MCE 504

AUTOMOBILE ENGINEERING

(3 UNITS)

PREPARED BY

BUKOLA O. BOLAJI *Ph.D/*PROF. P.O. AIYEDUN

DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF AGRICULTURE, ABEOKUTA

OGUN STATE, NIGERIA

MCE 504: AUTOMOBILE ENGINEERING (3 UNITS)

COURSE SYNOPSIS

Mechanics of vehicles. Vehicle component and design. Traction engine and transmission data. Fuel system, clutches, gear boxes – manual and automatic. Transmissions, steering systems. Brakes, tyres. Air conditioning. Electrical system. Exhaust system. Ignition system. Body and chassis.

1.0 INTRODUCTION

Automobile is a self-propelled vehicle used for transportation of goods and passengers on the ground. Automobiles or Automotive means a vehicle which can move by itself. It differs from aeronautical vehicle ship, like aeroplanes, helicopters, rockets e.t.c which fly in air as well as from marine vehicles like motor boat which sail in water.

The automobile is essentially a transportation equipment unit. It is made up of a frame supporting the body and certain power-developing and transmitting units. These are further supported by tyres and wheels through the springs and axles. The engine supplies the power. It is delivered by the transmitting system and the rear axles through the clutch or fluid coupling to the rear wheels. The automobile is propelled through the friction of the contact between the road and the wheels. The various units are held together in proper arrangement on the frame. The protection and comfort is provided by the body of the vehicle.

Germany is the birth place of automobile. It was invented there. It went through its first phases there and it was developed there to a high level of technical maturity. The list of German automobile pioneers is a long one starting with Nicholas Cugnot, August, Otto, Carl Benz, Gottlieb, Daimler, Wilhelm Maybach and Rudolf Diesel and going all the way up to Ferdinand Posche and Felix Wankel.

The leading manufactures or motor vehicles in the world are as follows:

i. U.S.A: General Motors, Ford-Ford Cars, Chrysler
ii. Japan: Toyota, Nissan
iii. West Germany: Volkswagon
iv. Italy: Fiat
v. France: Renault
vi. U.K: B.L.M.C, Austin / Morris BL, 1.

1.1 GENERAL CLASSIFICATION OF VEHICLES

There are numerous types of automobiles used in the world. In general, there are three main classifications of the various types of vehicles:

i.) The single unit vehicles or load carriers

ii.) Articulated vehicles

iii.) The heavy tractor vehicles

1.1.1 Single Unit Vehicle

There are conventional four-wheel types. The great majority of vehicles are of two axle design. In these vehicles the front axle is a steering non-driving axle. With the passage of time, a great many changes have taken place in the number of axles and the driving arrangements.

1.1.2 Articulated Vehicles

A lower powered three-wheeler with a single steering wheel in front and a conventional rear driving axle is an example of articulated vehicles. It has a greater handling ability in awkward places. It can be turned about its own tail due to the three-wheel construction. The coupling mechanism between semi-trailer and tractor in most of these vehicles is arranged for automatic connection and coupling up necessitating only its reversing into the position. But for uncoupling operation, a lever is provided within the driver's cabin to reverse the whole process. A pair of retractable wheels in front is also provided. Along with the coupling or uncoupling operation, they can be raised or lowered automatically.

1.1.3 Heavy Tractor Vehicles

Heavy tractor or independent tractor vehicles are used to move heavy loads, they commonly operate in pair either I tandem or as 'puller' and 'pusher.' While descending appreciable gradients, stability is provided by the later arrangement.

1.2 TYPES OF AUTOMOBILES

There are numerous types of automobiles found in different parts of the world. With respect to different purposes, the various type of automobiles are classified as under**:**

1.2.1 With Respect to the Use

i.) Auto-cycles and Mopeds

ii.) Scooters and Motorcycles

iii.) Cars, Station wagons and Pick-ups

iv.) Lorries (Buses) and Trucks

v.) Tractors

1.2.2 With Respect to Capacity

i.) H.T.V. or Heavy Transport Vehicles or Heavy Motor Vehicles: Bus, Coaches, Truck, Tractor.

ii.) L.T.V. or Light Transport Vehicles, or Light Motor Vehicles: Cars, Jeeps, Motor cycles

iii.) Medium Vehicles: Minibus, Station wagon

1.2.3 With Respect to Fuel Used

i.) Petrol Vehicles: Jeeps, cars, Motor Cycles

ii.) Diesel Vehicles: Truck, Bus, Tractor, Bulldozer, Mercedes

iii.) Gas Vehicles- Coal gas, Gas turbine or Producer gas Vehicles.

iv.) Electric Vehicles- Using electric storage batteries or accumulators to drive electric motors attached to the front or rear wheels, e.g. Heavy cranes, battery truck, cars and forklifts.

v.) Steam vehicles: Steam road rollers, it is now obsolete.

