Teaching Materials

Farm Power Engineering (ES 1103)

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Dept. of Agric. Eng. & and Soil Science,

Rajarata University of Sri Lanka

FARM POWER ENGINEERING

ES 1103 (2/25:10:65)

TEACHING MATERIALS

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PREFACE

These teaching materials on Farm Power Engineering (ES 1103) is prepared by myself, to be submitted to the 219th Faculty Board, Faculty of Agriculture, RUSL on 04th May, 2022. Hereafter, these materials could be used by the undergraduates who are enrolled for the Farm Power Engineering (ES 1103) in BScHons (Agriculture) Special Degree programme in Rajarata University of Sri Lanka to improve their learning environment.

April, 2022 Dr. G.V.T.V. Weerasooriya

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1. INTRODUCTION

1.1 Course aim

This course aims to develop a critical understanding of the practical and theoretical aspects relevant to farm power utilization

1.2 Course capsule

Sources of farm power: human power, animal power, mechanical power, electrical power, renewable energy; Principles of power transmission; Farm tractors: tractor performances, Internal combustion engine, two-stroke and four-stroke engines, engine systems.

1.3 Course ILOs

On successful completion of the course, the student will be able to

1. evaluate the different power transmission methods, components, and their uses in agriculture.
2. demonstrate engine components and systems with their usage.
3. compare the source of farm power with practical application toward the efficient power utilization.

1.4 Lesson outline

Lesson no.	**Lesson title**	**Number of hrs.**				**Method of delivery**	**Continuous assessments**
		DC		**IL**			
		T	**P**	DL	SDL		
1.	Sources of farm power; human power and animal power;	1				OTL	
	mechanical power; tractor, power tiller, oil engine;	2				L, D, V,	
	Electrical power			2		GL. WB	
2.	Renewable energy; biogas, solar energy, wind energy,	2				L, D, V	
	bio mass energy,	1				OTL	
	Tidal energy, geothermal energy			2		GL. WB	GA

3.	Power transmission methods; mechanical power transmission	2				L, D,	
	mechanical power transmission	1				OTL	
4.	Hydraulic power transmission	2				L, D	
5.	Power transmission			2		GL. WB	
	Power transmission methods		2			DM, D	PR1
6.	History and development of farm tractors			2		GL. WB	
	Classification of tractors,	1				OTL	
	tractor performance	2				L, D,	Q1
7.	Engine classification, engine component,			2		GL. WB	
	operation and working principles of internal combustion engines,	1				OTL	
	two-stroke and four-stroke engine operating cycles	2				L, D, V,	
8.	Engine operating cycles and components		2			DM, D	PR2
9.	Engine terminology	2				L, D, Q/A,	Q2
10.	Fuel system	1				L, D, V	
	Ignition system	1				L, D, V	
11.	Fuel and ignition system		2			DM, D	PR3
12.	Cooling system	1				L, D, V	
	Lubrication system	1				L, D, V	
13.	Cooling and lubrication system		2			DM, D	PR4
14.	Transmission system	2				L, D, V	Q3
15.	Transmission system		2			DM, D	PR5
Total		**25**	**10**	**10**	**55**		
L – Lecture; D – Discussion, GL - Guided Learning; Q/A- Questions and Answers; V – Video; DM-Demonstration; OER – Open Educational Resources; WB – Web Based Learning							
Q – Quiz; GA – Group Assignment; PR - Practical Reports; OTL – Online Teaching and Learning							

1.5 Assessment Strategy

Assessment strategy		**Proportionate marks (%)**
Theory	End Semester Examination : 2 hr. ● Part I – 20 MCQs : 30 min ● Part II – 04 Structured Questions: 1 hr. ● Part III – 01 Essay : 30 min	60
Continuous assessments	Quizzes – 3	15
	Assignments – 1	05
	Practical reports	20
Total		100

2. SOURCE OF FARM POWER

Human power, animal power, mechanical power (tractor, power tiller, oil engine), electrical power, and renewable energy (biogas, solar energy, wind energy, bio mass energy, tidal energy, geothermal energy) are the mainly use farm power sources.

2.1 Human Power

The power of average man is 0.1 - 0.2 hp. Worked by one or more people with their energy. Should be lighter and lower capacity implements.

FMRC low land seeder, High land seeder, six row manually operated rice transplanter- Mark II, Treadle Pump, Cono weeder, three-point inter-cultivator, High land weeder (Mulch), Swiss hoe, chopping hoe, and Groundnut de-coati cater, are the few examples for hand power implements.

2.2 Animal Power

These implements are operated by animal power. buffalos, cattle, horses, elephants, and dogs ae the commonly use animal power sources.

2.2.1 Advantages of Animal Power

Cheaper power source, no depreciation – can use the new generation, can do integrate farming systems, instead of power we can get milk, meat etc., and low capital are the main advantages of animal power.

2.2.2 Disadvantages of Animal Power

Want large space for animal rearing, not uniform power source – disease condition, limiting power only 10% from body weight, cannot use in bad environments, working time period is limited 6 h/day, should use light implements, 3% of power is wasting when using gang of animals, and take more time period are the main disadvantages of the animal power.

2.3 Mechanical/Electrical Power

Two-wheel and four-wheel tractors are used commonly. Internal combustion engine and the steam engine are also used. Internal combustion engine and electric motor are more popular.

2.3.1 Two Wheel Tractors

Mostly use power source in medium scale farmers in Sri Lanka. There are two types of two-wheel tractors; ridding type (Plate1.1) and walking type (Plate 1.2).

Plate 1.1 Ridding Type Two-wheel Tractor

Plate 1.2 Walking Type Two-wheel Tractor

Ridding type two-wheel tractor (12 hp) is having driving set and walking type two-wheel tractors (8 hp) do not having a driving stat.

2.3.2 Four Wheel Tractors

50 hp four-wheel tractors are common. But there are 300 hp or above tractors also.

2.3.3 Advantages of Mechanical Power

No daily maintenance as rearing of animal, not harmful to crop as animal, can use different attachments, high speed and higher power out-put are the major advantages of mechanical power.

2.3.4 Disadvantages of Mechanical Power

Higher capital cost, not suitable for small scale farms, trouble in muddy fields – 4 wheel, and using is limited by topography are the main disadvantages of mechanical power.

2.3.5 Advantages of Two-wheel Vs. Four-wheel tractor

Low investment, suitable for small lands, easy to maintenance and manipulation, and can be used for low - lands also are the relative advantages of two-wheel tractors.

2.4 Renewable energy

Biogas, solar energy, wind energy, bio mass energy, tidal energy, and geothermal energy are the available renewable energy sources.

Table 2.1 Advantages and Disadvantages of Energy Sources

Energy resource	Advantages	Disadvantages
Fossil fuels	Provide a large amount of thermal energy per unit of mass Easy to get and easy to transport Can be used to generate electrical energy and make products, such as plastic	Nonrenewable Burning produces smog Burning coal releases substances that can cause acid precipitation Risk of oil spills
Nuclear	Very concentrated form of energy Power plants do not produce smog	Produces radioactive waste Radioactive elements are nonrenewable
Solar	Almost limitless source of energy Does not produce air pollution	Expensive to use for large-scale energy production Only practical in sunny areas
Water	Renewable Does not produce air pollution	Dams disrupt a river's ecosystem available only in areas that have rivers
Wind	Renewable Relatively inexpensive to generate Does not produce air pollution	Only practical in windy areas
Geothermal	Almost limitless source of energy Power plant require little land	Only practical areas near hot spots Waste water can damage soil
Biomass	Renewable	Requires large area of farmland Produces smoke

2.4.1 Bio Gas

Clean and efficient fuel. It is a mixture of; Methane (CH_4), Carbon dioxide (CO_2), Hydrogen (H_2), and Hydrogen supplied (H_2S). The chief constituent of biogas is methane (65%). The bio gas production process is illustrated in figure 2.1.

Figure 2.1 Bio Gas Production

Bio gas can be utilized as a fuel, source of rural electrification, By- product as fertilizer, and pesticide.

2.4.2 Solar Energy

Modern residential solar power systems use photovoltaic (PV) (Photo – electricity produced by light and Voltaic -electricity produced by a chemical reaction) to collect the sun's energy (Figure 2.2). Commercial residential PV modules range in power output from 10 watts to 300 watts, in a direct current. Have an inverter to change the DC electricity into AC.

Heating and cooling of residential buildings, solar water heating, solar drying of agricultural and animal products, salt production by evaporation of seawater, solar cookers, solar engine for water pumping, solar refrigeration, solar electric power generation, solar photo voltaic cells, which can be used for electricity and solar furnaces are the main solar energy applications.

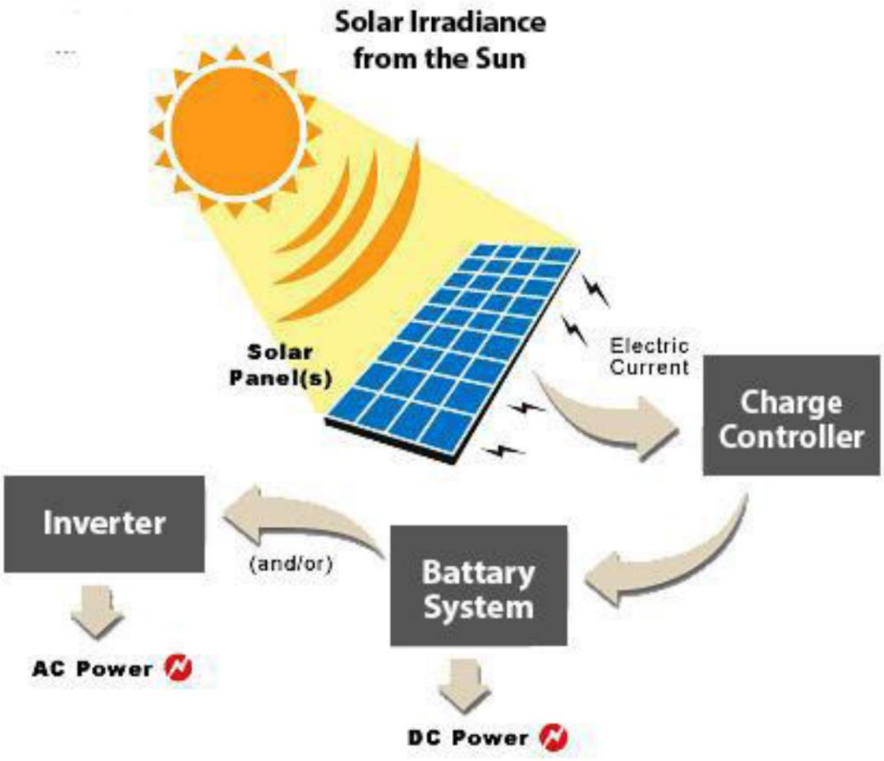


Figure 2.2 Solar Energy Production

2.4.3 Wind Energy

Wind energy (or wind power) describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Wind energy is used for water pumping, grind grain, crush sugar cane and to generate the electricity.

