal efficiency.
- Longer engine life due to robust construction.
- Better torque characteristics at lower engine speeds.

1.4 Four-Stroke Compression Ignition Engine Cycle

The **four-stroke cycle** is a standard in tractor diesel engines:

1. **Suction Stroke**:
    - Intake valve opens.
    - Piston moves from Top Dead Center (TDC) to Bottom Dead Center (BDC).
    - Air enters the cylinder.
2. **Compression Stroke**:
    - Both valves closed.
    - Piston moves from BDC to TDC.
    - Air is compressed, raising its temperature.
3. **Power Stroke**:
    - Just before TDC, fuel is injected.
    - Fuel ignites due to the high temperature.
    - Piston is pushed down from TDC to BDC.
4. **Exhaust Stroke**:
    - Exhaust valve opens.

- Piston moves up from BDC to TDC, pushing out burnt gases.

This cycle is repeated in each cylinder, with different strokes occurring simultaneously in multi-cylinder engines.

1.5 Inlet and Outlet Valves

Valves control the entry and exit of gases from the cylinder:

- **Inlet Valve**: Allows air to enter the cylinder during the suction stroke.
- **Outlet (Exhaust) Valve**: Allows combustion gases to exit during the exhaust stroke.

Valve Actuation System:

- Operated by **camshaft**, which is driven by the crankshaft via gears or timing chain.
- Includes **rocker arms**, **push rods**, **tappets**, and **valve springs**.

Proper valve timing ensures:

- Efficient air intake and exhaust expulsion.
- Maximum power output.
- Reduced emissions and wear.

1.6 Valve Timing Diagram

A valve timing diagram shows the **degrees of crankshaft rotation** at which the valves open and close.

Typical Timing in a Diesel Engine:

- Inlet Valve Opens: **10°–15° Before TDC**
- Inlet Valve Closes: **30°–40° After BDC**
- Exhaust Valve Opens: **40°–50° Before BDC**
- Exhaust Valve Closes: **10°–15° After TDC**

Valve Overlap (both valves open briefly): Aids in improving cylinder filling and scavenging of burnt gases.

1.7 Engine Efficiency

Definitions:

- **Indicated Thermal Efficiency**: Ratio of energy converted in the cylinder to total fuel energy.
- **Brake Thermal Efficiency (BTE)**: Ratio of actual useful power to the total energy input.
- **Mechanical Efficiency**: Ratio of brake power to indicated power.

Typical Efficiencies:

- BTE for diesel: **30–40%**
- Gasoline engines: 20–30%

Factors affecting efficiency:

- Compression ratio.
- Combustion quality.
- Engine load and speed.

- Maintenance condition.

1.8 Engine Operating Cycle

In tractors, a **4-stroke diesel engine** is the norm.

- One power stroke every **two revolutions (720°)** of the crankshaft.
- This setup is ideal for steady torque and fuel efficiency.
- Compared to 2-stroke engines, they:
    - Use fuel more efficiently.
    - Produce less pollution.
    - Have a longer operational life.

1.9 Firing Order and Firing Interval

- **Firing Order**: The sequence in which cylinders fire.
    - E.g., in a 4-cylinder engine: **1-3-4-2**
- **Firing Interval**: For a 4-cylinder 4-stroke engine:
    - Each cylinder fires every **180° crankshaft rotation**.

Correct firing order minimizes:

- Engine vibration.
- Load imbalance on crankshaft.
- Noise and wear.

1.10 Combustion Chambers

The combustion chamber is the space where the **air-fuel mixture burns**.

Types:

1. **Open Combustion Chamber**:
    - Simple bowl-shaped piston.
    - Direct fuel injection.
2. **Swirl Combustion Chamber**:
    - Tangential intake ports induce swirling of air.
    - Enhances mixing and combustion.
3. **Pre-Combustion Chamber**:
    - Initial combustion in a small separate chamber.
    - Flame spreads into the main chamber.
    - Improves cold-starting and reduces knocking.

1.11 Engine Block, Cylinder Head, and Crankcase

Engine Block:

- Main body housing the cylinders.
- Contains cooling passages and oil galleries.
- Made from cast iron or aluminum alloy.

Cylinder Head:

- Bolted to the top of the engine block.
- Contains intake/exhaust valves, fuel injectors, and glow plugs (if any).

Crankcase:

- Encloses crankshaft and oil sump.
- Supports the main bearings and holds the lubricating oil.

These three form the **core structural unit** of an engine.

1.12 Features of Cylinder, Piston, Connecting Rod, Crankshaft

Cylinder:

- A precision-bored tube where the piston moves.
- Must resist high temperatures and pressures.

Piston:

- Transmits force from combustion to the connecting rod.
- Has **piston rings** to:
    - Seal combustion gases.
    - Transfer heat to cylinder walls.
    - Control oil film.

Connecting Rod:

- Transfers reciprocating motion from piston to crankshaft.

- Made of forged steel or alloy.

Crankshaft:

- Converts linear piston motion to rotary motion.
- Contains journals, counterweights, and flywheel attachment.