1.2.4 With Respect to Wheels and Axles

i.) Two wheelers: Motor cycles

ii.) Three wheelers: Tempos, Auto Rickshaws, Tricycles

iii.) Four wheelers: Cars, Jeeps, Buses, Trucks (some buses and trucks have six tyres out of which four are carried on the rear wheels for additional traction.

iv.) Six axle wheelers (10 tyres) vehicles.

1.2.5 With Respect to the Motion

i.) Reciprocating – piston engines

ii.) Rotary – Wankel engine, Gas turbine

1.2.6 With Respect to the Suspension

i.) Conventional – leaf spring

ii.) Independent – coil, torsion bar, pneumatic

1.3 TYPES OF CYLINDER ENGINE

By enlarging the size of a single cylinder or having more cylinders of same size increases the power developed by an engine. Although a single large cylinder has fewer parts to manufacture and maintain, yet the advantage of are over – weighed by the disadvantages. This is due to the fact that the power may be increased by increasing the size of the cylinder, but the engine power varies as the square of the bore with the weight varying as the cube of the bore for a given speed and cylinder pressure. Therefore, by doubling the bore in size, the power would become four times as great while the weight would become eight times . hence the weight increase at a greater rate in comparison to the power providing a lower power to weight ratio.

The multi – cylinder engines are capable of producing higher powe output due to increase in revolution per minute in comparison to single cylinder engines. The benefits derived from multi – cylinder engines all developing the same horse power will be clear from Table 1.1

Table 1.1: Number of cylinders and their diameter, power and weight.

Number of cylinders	Cylinder diameter D (mm)	Power $P = \frac{N(D)^2}{10^3}$ (kw)	Total approx weight of piston m (kg)	Power – weigh ratio (kw /kg)
1	173	30	10.36	2.9 : 1
2	122	30	7.28	4.12 : 1
4	87	30	5.28	5.69 : 1
6	71	30	4.30	6.98 : 1
8	61	30	3.64	8.24 : 1

Source: Narang, 2005

1.3.1 The Single Cylinder Engine

This engine is generally employed in auto cycles, motor cycles and on certain small three wheeled cars. In this engine, there is only one power stroke in two revolutions of the crankshaft. It may be two or four-stroke cycle engine. 600 to 700c.c. is maximum size of such an engine. Very heavy flywheels are required for size above this. Due to the lack of balance of the reciprocating parts, the vibrating effects are very much marked. The crankshaft consists of one crankpin and the two main journals made either as a one-piece forging of alloy steel or as bolted together assembly.

1.3.2. Twin Cylinder Engines

In order to provide larger power, better balance, smaller size, reduced overall height and even torgue, the cylinders of motorcycles and light car engines are duplicated. The capacity of the twin cylinder engines ranges from 500 to 1000c.c. for motorcycles while for small cars and three wheelers, it ranges from 500 to 800c.c. The identity of an engine is dictated by the layout of the cylinders. The three common arrangements in two cylinder engine are shown in Fig 1.1.

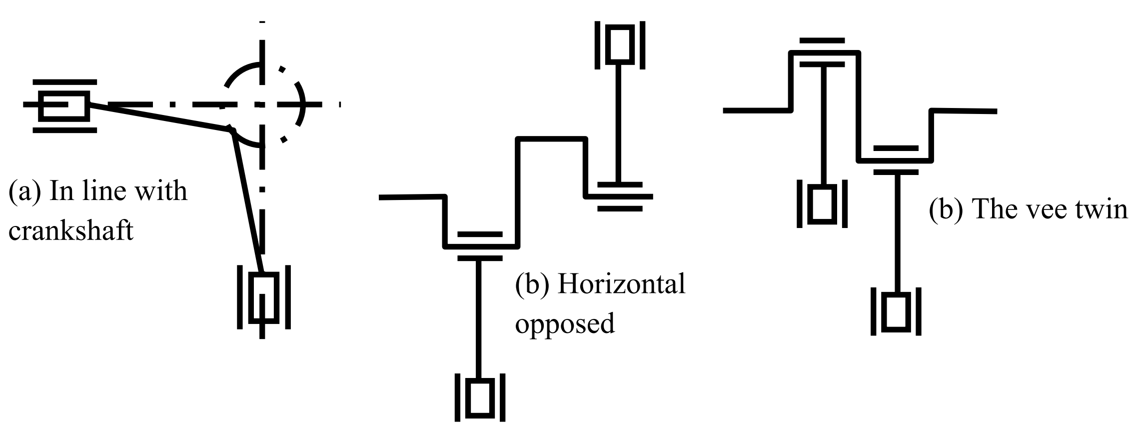

Fig. 1.1: Two cylinder engine

A twin cylinder engine operating on four stroke cycle has two power strokes in two revolutions (Table 1.2.)