2.4.4 Biomass Energy

Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat.

2.4.5 Tidal Energy

Form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Tides are more predictable than the wind and the sun. Relatively high cost and limited availability of tidal energy (Figure 2.3).

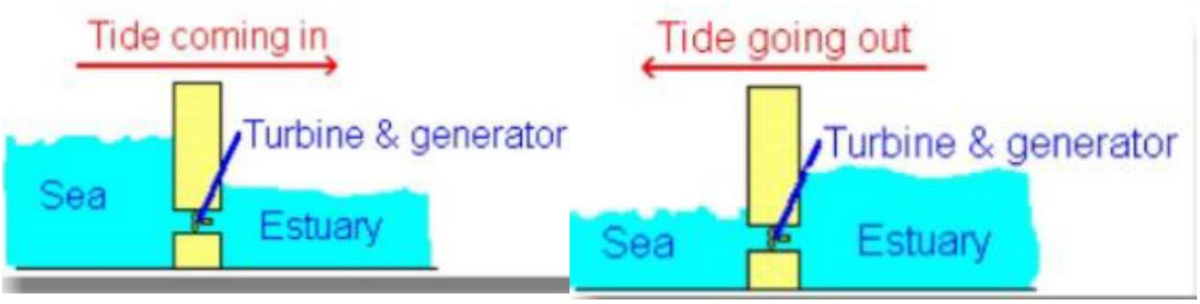


Figure 2.3 Tidal Energy Production

2.4.6 Geothermal Energy

Geothermal energy is heat from within the Earth. We can recover this heat as steam or hot water and use it to heat buildings or generate electricity.

3.PRINCIPLES OF POWER TRANSMISSION

Transmit the power from producing place to another is called power transmission. Mechanical (gears/shafts/lever), Electrical (wire/switch), and Hydraulic (fluid/pump/valve/activators) are the main power transmission methods.

3.1 Mechanical power transmission

Direct drive, Belt & pulley, Chain & sprockets, Gears, Shaft & universal joints, Flexible shafts, and Frictional devices are the mechanical power transmission elements.

3.1.1 Belt and Pulley Power Transmission

Oldest and most common method of power transmission. Simple and easy to maintenance. Friction between pulley and the belt is used (Figure 3.1). Friction depends on; Width of the belt, Tension of the belt, Diameter of the pulley, Material and condition of the pulley and Angle of contact

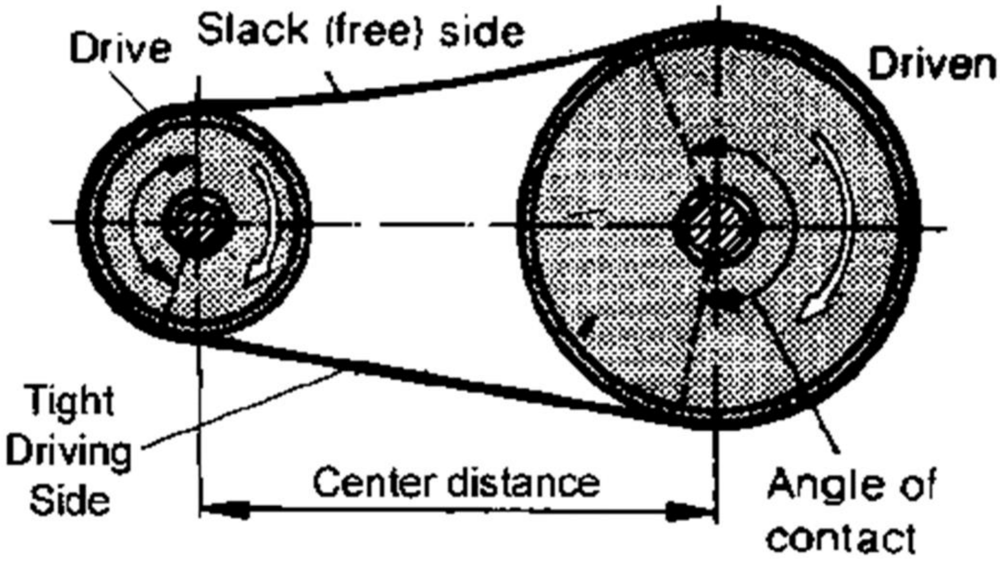


Figure 3.1 Belt and Pully Power Transmission

"V" belts, Flat belts and round belts are the mostly common belt types. "V" belts are more efficient, have higher contact surface and bear higher tension. Flat belts are used for faraway power transmission. Canvas, rubber and lather are used to make flat belts.

There are two belt drive methods; Open belt drive and cross belt drive. In open belt drives; Drive and driven pulleys are rotate to the same direction and relatively low angle of contact (Figure 3.2). In cross belt drives; Drive and driven pulleys are rotate in to opposite directions and relatively higher angle of contact (Figure 3.3).

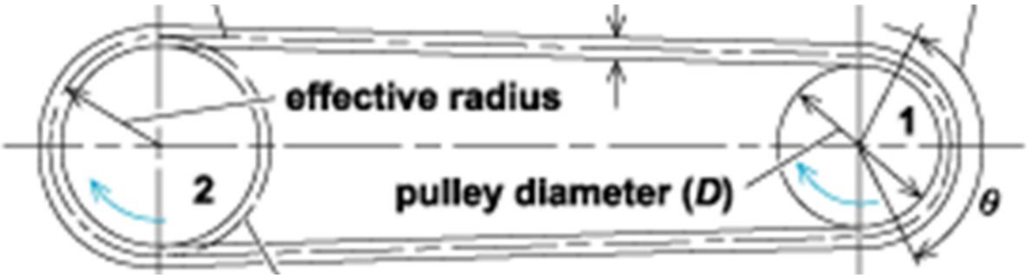


Figure 3.2 Open Belt Drive

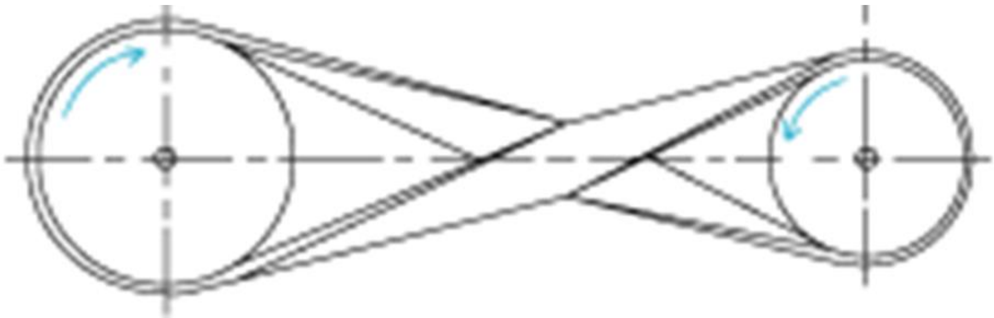


Figure 3.3 Cross Belt Drive

Angle of Contact

Angle between end contact points (Figure 3.4).

Figure 3.4 Angle of Contact

Idling pulley

Idling pulley is help to increase the lap angle of the belt system (Figure 3.5)

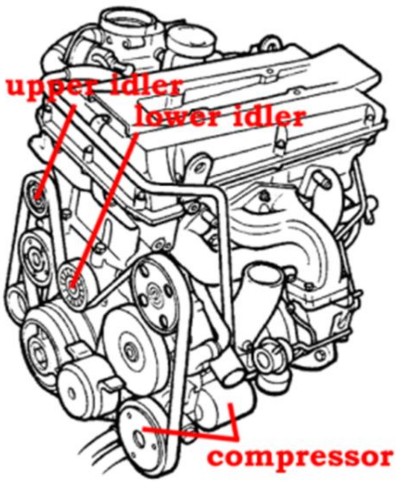


Figure 3.5 Idling Pulley

Side wearied belts, wearied pulley, belt with lower tension are the features that could be identified with over used belt and pulley system. Using tension pulley, Changing the distance between pulleys, replacing the pulley and belts are the remedies to overcome above conditions.

Driven and driving pulley may at different levels, adoption of speed changes, not required lubrications, and can be used as a clutch are the main advantages of belt and pully system. Different speed ratios can be taken, by using pulleys with different diameters.

$$\frac{D_A}{D_B} = \frac{N_B}{N_A}$$

D_A= Diameter of pulley A D_B = Diameter of pulley B

N_A = Speed of pulley A N_B = Speed of pulley B

Torque of the Belt System

$$T_A = (T_2 - T_1)\, r_A \qquad T_B = (T_2 - T_1)\, r_B$$

T_A = Torque at pulley A T_B = Torque at pulley B

T_2 = Tension at the tide side of belt T_1 = Tension at the slate side of belt

r_A = Radius of pulley A r_B = Radius of pulley B

Power of the Belt System

$$P = (T_2 - T_1)\, V$$

T_2 = Tension at the tide side of belt T_1 = Tension at the slate side of belt

V = Belt velocity

Bent or broken pulleys, abrasive environments, wearied pulley/alley, higher or lower tension and smaller pulleys are the factors affecting for short life time for belt and pulley system.

3.1.2 Gear Power Transmission System

Gear power transmission is used in short distance power transmissions. Have more advantages. Use to transmit torque from one shaft to another. These shafts may be; on line, parallel, with an angle. High speed gears are drip in the oil baths. Constant speed power transmission method.

Gear classification depends on; speed and Torque of gears, type of teeth, surface which teeth are cut. Straight spur, helical spur, herringbone, bevel, planetary, worm and rack & pinion are the commonly available gear types.

Straight Spur Gear

Straight spur gears are having straight teeth cut parallel to the axis of rotation. One or two pairs of teeth engaged at every time. Noisier and use in low-speed conditions (Figure 3.6). Usage: hand or powered winches, Sliding gear transmission systems.

Figure 3.6 Straight Spur Gear

Helical Spur Gears

Teeth are cut obliquely across the perimeter. Quieter in operation. Having greater strength. Higher durability (Figure 3.7). Usage: power transmission in machines.