Table 1.2: Firing order of two cylinder four stroke engine

Cylinder	Firing Order			
	1	2	3	4
1	Power	Exhaust	Induction	Compression
2	Compression	Power	Exhaust	Induction
Crankshaft rotation	0^0 - 180^0	180^0 - 300^0	300^0 - 540^0	540^0 - 720^0

In case of a two cylinder two-stroke engines, two power strokes are produced in one revolution of the crankshaft with firing interval of 180^0 (Table 1.3.)

Table 1.3: Firing order of two cylinder four stroke engine

Cylinder	Firing Order	
	1	2
1	Power	Compression
2	Compression	Power
Crankshaft rotation	0^0 - 180^0	180^0 - 360^0

1.3.3. Three Cylinder Engines

These engines are confined to only two strokes. They produce a power impulse every 120^0 indicating that the torgue produced is comparatively smooth. The cylinders are arranged vertically in line with crankcase serves as intake and pre-compression chamber. Its differential is located between the engine and the transmission. It is mainly used on a front-drive car. In the three cylinder two stroke engine, three power strokes in one revolution of the crankshaft with firing interval of 120^0 take place. (Table 1.4.)

Table 1.4. Firing Order of three cylinder two stroke engine

Cylinder	Firing Order		
	1	2	3
1	Power	Finishing Power	On compression
2	On compression	Power	Finishing Power
3	Finishing Power	On compression	Power
Crankshaft rotation	0^0 - 120^0	120^0 - 240^0	240^0 - 360^0

1.3.4. Four Cylinder Engine

Four-cylinder engine is the most popular arrangement for use in the small light and medium sizes of present day cars. These engines are operating on a four stroke principle. A 180^0 crankshaft arrangement is always used. The cylinders are arranged in a line above a flat, four-throw crankshaft.

Four cylinder four stroke engines produce four power strokes in two revolutions of the crankshaft with firing interval of 180^0 (Tables 1.5. and 1.6.)

Table 1.5: 4-stroke four cylinder with firing order 1,3,4,2.

Cylinder	Firing Order			
	1	2	3	4
1	Power	Exhaust	Suction	Compression
2	Exhaust	Suction	Compression	Power
3	Compression	Power	Exhaust	Suction
4	Suction	Compression	Power	Exhaust
Crankshaft rotation	0^0 - 180^0	180^0 - 360^0	360^0 - 540^0	540^0 - 720^0

Table 1.6. 4-stroke four cylinder with firing order 1,2,4,3.

Cylinder	Firing Order			
	1	2	3	4
1	Power	Exhaust	Suction	Compression
2	Compression	Power	Exhaust	Suction
3	Exhaust	Suction	Compression	Power
4	Suction	Compression	Power	Exhaust
Crankshaft rotation	0^0 - 180^0	180^0 - 360^0	360^0 - 540^0	540^0 - 720^0

1.3.5 Six Cylinder Engines

As compared to a four cylinder engine, a better dynamic balance and a more uniform torgue or turning moment can be obtained by six-cylinder engines. Most of the high powered as well as the modern cars of moderate powers are employing the six-cylinder engines. Though expensive and complicated, these engines have much smoother, more flexible and quite running. It requires only a light flywheel due to the lower ratio of maximum to mean torgue.

In six-cylinder engines, there are six power impulses during two rotations of the crankshaft or three firing strokes per one revolution of crankshaft or one power stroke every 120^0 of crankshaft rotation. For good distribution of fuel to all cylinders, the possible firing orders are 1, 5,3,6,2 and 4; and 1, 4,2,6,3 and 5.

Other types of engines are eight-cylinder engines, twelve-cylinder engines, sixteen-cylinder engines e.t.c.

1.3.6 Comparison between Four Stroke and Two Stroke Engines

(A) Characteristics of four stroke engines

1. They have one power stroke during two revolutions or four strokes of the engine while two stroke engine has one power stroke during every revolution.
2. Their design and construction are complicated compared with 2-stroke engines
3. The torgue produced at the crankshaft is not uniform
4. Its mechanical efficiency is less compared with 2-strokes engine due to large number of moving parts
5. Due to positive scavenging (removing exhaust gases) and presence of a separate exhaust stroke major portion of the exhaust gases is removed from the engine cylinder. This results in higher thermal efficiency.

6. The engine usually runs cooler because more time is available for removing the heat from the cylinder due to the presence of one working stroke in four strokes. This results in better compression.
7. These engines are generally water-cooled.
8. The fuel and lubricating oil consumption is low.
9. They are heavier and requiring more space than 2-stroke engines due to presence of large number of parts.

(B) Characteristics of two stroke engines

1. Therefore, for a given speed and for a given output, a two stroke engine require one-half piston displacement, i.e. the piston is half as heavy , half as bulky and half as expensive as a four-stroke engine piston.
2. They are simpler in design and less complicated in valve design and operation than four-stroke engines
3. Since every revolution produces one power stroke, therefore torgue produced at the crankshaft is uniform, necessitating a lighter flywheel
4. Due to the absence of moving parts like cam and followers, rocker arm and other valve actuating mechanism, it has higher mechanical efficiency in comparison.
5. They have a poor scavenging due to absence of separate exhaust stroke. This results in less oxygen and less burning of fuel in the cylinder and less output due to diluting of the fresh incoming gases by the leftover exhaust. Hence, the thermal efficiency is quite low.
6. These engines are usually air-cooled.
7. The fuel and lubricating oil consumption is comparatively high due to loss of fresh gases through the exhaust ports.
8. They are lighter in weight and require lesser space due to absence of valves and valve gears.

1.4. TYPES OF IGNITION ENGINES

1.4.1. Spark Ignition Engines

Spark ignition engine is a type of internal combustion engine in which the compressed air/fuel mixture is ignited by a spark. The spark ignition (S.I) engine is also referred to as the petrol, gasoline or gas engine from its typical fuels, and the Otto engine, after the inventor.

1.4.2. Compression Ignition Engines

These are the engines in which the charge is neither pre-mixed at a carburettor nor is it ignited by a spark but the air entering through the inlet valve or ports in the cylinder wall is highly compressed raising its temperature beyond the self-ignition temperature of fuel. By injecting the fuel in a fine spray, it gets ignited by the turbulent hot air to get burnt with the oxygen present in the air. The compression ignition engine is also referred to as diesel or oil engine, the fuel is named after the inventor.

A spark invention engine is volume-controlled while the compression ignition engine is quality controlled with the mixture strength varying from 10:1 to 16:1 and 20:1 to 120:1 respectively. Due to this higher compression ratio, the thermal efficiency is higher in case of compression ignition engine as compared to spark ignition engines. The higher compression ratio requires the temperature of the air to be raised to high valve resulting in large thermal forces exerted on the cylinder head, cylinder piston, gudgeon pin, connecting rod, crankshaft and bearings. This necessitates a more robust construction in compression to a spark ignition engine. These engines are generally used in certain commercial vehicles like trucks, buses, Tata Mercedes Benz trucks e.t.c.

Advantages of Compression Ignition Engines over Spark Ignition Engines

1. These engines are more economical having thermal efficiency about 50% more than that of spark ignition engines. They also have high compression ratio, expansion ratio and thermal efficiency.
2. They are less wear and tear in compression ignition engine than the petrol engine.
3. Their maintenance cost is less
4. The volumetric efficiency of the efficiency is greater because the speed is lower at full load. This results in a more uniform torque over a wide range of engine speeds providing a better top gear performance.
5. The injection equipment in compression ignition engines is more reliable and stable than the carburettor and electrical ignition system in spark ignition engines
6. The danger of fire is considerably reduced in C.I engines due to the higher flash point of diesel as compared to that of petrol in S.I engines.

Disadvantages of Compression Ignition Engines

1. They have tendency to slow running as well as vibration and noise
2. Due to high compression ratio required for combustion, power to weight ratio is very low
3. The rotational speed is lower than the spark ignition engine resulting in less efficient fuel combustion
4. Their mean effective pressure is low
5. They have higher compression ratio which makes starting difficult
6. The cost of precision of fuel injection equipment is high compared to the carburetor of petrol engines.

1.4.3 Petrol Injection Spark Ignition Engines

These petro engines do not use carburettor. During the suction stroke, air is drawn into the cylinder with fuel injected directly into the cylinder during the compression stroke. At the end of the compression stroke, it is ignited by means of a sparking plug. This engine having very low compression ratio, 8: 1 to 9.5 : 1 does not operate on the principle of compression ignition.