Figure 3.7 Helical Spur Gear

Herringbone Gears

Double helical. Quieter in operation. Higher durability, Suitable for high-speed, heavy loads conditions (Figure 3.8), Usage: turbine and generators

Figure 3.8 Herringbone Gear

Bevel Gears

Use to turn the power flow with an angle. Consist two parts; ring gear (large driven gear) and Pinion gear (small driving gear). Plain bevel gears, spiral bevel gears and hypoid gears are the major types of bevel gears.

Plain Bevel Gears

Use to turn the power flow with an angle, Gear teeth are cut straight on a line. Slow speed application as straight spur gears (Figure 3.9). Usage: Slow speed applications, hand weeders

Figure 3.9 Bevel Gear

Spiral Bevel Gears

Use to get high speed & strength while changing the angle of power flow. Teeth are cut obliquely (Figure 3.10). Usage: farm and industrial machines

Figure 3.10 Spiral Bevel Gear

Hypoid Gears

Same to spiral bevel gears, but pinion gear is located bellow the center of ring gear (Figure 3.11). Usage: Modern automobile differential

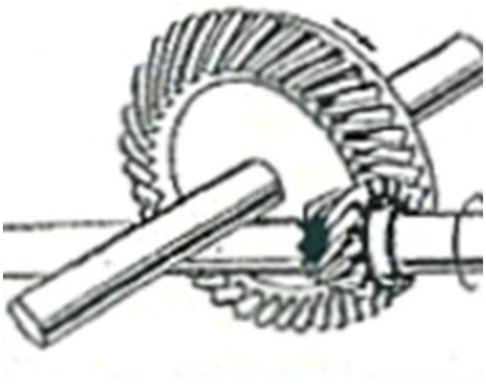


Figure 3.11 Hypoid Gear

Planetary Gears

This type gears consist with; Outer ring gear which has internal teeth, smaller planet gears, center or sun gear (Figure 3.12). Usage: Final drive, in heavy machinery

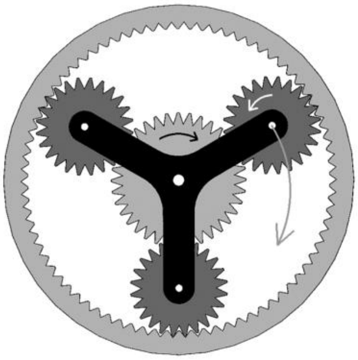


Figure 3.12 Planetary Gears

Worm Gears

Use for right angle power transmission. Consist with worm like screw and gear (Figure 3.13). Usage: steering mechanism of vehicle.

Figure 3.13 Worm Gear

Rack and Pinion

Linear motion converts to curve linear motion (Figure 3.14). Usage: injector pumps, to control the diesel flow.

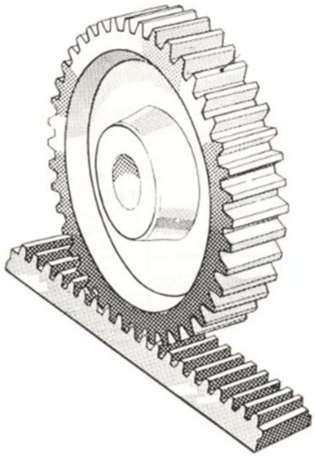


Figure 3.14 Rack and Pinion Gear

Terminology Use in Gear Power Transmission

Back lash: Clearance or play between two gears (Figure 3.15)

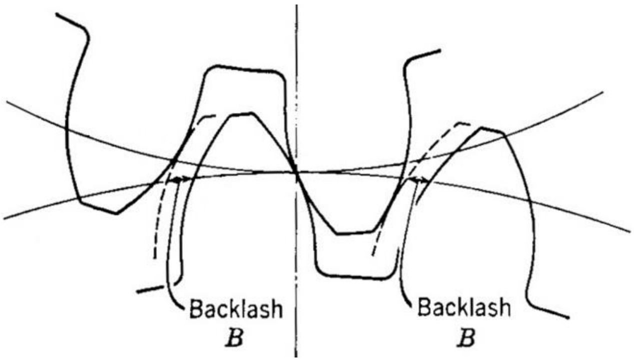


Figure 3.15 Back lash

Diameters and working depth: Pitch diameter, root diameter, outer diameter, and working depth are shown in figure 3.16.

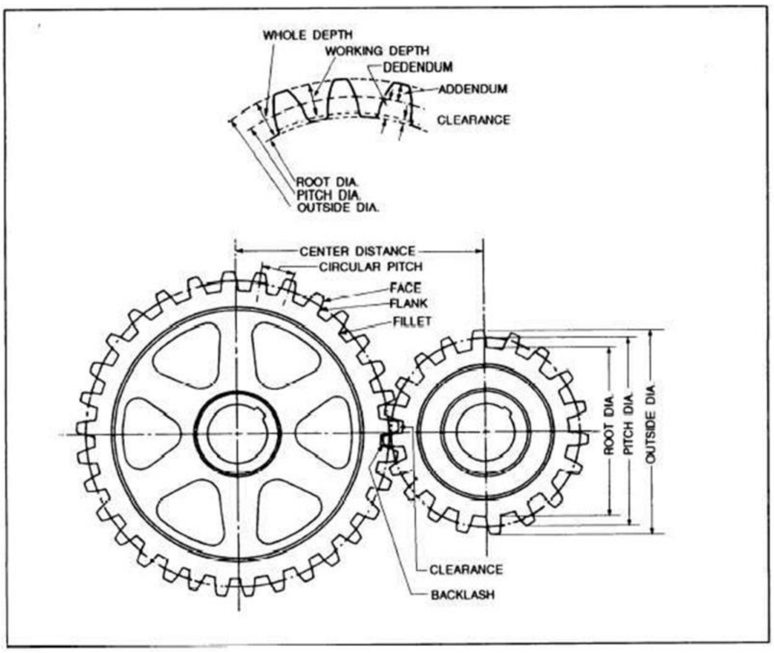


Figure 3.16 Diameters and Working Depth

Circular pitch: Distance between adjacent two pith point (Figure 3.17).

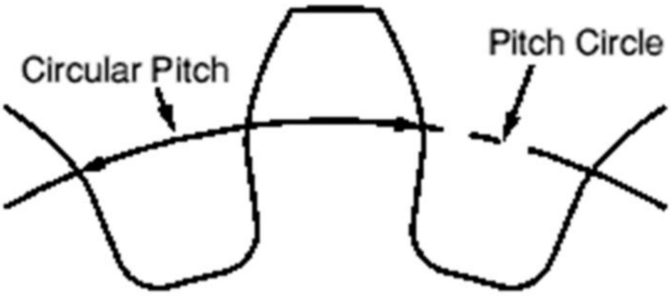


Figure 3.17 Circular Pitch

Gear range:

- Lower gear range: slow speed, High torque
- Higher gear range: high speed, Low torque

Gear ratio

$$\frac{D_A}{D_B} = \frac{T_A}{T_B} = \frac{N_B}{N_A}$$

D_A = diameter of gear A

D_B = diameter of gear B

T_A = No of teeth in gear A

T_B = No of teeth in gear B

N_A = speed of gear A

N_B = speed of gear B

Compatible gear: Two gears whch have;same circular pitch, same working depth and enough backlash.

3.1.3 Chain and Sprockets

Consist with chain & gear. Same to the gear power transmission system. Relatively higher distance than the gear transmission system. Constant speed power transmission. Not use in high speed conditions (Figue 3.18).

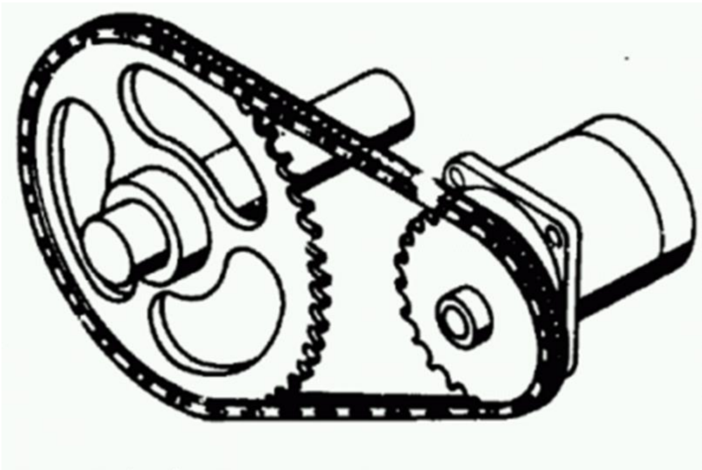


Figure 3.18 Chain and Sprockets

3.1.4 Universal Joints and Shafts

Consist with drive axial and driven axial. Mostly use in different elevations (Figure 3.19). Ex: differential

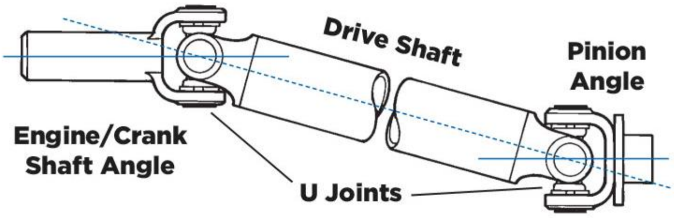


Figure 3.19 Universal Joint and Shafts

3.1.5 CV (Constant Velocity) Joints

Used in front wheel drive vehicles. Widely used because of low production cost, simple design, longer lifetime and easy to maintenance (Figure 3.20).

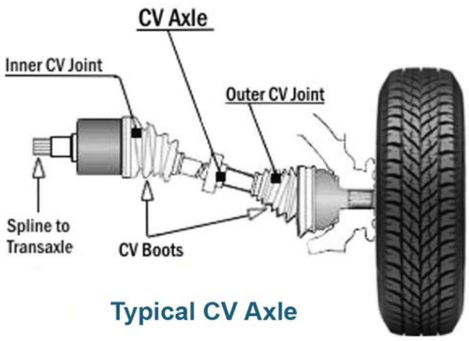


Figure 3.20 CV joint

3.2 Hydraulic Power Transmission

hydraulic power transmission often uses because; a single source (pump) handle widely varying load. (Using different size of activators, cylinders, and motors), flexibility of installation, compactness, and low cost.

Easy to operate, higher precession, flexibility, higher power/weight ratio, less wearing, low noise and safety are the major advantages of hydraulic power transmission. Low efficiency, expensive in purchasing and maintenance, frequent dirty of hydraulic oil, a leak proof system is required are the major disadvantages of hydraulic power transmission.

3.2.1 Operation principles

Pressure: Force per unit area (N/m^2).

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

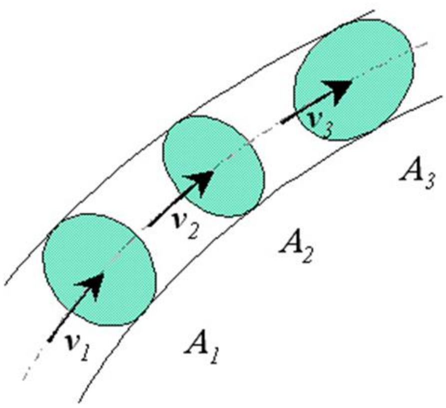
Pascal's 1st law

In case of liquid at rest, pressure of liquid at any point is equal in all directions.

Pascal's 2nd law

In case of liquid at rest, pressure put on a part of the liquid in a sealed container is transposed to all part of the liquid as it is.

Continuity equation



$$V_1 A_1 = V_2 A_2 = V_3 A_3$$

V = Flow velocity

A = Cross sectional area

3.2.2 components of a Hydraulic System

Reservoir

It should be an air proof container (Figure 3.21). Purpose: Storing hydraulic fluid (free of air condition), Cleaning the hydraulic fluid, Cooling hydraulic fluid

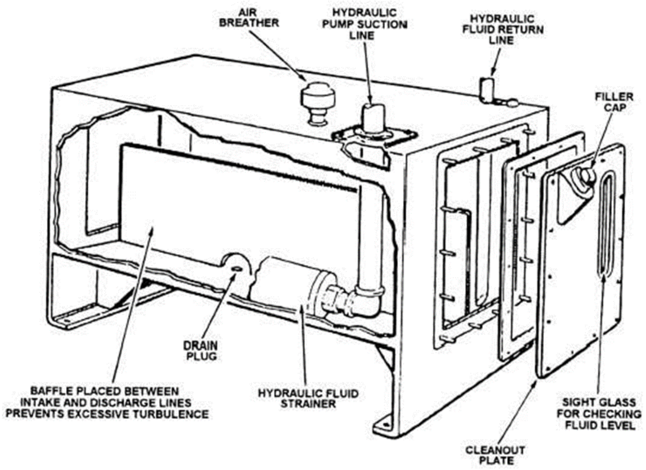


Figure 3.21 Hydraulic Reservoir

Hydraulic Pump

Hydraulic pumps are used to convert mechanical energy to hydraulic energy. Positive displacement pumps are used.

Cylinders

Cylinders are used to convert hydraulic energy to mechanical energy. There are two types of hydraulic cylinders; single action and double action.

Control Valves

There are three types of control valves; Direction control valves, flow control valve and Pressure control valve (Pressure reducing/releasing/adjusting valves).

Hydraulic Oil Coolers

Use in modern high-pressure hydraulic systems. Water or air is used as cooling agent.

Hydraulic Lines

There are three types of hydraulic lines; Rigid, semi rigid or tubing and Flexible. They Should be leak proof.

Hydraulic Fluid

Hydraulic fluid is used as the medium of power transmission. In addition of that hydraulic fluids are used to lubrication, heat transfer and protect the system form rust and corrosions.

Keep hydraulic fluid at recommended level, use only recommended fluid, service filters at due time and use correct type of filters are the good practice for maintenance of hydraulic fluid.

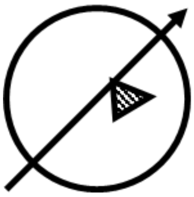
Hydraulic Motor

Hydraulic motors are used to convert hydraulic energy to rotary motion.

3.2.3 Simple Hydraulic Systems

Pumps

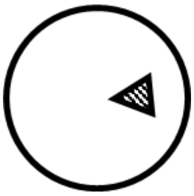
One way pump – fixed displacement



One way pump – variable displacement

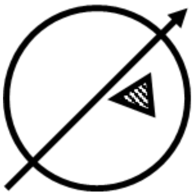
Air pump (compressor)

Motors



One way motor – Fixed displacement

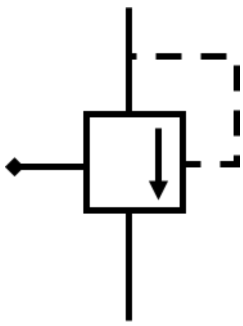
Two-way motor – Fixed displacement



One-way motor – Variable displacement

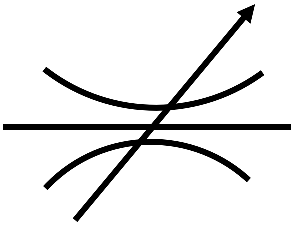
Electric motor

Control Valves



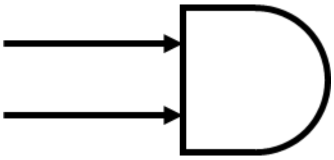
Pressure relief valve

Flow control valve – Fixed displacement



Flow control vale – Variable displacement

Activators or Cylinders

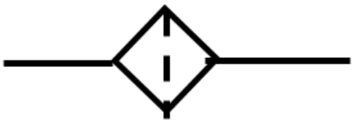


Simi rotary activator

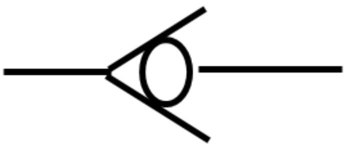
Double action cylinder

Single action cylinder

Others



Filter



Check valve

Example 3.1: Draw the simple hydraulic diagrams for the following conditions. (i)Hydraulic jack with including single action cylinder (ii) Hydraulic jack with including double action cylinder

Example 3.2: Draw a complete hydraulic system to show; the Hydraulic jack with including double action cylinder with coupling hydraulic motor

4. FARM TRACTORS

Agricultural Tractor is a Self-propelled machine, having 2 axel or tracks. It is design to carry out following operations; pull trailer, to carry out/pull/propelling agricultural tool or machine, Supply power for agricultural operations.

4.1 Historical Development of Farm Tractor

- Engine development
- Frame and transmission development with enclosure of part
- Redesigning for straight – line assembly
- Development of general-purpose models with their associated equipment
- Development of Multipurpose models with accessories

Early Steam Traction Engine

Invented in the late 1700's. Hauled into position by horses. used for threshing process and drainage pumping (Figure 4.1).

Figure 4.1 Early Steam Traction Engine

Steam Traction Engine

Use steam engine – external combustion engine. Fuel burns in a boiler with considerable distance. Heart from the burning fuel.

Steam Tractor

self-propelled machine. Introduced at early 1800's. used for ploughing. application was limited because of the enormous weight. high-pressure boilers(1850's) – lighten engines. Popular 1885 - 1914.

Gas Tractor

Use internal combustion engine. At first stationary machine. Run threshers and other machinery. Some mounted-on wheels for transferred from field to field. Utilized wide metal tires.

J. I. Case tractor

Self-propelled 1st gas tractor. Built 4-cylinder engine capable of pulling ten 14-inch plows. Limitations: lack of satisfactory carburetion and ignition.

Farmall A Tractor

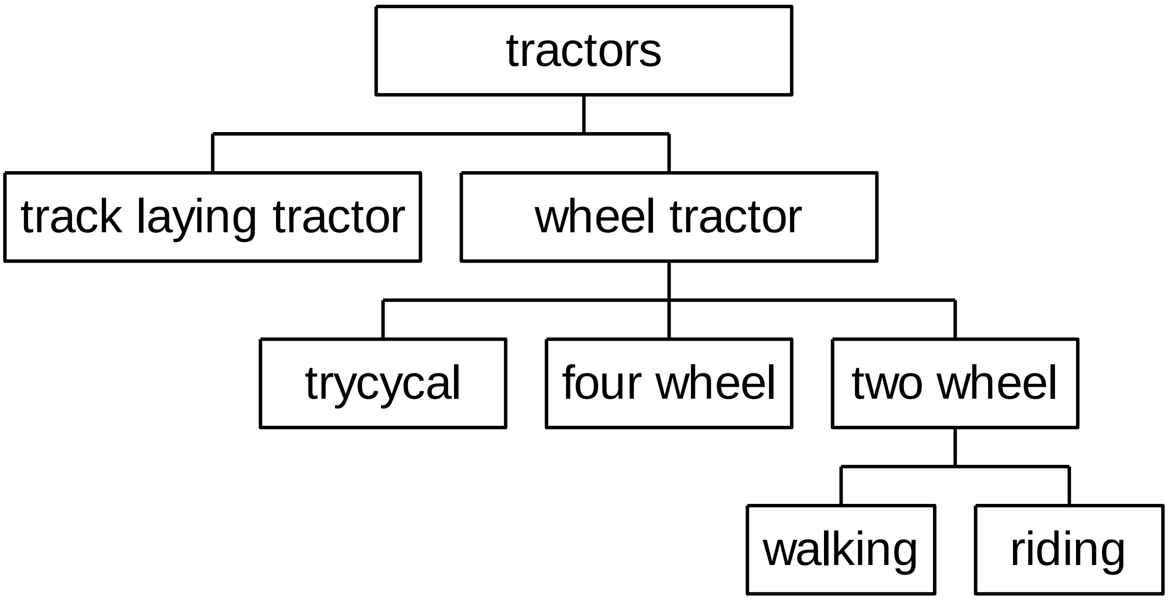
Introduced in 1939. Used rubber tires. Consist with four-speed transmission system with PTO. Available with gasoline/kerosene engines.

General Purpose Tractor

Present Day Multipurpose Tractor

4.2 Tractor Classification

4.2.1 According to the Traction Members Used



4.2.2 Based on Tractor Category

Category	Max. Draw bar Power (kW)
1	15 -35
2	30 - 75
3	60 - 168
4	135 -300

Category I – Use category I accessories, small to medium tractors, Lower power output

Category II – Widely use tractor category, use category II accessories

Category III/IV – Large tractors

4.2.3 Based on Usage and Their Size

a) Utility tractors
b) Large field tractors
    i. Two-wheel drive
    ii. Four-wheel drive
c) Orchard or vineyard tractors
d) Garden tractors
e) Industrial tractors

Utility tractor - Manufactured in size up to 80 hp, major power source of small – medium farmers, front and rare thread width can be adjusted - row crop, higher wheel clearance. Application: Row crop, Tillage, harvesting

Large field tractors (two-wheel drive) - Power range 85 – 185 hp, use for heavy tillage and other field works, adjustable thread width, higher wheel clearance, suited for row crop applications.

Large field tractor (four-wheel drive) - Size up to 400 hp, use for field works in large farms, can be used for row crop applications.