Advantages

1. They have high volumetric efficiency due to better fuel distribution to individual cylinders.
2. Their fuel consumption is low due to their well-designed fuel injection system

Disadvantages

A complicated and costlier fuel injection pump along with fuel injection nozzle and fuel pipe line for cylinder are required instead of a relatively simple carburettor of well-developed design.

1.4.4 Gas turbines or gas power plant

Turbines are used to propel automobiles, trucks, boats, airplanes as well as other stationary power plants. A gas turbine in simple terms is a heat engine utilizing the expansion from the combustion of fuel and air in a combustion chamber. The energy is directly transformed either into thrust or shaft power to push an airplane or vehicle or automobile wheel for turning. It consist of two sections: a gasifier section and a power section. The gasifier section further consists of two units, i.e. the rotary axial or centrifugal type of the compressor and a combustion chamber.

Advantages

In comparison to reciprocating type petrol engine, gas turbine has the following advantages:

1. Smoother running due to absence of reciprocating parts
2. No vibration
3. Very high mechanical efficiency
4. Very much compact shape
5. Due to the absence of reciprocating part and continuous exhaust the operation is very silent.
6. Internal pressure is very low
7. Due to simplicity of design, maintenance costs are reduced.
8. Oil consumption is very much lower
9. Weight is very much lower
10. No clutch or gear-box is needed except for emergency low gear for reversing.
11. Cheaper fuel like paraffins can run it efficiently.

Disadvantages

1. If paraffin fuels were used in the gas turbine, larger quantity of exhaust gases would be emitted.
2. The fuel consumption of gas turbine power plant for automobile is relatively high
3. It has low volumetric efficiency.

2.0 BODY AND CHASIS

The shape of the chassis is determined by location of the power unit, the arrangement of the suspension system and the loads to be carried. The function of the chassis is to act as the frame or skeleton of the vehicle, providing a mounting for all the other assembles and keeping them in correct relative positions, inspite of all the varying loads to which they are subjected. It must be strong and rigid, and is usually made from steel pressings which are welded and riveted together. Reinforcement is provided, where necessary, to add to its rigidity

2.1 LAYOUT OF A CHASSIS AND ITS MAIN COMPONENTS

Various components of the motor vehicle, i.e. engine car body, wheels e.t.c. are required to be supported. These are supported on a rigid structure providing a skeleton to hold the components together. To withstand the shocks, blows, twists and vibrations coming during operation, chassis are provided cross-bracings to increase rigidity. The whole of the chassis is now fastened to a frame of channel or U-shaped section. The engine is mounted in the front portion of frame through rubber cushioned motor mounts or pads or washer placed between the brackets on the frame and support lugs on the engine.

Layout of Power Assembly and Transmission

To form a compact power assembly and transmission, the engine is connected to the clutch and transmission which are further connected to final drive gears through the propeller shaft and universal joints.

2.2 TYPES OF CHASSIS LAYOUT

Some of the important layout of a motor vehicle based on the drive are:

(i) Front engine rear wheel drive

(ii) Rear engine rear wheel drive

(iii) Front engine front wheel drive

(iv) Four wheel drive

(v) Heavy vehicle layout

(vi) Articulated vehicle layout

2.2.1 Front Engine Rear Wheel Drive

In this layout a front mounted engine-clutch-gear box unit drives a beam type rear axle suspended on leaf springs through a propeller shaft with two universal joints. With the help of coil springs, the front wheels are independently sprung. This layout is one of the oldest layouts which remained unchanged for many years. Some of the advantages provided by this system are:

Advantages

(a) Reasonably balanced weight distribution between the front and the rear wheels providing good handling characteristics

(b) For easy front wheel steering movement engine occupies the reduced width between the arches.

(c) Behind the rear seats, large luggage space is available providing increased carrying capacity as well as space for easy body movement

(d) Accessibility to various components like engine, gear box and rear axle is better in comparison to other layouts

(e) The control linkages such as accelerator, choke, clutch and gear box are short and simple

(f) Full benefits of the natural air stream created by vehicles movement is taken by the forward facing radiator in reduced power losses from a large fan.

2.2.2 Rear Engine Rear Wheel Drive

This arrangement eliminates the necessity for a propeller shaft when the engine is mounted adjacent to the driven wheels. The engine-clutch-gearbox-final drive form a single unit in this layout. In order to reduce the ‘overhang’ distance between the wheel centres and the front of the engine, the final drive is generally placed between the clutch and the gear box.

Advantages

(a) It has a simpler drives shaft layout in comparison to front wheel drive.

(b) The weight of rear engine on the riving wheels provides excellent traction and grip especially on steep hills as well as when accelerating.

(c) Effective rear wheel braking is possible with this layout.