Orchard and vineyard tractors - Have low and smooth profiles to avoid the injuries to branch and vine.

4.2.4 Based on the Arrangement of Frame and Traction Members

a) Standard
b) Utility
c) Row-crop
d) Four-wheel drive (wheel steering)
e) Four-wheel drive (frame steering)
f) Tool carrier
g) Implement carrier
h) Garden two-wheel
i) Front-wheel drive
j) Crawler

Standard tractor - Developed as a traction or pulling units, drive through the two rare wheels, center of gravity located approximately 1/3 ahead from the rare wheel.

Utility tractor - Developed to industrial requirements, have more accessories; Adjustable wheel, Three-point linkage

Row crop tractors - Suited for traction applications, easy provision for quick attachment of various tillage implements, four wheel/tricycle types

4.2.5 Two-wheel Tractor Classification

1. Pull type
2. Power tilling type
3. Dual purpose type
4. Cultivation type

4.3 Tractor Performances

4.3.1 Tractor Performances Criteria

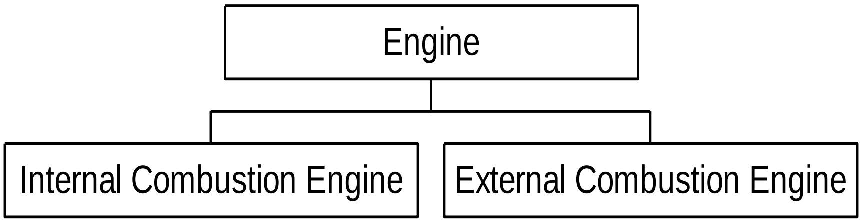
- Size of the tractor
- Max. draw bar pull
- Max. draw bar power
- Max. PTO power
- Fuel consumption
- Torque or logging ability

4.4 Internal Combustion Engine

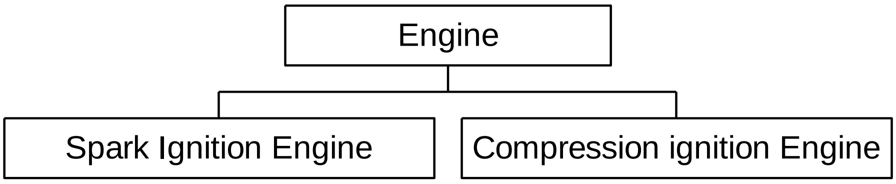
An engine is a mechanical device designed to convert energy into useful mechanical motion.

4.4.1 Engine Classification

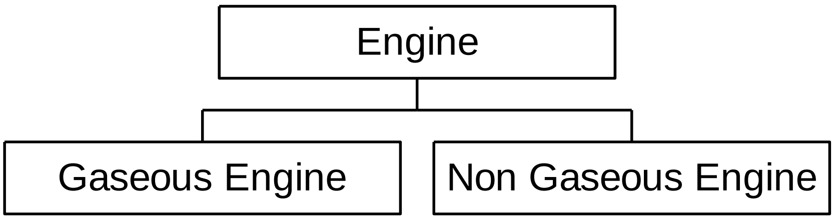
01. According to the combustion place



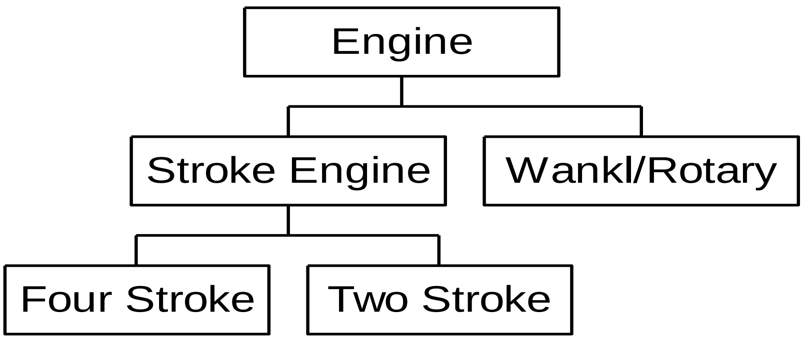
02. According to the spark mechanism



03. According to the fuel used



04. According to the working principle



05. According to the piston moving direction

- Vertical
- Horizontal
- "V" Shape

06. Number of cylinders

4.4.2 Engine Components

Major components of the internal combustion engine are illustrated in figure 4.2 – 4. They can divide in to three categories as;

- Fixed parts (Cylinder, Cylinder head, Cylinder block, Oil sump, Gasket)
- Moving parts (Piston, Crank shaft, connecting rod, Gudgeon pin, Fly wheel)
- Valve and timing parts (Inlet valve, Exhaust valve, Push rod, Rocker arm, Cam shaft)

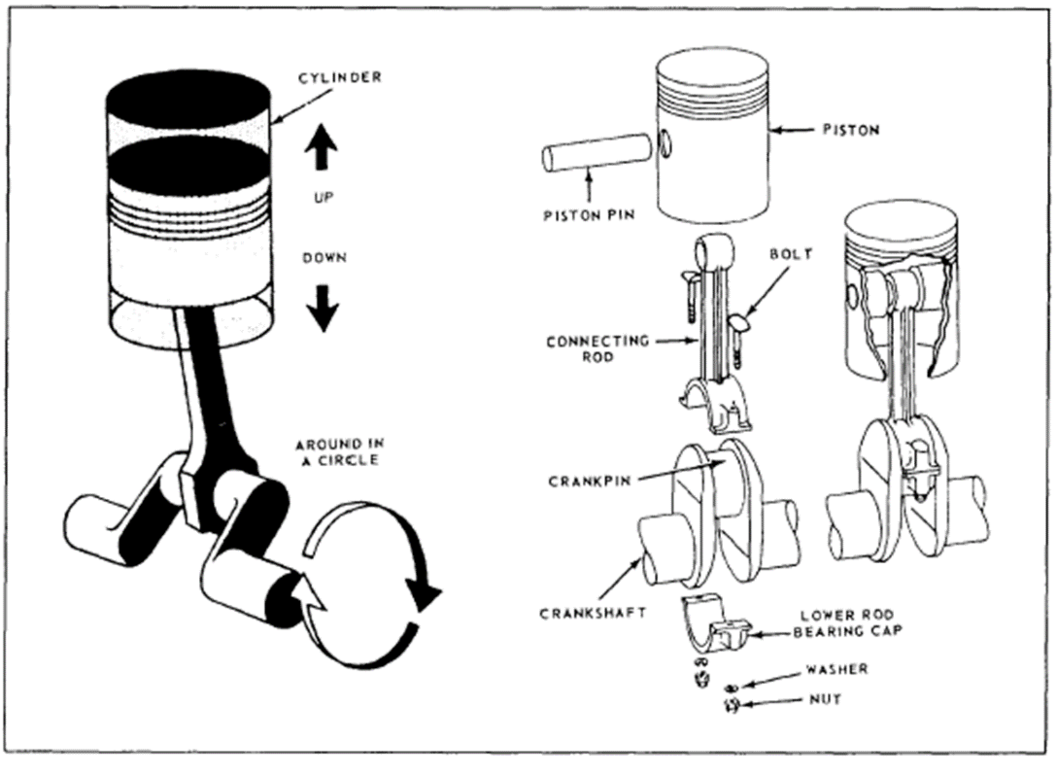


Figure 4.2 Engine Components

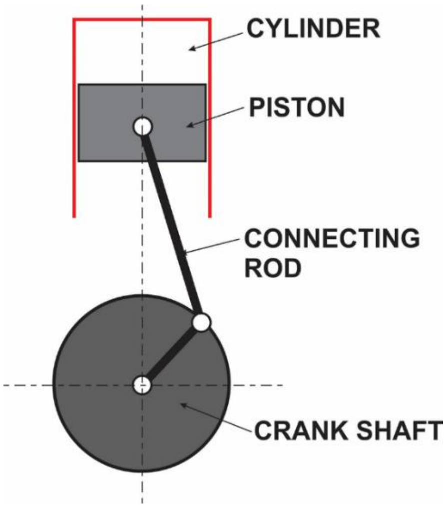


Figure 4.3 Major Components of a Reciprocating Engine

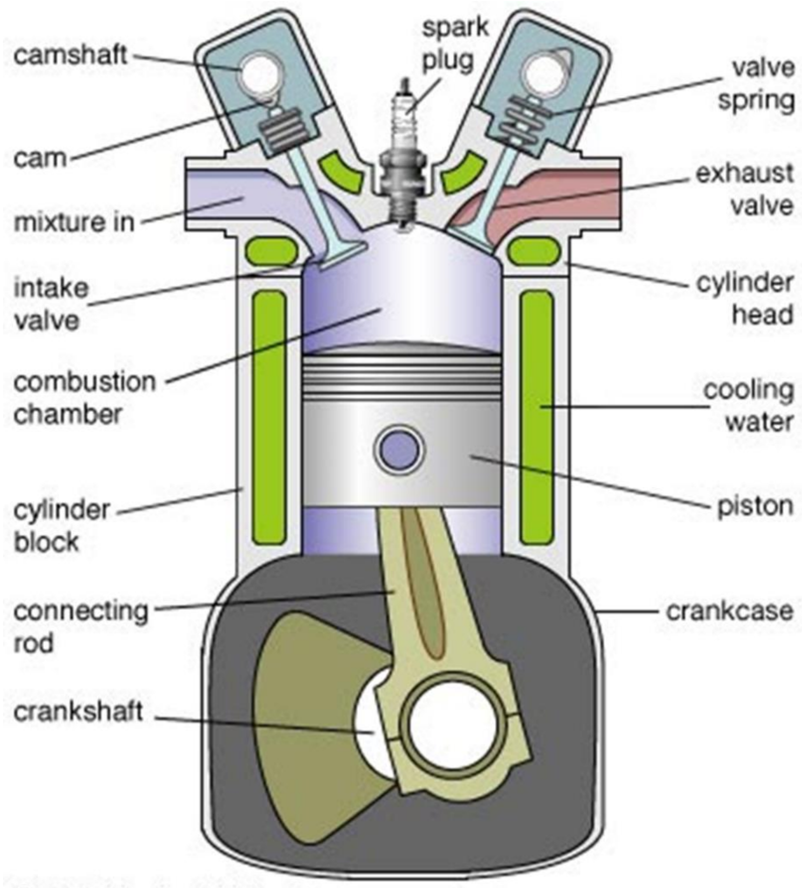


Figure 4.4 Engine components

4.4.3 Working Principles of the Engine

Fuel air mixture comes in to the burning chamber, when inlet valve is open. When the inlet valve is close, the mixture is compressed by the piston moving up. An ignition is made and mixture is burned, then volume of the mixture is getting expand. Sudden movement of piston to down wards. Rotate the crankshaft, power absorbed by the flywheel and make operating cycle. Piston moves up and release the exhaust gases throughout the exhaust valve opening.

4.4.4 Valve Timing

Both the inlet and exhaust valves are open longer than it takes the piston to make a stroke. The exact number of degrees that a valve will open or close before top or bottom dead centers varies depending on engine design. The early opening and late closing of both valves greatly improves the intake of fresh air/fuel mixture and the through exhausting of burned gasses. The situation both intake and exhaust valves partially open is called, valve overlapping period. In this valve timing diagram, the valve overlapping period is 73^0(Figure 4.5).

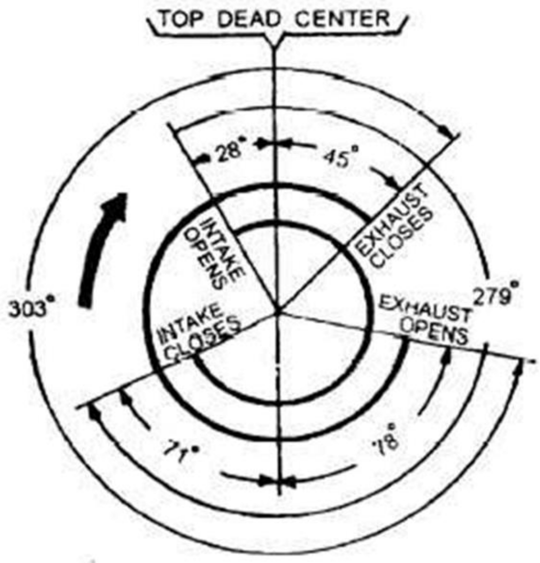


Figure 4.5 Valve Timing Diagram

4.5 Two-Stroke and Four-Stroke Engines

4.5.1 Four Stroke Engine

The four-stroke engine cycle is having four strokes; Suction stroke, Compression stroke, Power stroke and Exhaust stroke (Figure 4.6).

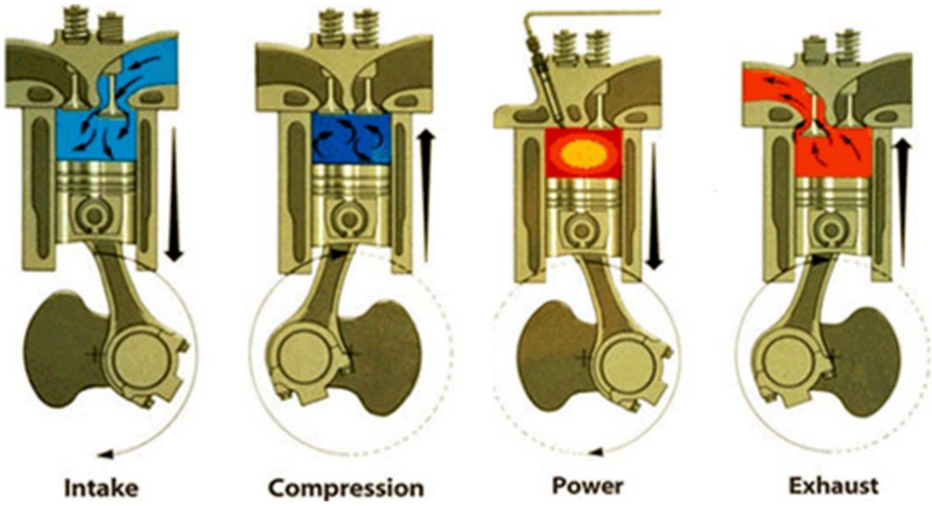


Figure 4.6 Four Stroke Engine Cycle

Suction stroke - Open inlet valve, piston moves from TDC to BDC, fuel air mixture drawn to the burning chamber.

Compression stroke - Close inlet valve (both valves are closed), piston moves from BDC to TDC, fuel air mixture is compressed.

Power stroke - Compressed air fuel mixture is ignited, sudden expansion of air, piston suddenly moves from TDC to BDC, power is generated and stored in the flywheel.

Exhaust stroke - Open the exhaust valve, piston moves from BDC to TDC, release the exhaust gases throughout the exhaust valve opening.

4.5.2 Two stroke Engine

Two stroke engine cycle is consisting with two strokes; Up stroke and down stroke (Figure 4.7).

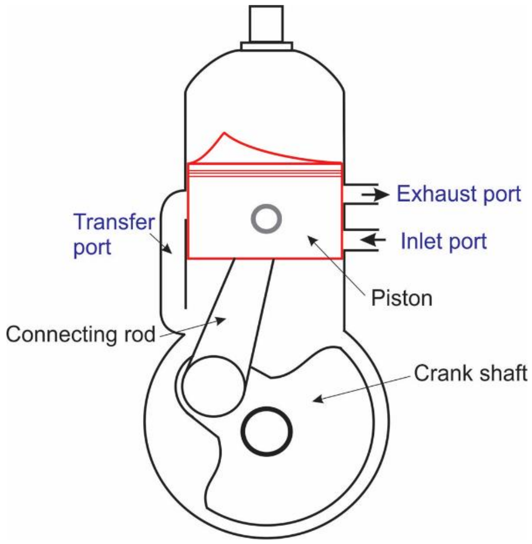


Figure 4.7 Two Stroke Engine Cycle

Up stroke - Piston moves up, fuel air mixture is drawn to the crank case through the inlet port, ignite the compressed fuel air mixture in the combustion chamber, complete suction and compression stroke of four stroke cycle.

Down stroke - Piston moves down, fuel air mixture at crank case transfer to the combustion chamber through the transfer port, burned gasses are release through the exhaust port, complete power and exhaust stroke of four stroke cycle.

4.6 Engine Terminology

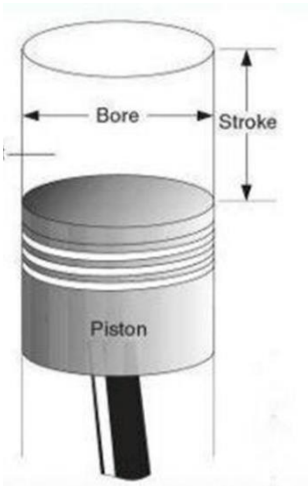
1. Engine Speed

The speed of the engine, rpm of the crank shaft, Tacho meter is used to measure the engine speed.

- 350 rpm > Low speed
- 350 – 1000 rpm medium speed
- 1000 rpm< high speed

2. Stroke Bore Ratio

The ratio of the stroke length to cylinder bore.



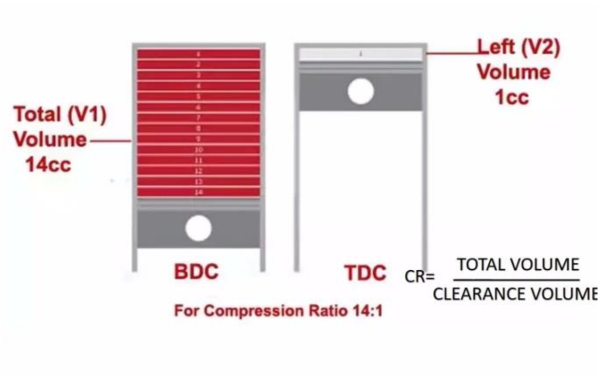
$$\textbf{Stroke bore ratio} = \frac{\mathbf{L}}{\mathbf{D}}$$

L = Stroke length

D = Bore length

3. Compression Ratio

The ratio of the volume of the air in the cylinder before compression to after compression.



$$\textbf{Compression ratio} = \frac{\mathbf{V_1}}{\mathbf{V_2}}$$

V_1 = Air volume before compression

V_2 = Air volume after compression

4. Piston Displacement (Swept volume)

The volume displaced by the one stroke.

$$\textbf{Piston Displacement} = \mathbf{AL}$$

A = Cross section area of the cylinder L = Stroke length

5. Displacement Volume

The volume displacement within one minute.

$$Vd = A \times L \times N$$

A = Cylinder cross section area L = Stroke Length

N = No. of power stroke / min.

6. Piston Speed

Linear speed of the piston.

$$Sp = 2LN$$

L = Stroke length N = rpm

Example 4.1: A four-cylinder four stroke engine with 50 mm diameter of cylinder and 1.1 stroke bore ratio is running in 2500 rpm. Calculate engine capacity and displacement volume.

7. Mean Effective Pressure

Indicated mean effective pressure (IMEP) - Average pressure in the cylinder at the end of compression stroke. Measured by the pressure gage

Brake mean effective pressure

$$BMEP = \frac{Pb}{LANn}$$

L = Stroke length A = Piston area

N = No. of power stroke/min n = No. of cylinders

8. Power of Engine

Power is Rate of doing work. Unit Watt, J/s, Nm/s.

Indicated power (P_i) - Power available at the piston.

$$P_i = PLANn$$

P = mean effective pressure L = length of the stroke

A = cross section area of the piston N = Number of power stroke/second

n = number of cylinders

Brake power (P_b) - Output power of the engine flywheel.

Friction power (P_f) - Power losses due to friction.

$$P_f = P_i - P_b$$

4.6.1 Engine Operating Characteristics

Mechanical Efficiency

The ratio of brake power to indicated power.

$$\text{Mechanical Efficiency} = \frac{P_b}{P_i} \times 100$$

normally ME is 75 – 90%. Higher internal friction, pumping losses, power losses for other systems, and heat losses are the reasons for lower ME.

Volumetric Efficiency

$$\text{Volum. eff.} = \frac{\text{Volume of drawn fuel ari mixture}}{\text{Piston displacement}} \times 100$$

Atmospheric temperature & pressure, mani fall design, length, size and smoothness, inlet mani-fall temperature, fuel characteristics, compression ratio, valve size and timing, engine operating temperature are the main reasons for lower volumetric efficiencies.

Increasing inlet valve diameter/opening time, use number of valves, air filter design, using double carburetors, using turbo-engine are remedies to increase the volumetric efficiency.