(d) Due to the absence of the propeller shaft the obstructed floor space is reduced.

(e) The front of the vehicle can be designed for good visibility and smooth air flow.

(f) The exhaust gases, fumes, engine heat and noises are carried away from the passengers.

(g) This drive arrangement results in compact layout and short car.

Disadvantages

(a) It has a restricted luggage compartment due to narrow front, which houses the fuel tank also.

(b) Natural air cooling is not possible, it requires a powerful fan.

(c) Long linkages are required for the engine, clutch and gear box controls.

(d) The rearward concentration of weight causes the vehicle to be more affected by side winds at high speeds. This makes the vehicle unstable resulting in oversteering and turning very sharply into a curve.

2.2.3 Front Engine Front Wheel Drive

No propeller shaft is used in front engine front wheel drive and differentials are included in the same assembly. This layout provides optimum body-luggage space and a flat front line resulting in a transverse longitudinal engine position. Good road adhesion is provided by the large proportion of the vehicles' weight acting on the driven wheels.

Advantages

(a) As compared to rear wheel driven car, this is faster and safer travelling due to good road holding.

(b) Good road adhesion is obtained due to a large part if the vehicles' weight being carried on the driving wheels under normal conditions

(c) Under steady conditions generally preferred by many drivers are promoted by this type of drive.

(d) Lower flat floor line is provided due to dispensing with the propeller shaft resulting in lowering of centre of gravity.

(e) The engine clutch, gear box and final drive are combined similar to the rear engine car. This provides a more comfortable drive due to final drive spring.

Disadvantages

(a) Due to the combination of steered and driven wheels with short shafts, special universal joints and a more complicated assembly are required.

(b) To prevent the rear wheels from skidding under heavy break, the required weight at the rear usually necessitates special arrangement.

(c) The tractive effort which most needed on steep gradients and during acceleration is reduced.

2.2.4. Four-Wheels Drive

To increase manoeuvrability of the vehicle required to travel on rough unconstructed roads and trucks another arrangement known as Four-wheel drive is provided. Due to all the four wheels getting driven, whole weight of the vehicle is available for traction. But this advantage ia not worth the additional cost on good road surfaces. The system is provided in jeeps which are known as 4 x 4 wheel drive vehicles.

3.0 VEHICLE COMPONENTS

An automobile is a combination of a large number of parts. It can be divided into chassis and body as the two major constituents. Body is the part where the passengers have their seat on the luggage and cargo to be carried is placed. Chassis is the main machine portion, which contain most of the components required for the operation and running of the automobile. The portion of the automobile without body is called chassis. The body fixed over the frame of the vehicle is generally detachable. All parts and accessories needed for the comfort of the human being are contained in the body of the vehicle. These include doors, windows, lights, fans, seats, air-conditioner and other accessories. The body differing in shape and size from vehicle to vehicle is generally made of steel and wood or steel alone.

The components of the cars and their proper locations are discussed below:

3.1 WHEELS

The wheels which are four in number are fitted below the car chassis to support the load of the vehicle and passengers as well as run the car. They are fitted with hollow rubber tyres filled with air in rubber tubes under sufficient pressure necessary for carrying the load. The shocks caused by road irregularities are absorbed by them. By fitting springs between the wheels and the vehicle allowing the vertical movement of the wheels in relation to vehicle, greater part of unevenness of road surfaces is taken care of.

3.2 FRONT AXLE

It is used for steering front wheels carried on stub axles swiveling upon king pins the axle extremities. Steering arms and track rod link the two stub axles together for swiveling them by a steering wheel about the king pins. The steering wheel linked to one of the stub axle by a shaft, a gear box and suitable linkage is operated by the driver's hand wheel. An axle in which one-piece beam was used to support the vehicle through springs (axle and spring arrangement) was previously used. Now, an arrangement known as independent front suspension has replaced the axle and spring arrangement. Under the control of springs, the wheels are free to rise and fall vertical independently of each other.

3.3 REAR AXLE

Rear axle or driving axle is a tube like shaft enclosing driving shafts with suitable bearings for rotating the wheels. It is used for fixing the rear wheels. It is enlarged at the centre for enclosing the final drive gears used for providing main speed reduction between the engine and the driving wheels. The change of direction from the line of propeller shaft to the transverse line of the axle shafts is also provided by the rear axle.

When going round a curve, the inner wheel has to travel a smaller distance in comparison to the outer wheel. But both the rear wheel would rotate at the same speed if they are connected by a shaft. This rotation of both the wheels would result in slipping of one or both of them on the road surface causing excessive tyre wear as well as severe twisting loads on the shaft. Moreover, the two wheels of the exactly similar diameter can only turn at the same speed without slip on the straight road. Each wheel is provided with its own separate half-shaft connected by a differential gear and meeting at about the centre of the axle. Therefore, when going round a curve, the wheels are free to rotate at different speeds although they are provided with equal drive by the differential gear.