Thermal Efficiency

The ratio of the out-put of engine (Pb) to use-full mechanical power from fuel consumption.

$$\text{Thermal efficiency} = \frac{P_b}{\text{Power of the fuel}} \times 100$$

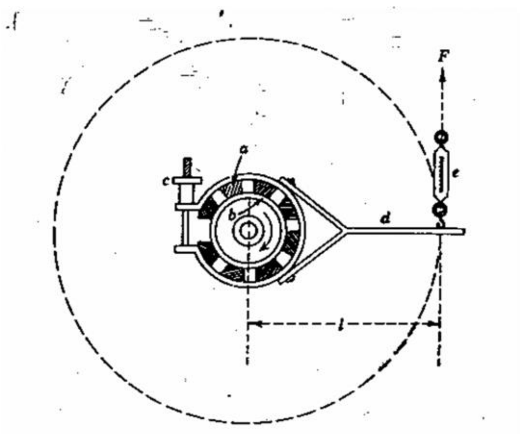
Example 4.2: A four-stroke four-cylinder engine is running in 3000 rpm speed, and shows following specifications; Compression ratio = 7:1, Stroke bore ratio = 1, Ø of cylinder = 100mm, Mean effective pressure = 760 kPa, Mechanical efficiency = 85%. Calculate;

i. Displacement volume
ii. Total space volume
iii. Indicated power
iv. If volumetric efficiency is 90%, Air consumption rate
v. If 32 lit of fuel is consumed for 8 hrs. Specific fuel consumption

4.7 Measurement of Engine Power

Use dynamometers to determine the power by using force, time and displacement. Prony Brake dynamometer, hydraulic dynamometer, spring dynamometer, and strain gauge dynamometer are the several types of dynamometers.

Prony Brake Dynamometer



$$\text{Power} = \frac{F 2\pi l n}{60}$$

$$\text{Dynamometer constant} = \frac{2\pi l}{60}$$

Example 4.3: A Prony Brake Dynamometer with 1.4m arm length is used to measure the brake power of an engine, which was running in 2500 rpm speed. If Dynamometer reading is 80N, calculate the brake power of the engine.

4.7.1 Morse Test

Morse test is used to measure; Indicated power, Frictional power, and Mechanical efficiency of the engine.

Procedure - Take dynamometer meter reading when all cylinders are working. Stop functioning of cylinders one by one & take each dynamometer readings. Repeat same procedure four times and get average values.

Example 4.4: A Morse test on an engine gave the following Dynamometer readings: when all cylinders are working 100kW, when cylinder No. 1 is not functioning 69 kW, when cylinder No. 2 is not functioning 71 kW, when cylinder No. 3 is not functioning 68.5 kW, when cylinder No. 4 is not functioning 71.5 kW. Calculate: a) Indicated power of the engine, b) Friction power of the engine, c) Mechanical efficiency of the engine

4.8 Engine Systems

4.8.1 Fuel System

Petrol Engine Fuel system

Air cleaner, Fuel tank, Fuel pump, Fuel filter and Carburetor are the main components of Petrol Engine Fuel system (Figure 4.8).

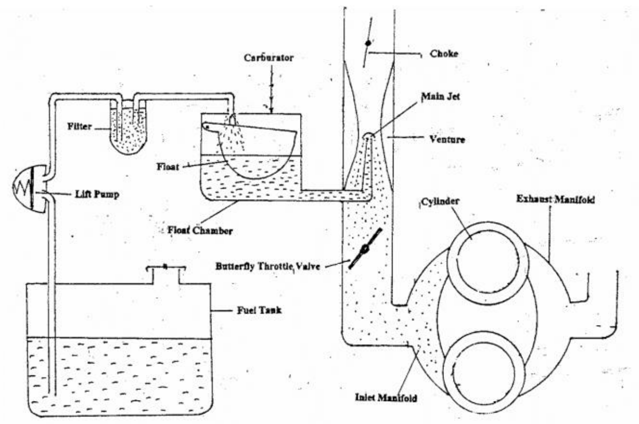


Figure 4.8 ***Petrol Engine Fuel system***

Air cleaner - Wet/Dry type

Fuel lift pump - Gravity flow (use in more petrol tractors), Lifting pump (use to increase efficiency), Use diaphragm pump

Carburetor - Supply fuel/air mixture in correct proportions (fuel: air = 1:15). Float chamber Maintain a constant level of fuel and consist with floater and needle valves (Figure 4.9).

Choke/throttle valve - Flat circular disks, Choke valve: At air cleaner side, supply rich fuel mixture at starting, Butterfly/throttle valve: At engine side, connect to the accelerator, supply more fuel and air to burning chamber.

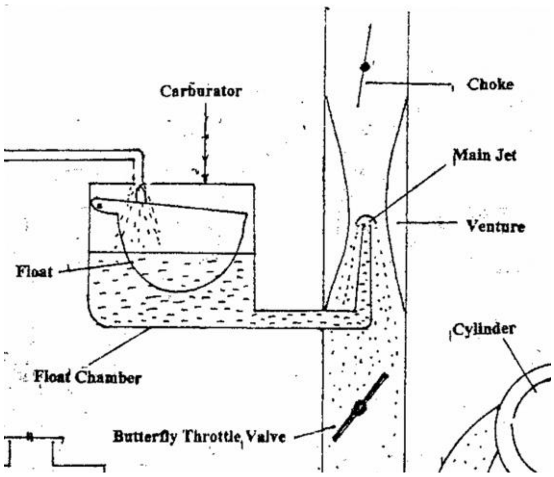


Figure 4.9 Carburetor

Diesel Engine Fuel System

Air cleaner, fuel lift pump, fuel filter, fuel injection pump and fuel injectors are the main components of diesel engine fuel system (Figure 4.10).

Fuel lift pump - Use force feed system. Diaphragm pumps are used.

Fuel injection pump - Important and expensive part. Supply very small amount of fuel with constant pressure. Supply fuel to correct injector at correct time. Two types: Plunger type and Distributor type.

Fuel injectors - Supply small quantity of fuel at high pressure (140 kg/cm^2).

Governor - Control the fuel supply by fuel pump. Release enough quantity of fuel when Changing load, and speed.

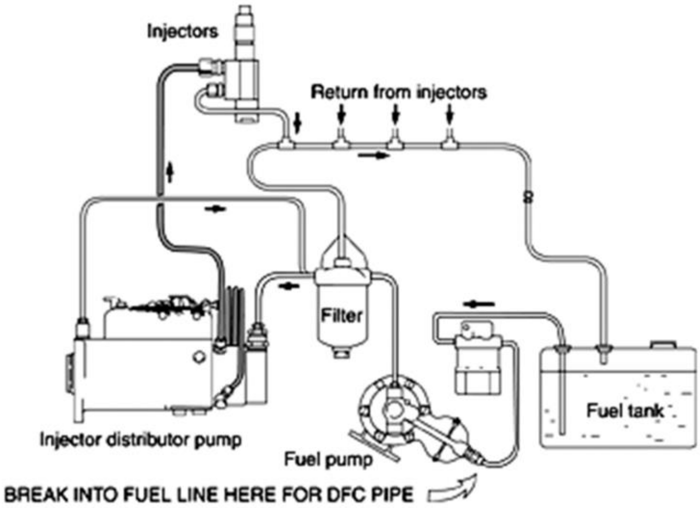


Figure 4.10 Diesel Engine Fuel System

4.8.2 Ignition System

Battery Coil Ignition System

Battery, Ignition switch, Ignition coil, Condenser, contact breaker, Distributor cap and Spark plugs are the major components of battery coil ignition system (Figure 4.11).

Magneto Ignition

Battery is not required. Eg: water pump, two-wheel tractor. Magnet, Primary & secondary windings, contact breaker, Condenser, Distributor and Spark plugs are the major components of magneto ignition system.

Firing Order

Order of Sparking / self-burning. Help to reduce torsional-stress. Ex: Four-cylinder engines:1-3-4-2 or 1-2-4-3, Three-cylinder engines:1-2-3, Six-cylinder engine:1-5-3-6-2-4.

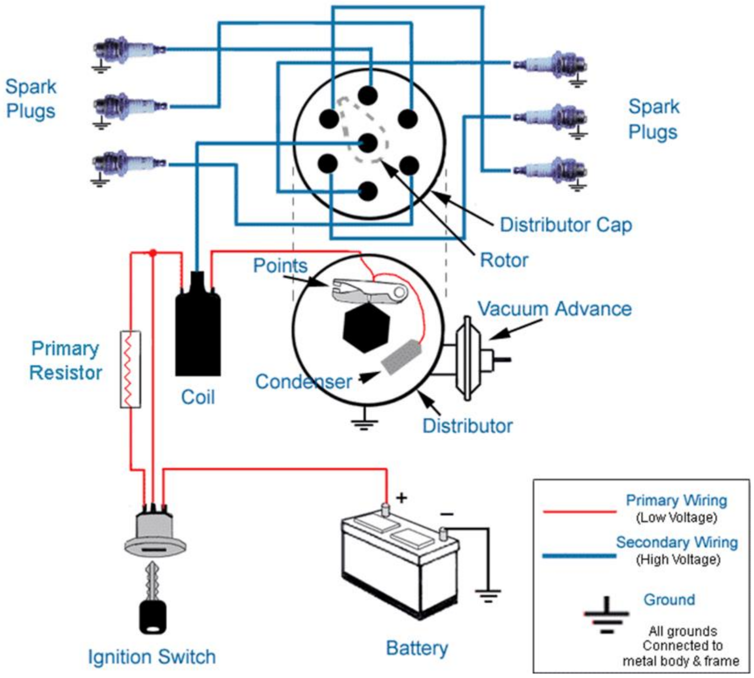


Figure 4.11 Battery Coil Ignition System

Firing Interval

The area of travel of the crankshaft in degrees between successive explosion.

Two stroke engine: Firing Interval = (360 / No. of cylinders)

Four stroke engine: Firing Interval = (720 / No. of cylinders)

Other Components

Starter motor. Dynamo, Dynamo regulators (Cut-out/Voltage regulators)

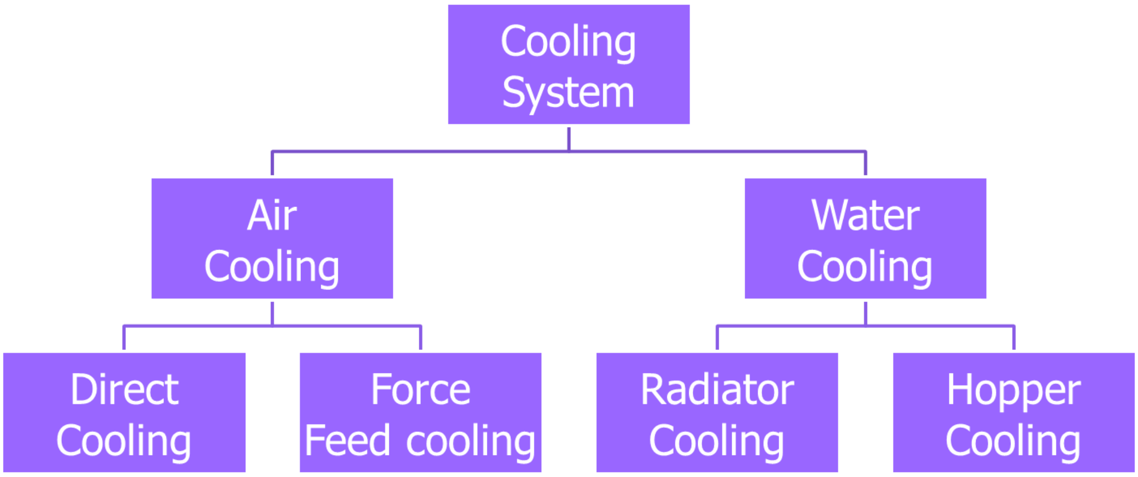
4.8.3 Cooling system

End of power stroke generate large amount of heat is released. Eg: 16000 C – Diesel engine. It is greater than the malting point of engine parts

Efficient Cooling System

Does not over-heat / boil the water. Not run in too cold conditions.

Classification for Cooling Systems



Air-cooling - Use for single cylinder small engines. Cooling is done by direct expose of air. Cooling fins are used to Increase surface area and spread heat.

Water-cooling - More effective method. Used in agric. Tractors/other vehicles. Cylinders are completely surrounded by water jacket. Thermo-siphon principle is used to circulate water.

Radiator Cooling System

Radiator, Impeller, Water tubes, Water jacket, Thermostat valve, and Thermometer are the major components of radiator cooling system.

Radiator - Use to increase the surface area, honeycomb appearance (Figure 4.12)

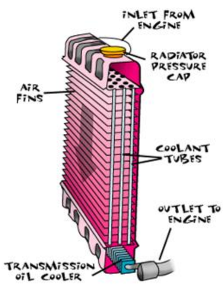


Figure 4.12 Radiator

Anti-freeze/Coolant - Chemical with water, Improve the heat capacity/anti-freeze ability

4.8.4 Lubrication System

Impotence of lubrication system: To reduce the friction of parts, to reduce the wearing of parts, Absorb the heat.

Friction could be reduced by: Using soft metals (Ni, Brass) Eg: Bush, using bearings (Ball bearings/Roller bearings/Plane bearing), Using lubricants (Lubricant oils/ Grease)

Reduce the friction of moving parts, reduce the wearing of parts, absorb the heat, acting as a sealing agent, as voice absorption, and for collect engine debris are the usage of lubrication system.

Classification for the Lubricant

- Lubricant oil
- Low or non-flowing lubricants / semi solid lubricants

Classification for lubricant oil - Classify according to the viscosity. SAE (Society of Automotive Engineering) Classification: Engine oil SAE 10 – 40, Gear & transmission oil SAE 50 – 90

Low SAE -Low viscosity, for cold climate, Engine, which run for short time

High SAE - High viscosity, Hot climate, Engine, which run long time

Multi grade oil - Range of SAE, ability work at hot and cool climates. Eg: SAE 10/30, SAE 20/50

Detergent oil - Content additives which help to prevent formation of carbon and lacquer, mostly use in diesel engines, help to prevent oxidation/corrosion of engine.

Universal oil - One oil of ever purpose

Properties of Lubricant

- Should be enough viscosity
- Compatible for the engine

- Should be a constant value of viscosity for range of temperature
- Should be consist with inhibitors (Oxidation inhibitors/Corrosion inhibitors/Form inhibitors)
- Consist with detergent additives
- Pressure bearing quality

Lubrication Systems

Petroil lubrication system - Lubrication oil mixed with petrol, Petrol: oil = 16:1 (Large engine), 24:1 (Small engine)

Splash lubrication - Used in fixed machines

Force feed lubrication - Use in complex engines

Maintenance of lubrication system

- Check the oil level
- Lubrication oil change in due time
- Change the oil filter in due time

4.8.5 Transmission Systems

Clutch, Gear box, Differential and Final drive are the major components of transmission system.

Clutch

Use to connect and disconnect the power flow, help to change the gear ratio and help to get the smooth pick up (Figure 4.13).

Gear Box

Can get different gear ratio (using different gear range). Torque, speed and direction may change (Figure 1.14).

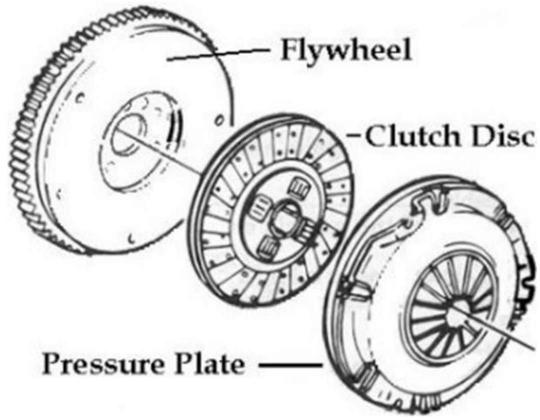


Figure 4.13 Clutch

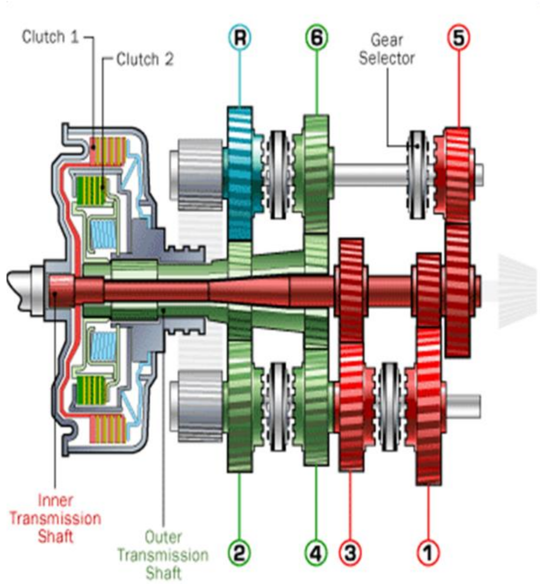


Figure 4.14 Gear Box

Differential

Allow each drive wheel to rotate in different speeds. Turn power flow in 90^0 angle, Reduce the speed and increase the torque (Figure 1.15).

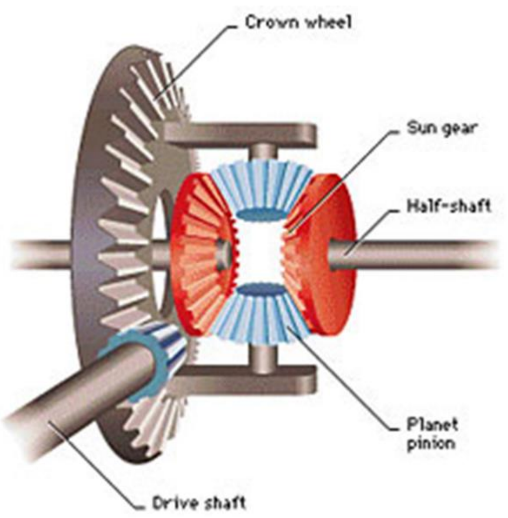


Figure 4.15 Differential

Final Drive

Last phase of power transmission. Reduce the speed and increase the torque (Figure 4.16).

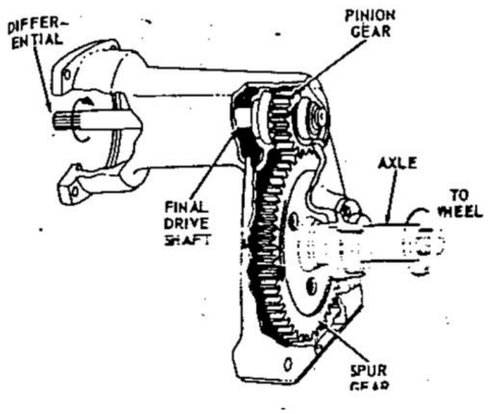


Figure 4.16 Final Drive

Process of Power Transmission

Clutch - Connect and disconnect the power flow

Gear box - Select suitable speed, torque, and direction

Differential - Equalize the power to driving wheels

Final drive - Increase the traction power

Clutch Types

- Fluid clutch - use in hydraulic power transmission
- Magnetic clutch - use current and make magnetic field
- Cone type clutch
- Disk type clutch - use in modern vehicle

Types of gear box

Sliding mesh gearbox - Use in farm and industrial machines, simple, use straight spur gears, cannot change gear ratios when vehicle is running.

Synchromesh gearbox - Can change the gear ratios when the vehicle is running. Gears are not change but brass-cones are shifted

Power Drain-off of a Farm Tractor

1. Power take off drive – PTO
2. Hitches – Draw bar pull
3. Hydraulic power

PTO

Two categories: Six splines, 35 mm Ø, 540 r/m and 21 splines, 35 mm Ø, 1000 r/m. Direction: clock wise

Types of PTO

i) Transmission driven or gearbox driven PTO

PTO shaft is an extension of gear box shaft. Continuously running when clutch is engaged. To stop of running of PTO have to disconnect the power transmission by clutch. It can be done by using an engagement lever. Do not use in mostly

ii) Continuous running or engine PTO

Both transmission and PTO are operated by one clutch. First half for transmission and second half for PTO. Mostly used type of clutch.

iii) Independent PTO

Have two separate clutches. Mostly used.

Hitch Types

Swinging drawbar hitches - Attached to the bottom of the rare axel

The pickup hitches - Hook can be shifted up and down by hydraulics

4.8.6 Tractor Hydraulic System

Most useful mechanism. Main usages: Carry and operating of field machinery by three-point linkage, raise trailer / tipping trailer, Remote motors – harvesting machine.

Hydraulic Controllers

- Draft controller
- Position controller
- Response controller
- Automatic draft controller

Position controller - Directly represent the corresponding position or depth of the implement. Control the working depth. Mostly use for weeders, planting and sowing machines, sprayers and transportation of implement

Draft controller - Implement is set for the particular draft (drawbar pull)

Automatic draft controller - Any sudden increment of the soil resistance, compress the top link, force is transferred to control valve through the spring, then left the implement slowly. Then soil resistance goes down and lowering the implement again to maintain the predetermined soil resistance.

Response controller - Responsible for the working speed of tractor hydraulic system. Consist with flow control valve

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