For preventing the transmission of shock from uneven road surfaces to the vehicle, springs are used to support the vehicle on the axle. In order to allow for the vertical movements of the wheels relative to the frame as well as to allow the parts of the shaft to operate at different angle, another arrangement is used in which the final drive gears and the differential gear is mounted in a casting attached to the frame with independently sprung wheels attached to them by means of shafts through devices called universal joints.

3.4 POWER UNIT

Power unit consist of an internal combustion engine. It is usually mounted at the front end of the car. The clutch and the gear-box are placed immediately behind it. The three components (engine, clutch and gear-box) are assembled into a single unit.

3.5 THE SUSPENSION SYSTEM

The various parts are attached to the basic structure by means of springing suspension system. This system is used to prevent the road shocks to the various vehicle components and the occupants and to preserve stability under various road conditions. There are two distinct types of suspension system:

(a) *The conventional system; where the road springs are attached to a rigid beam axle.* It is mostly used in the front axle of commercial vehicles and for rear axle of all types of vehicles.

(b) *The independent system;* in this system there is no rigid axle. Each wheel is free to move vertically without any reaction on its mating wheel. This is mostly used is small rear axle suspensions.

3.6 TRANSMISSION SYSTEM

This system or mechanism carries the power from engine to the wheels of the vehicle. It is bolted through the clutch to the engine at the front and the rear to the springs which are connected to the chassis to prevent the engine vibrations from transmitted to vehicle. It generally consists of a friction clutch, a gear-box providing three, or four different ratios of torque (output to input) a propeller shaft for transmitting the torque output from gear-box to the rear axle, a final gear reduction in the rear axle and a differential gear for distributing the final torque between the wheels equally. In certain cases clutch is replaced by fluid fly wheels. The function of clutch and gear-box is completely served by the hydraulic torque converter. The various components of the power train or the transmission system are: clutch, gear-box, propeller shaft, universal joint and the differential gear.

3.6.1 Gear Box

It consists of various types of gears which are constantly in mesh. The Gear changes are made by sliding the dogs. The main function of the gear-box is to provide the necessary variation to the torque applied by the engine to the road wheel according to operating conditions. The necessary variations are provideddue to the presence of different gear ratios among various meshing gears.

3.6.2 Propeller Shaft

It is universally jointed shaft. Its function is to transmit the power from the rear end of the gear-box to the final reduction gear in the axle. The vertical movements of the rear axle relative to the frame are also accommodated. In construction, it is an ordinary Hooke‘s joint, the small and limited angular displacement in the rubber joints is advantageous in damping out torsional vibrations.

3.6.3 Universal Joint

Due to the flexing of the road springs, the rear axle is constantly moving up and down. The propeller shaft fitted to the rear axle must also be free to move up and down. To permit the turning of the propeller shaft when this movement is taking place, universal joints are fitted at each of its ends. Therefore, the relative movement between the engine and the driving wheel is maintained by the universal joint.

3.6.4 The Differential Gear

The differential gear carries the power from the propeller shaft to the rear wheel axles. It helps the two rear wheels to turn at different speeds when rounding a curve. The outer wheel must over-run the inner wheels when taking a turn. The differential gear also ensures that the final output torque is equally distributed between the two wheels without any consideration of their relative speeds.

3.6.5 Clutch

It is a friction type uncoupling device. It consists of a single steel disc faced with suitable friction material. It is clamped between two surfaces directly driven by the engine. For disengaging the clutch, the two surfaces are positively separated by pressing the clutch pedal. The main function of the clutch is to take up the drive smoothly from the engine and to release or disengage that drive whenever desired. The disengagement of clutch is required while changing the gear or bringing the vehicle to rest.

3.7 FRAME

Frame is the foundation for carrying the engine and body of the vehicle as well as steering, power train etc. by means of springs, axles, rubber pads etc. The frames are made of box, tubular channel or U-shaped section, welded or riveted together. In order to make them rigid to withstand the shocks, blows twists and the vibrations met during the operation, cross-bracing or cross members are used. When the engine, wheels, power trains, brackets and steering systems are fitted on the frame, the assembly is known as the chassis. Frame curves upwards in shape at the rear to provide space for the rear springs and to provide space for the turning of the front wheels when steered, it is tapered at the front. There are two types of frame constructions in use.

(a) Conventional pressed steel frame

Here all the mechanical components are attached to it and the body is superimposed on it. This is a standard practice for all commercial vehicles and in some private and open cars.

(b) The frameless construction

Here the body is designed I such a way as to combine the function of the body and the frame. The components are generally attached to the frame than to the body directly. This is preferably used in case of a closed car where the roof screen pillars, door pillars and rear panel are the main parts.

4.0 SUSPENSION AND CLUTCH

4.1 SUSPENSION SYSTEMS

Suspension systems are used in vehicles to insulate the wheel and axles from the frame in order to avoid transmission of road effects to the passengers while travelling on uneven road, to provide comfortable ride to the passengers and avoid additional stresses in the motor car frame.

4.1.1 The Objectives of Suspension System

1) To safeguard the occupants against shocks and provide riding comfort.
2) To minimize the rolling, pitching or vertical movement tendency of motor vehicle while travelling over rough road or when turning.
3) To minimize the effects of stresses due to road shocks on the mechanism of the motor vehicle and provide a cushioning effect.
4) To isolate the structure of the vehicle from shock loading and vibration due to irregularities of the road surface without impairing its stability.
5) To provide the requisite height to body structure as well as to bear the torque and braking reactions.

4.1.2 Principles of Suspension System

There are three principles of the suspension system underlying the satisfactory springing of motor vehicles. These are:

(a) Reduction of the weight of the wheels and other components receiving the road shocks to minimum or reduction of un-sprung weight.

(b) Reduction of rolling or pitching of the body to a minimum with suitable design and attachment of springs.

(c) To absorb satisfactorily the large as well as the smaller road impacts with the help of a single springing device.

4.1.3 Independent Suspension

It is the suspension system arrangement for connecting the road wheels to the frame in which the rise or fall of one wheel has no direct effect on the other wheels. In this system, car is not tilted as each wheel can rise and fall freely. The independent suspension systems are greatly advantageous for front, rear or both the suspensions due to the fact that more components can be mounted on the rigid vehicle frame resulting them to become spring weight.

(a) Independent front suspension

This system is now used on most of the passenger cars has each of the front wheel supported independently by a coil or leaf spring. It helps to provide softer springing action, improved steering, better contact of road wheels with bumpy road surface and a better ride for the occupants.

Advantages of independent front suspension

(1) It results in low inertia for resistance to change of state of chassis body and wheel tenderness to move instead of chassis body

(2) Due to low spring rates enabling large wheel movement, softer suspension is possible

(3) Considerable reduction or elimination of tilting tendency of vehicle and rotating road wheels of turning about king pin.

(4) It promotes under steer conditions

(5) It overcomes the effects on steering geometry caused by twisting of beam axle between the stub axle and the spring seats due to spring deflection while braking or accelerating

(6) It provides larger space for engine accommodation

(b) Independent rear suspension

In this case rear axle housing is mounted on the frame. But the reduction of the un-sprung weight is the most important item. The final drive unit and the brakes are the main weight items. Therefore, as much as 50 % reduction in un-sprung weight can be achieved if the brakes fitted to the frame mounted final drive are inboard type. They have the same advantages with the independent front suspension system.

4.1.4 Springs

Springs are fitted between the frame and the wheel to prevent the upward movement of the frame along with the up and down movement of the wheel. A spring is a reservoir of energy which is stored in steel springs by bending them or by twining them. When the spring resumes its normal state this energy is released

Different types of springs used in the suspension system are:

i.) Steel-laminated, helical coil type, leaf type and torsion bar

ii.) Rubber suspension spring

iii.) Air or pneumatic suspension bags.

4.1.5 Laminated or Leaf Springs

These are preferably for the rear suspension of passenger cars, front and rear spring of commercial vehicles and in certain types of independent front suspension system in transverse situation. To provide even stress distribution and a varying frequency of spring vibration the leaves of a laminated spring are made of different lengths. To prevent the main leaf from overloading during rebound leaves known as rebound leaves are fitted above them. To locate and hold the spring to the axle, a centre bolt and two U-bolts are used.

5.0 TRANSMISSION AND GEARING SYSTEMS

Transmission is the mechanism through which the driving torque of the engine is transmitted to the driving wheel of the vehicle. The transmission is a sort of speed and power changing device needed between the engine of the automobile and its driving wheels.

5.1 THE PURPOSES OF TRANSMISSION

(1) It enables the engine to be disconnected from the driving wheels.

(2) It enables the running engine to be connected to driving wheel smoothly and without shock

(3) It enables the leverage between the engine and driving wheels to be varied.

(4) It enables the reduction of the engine speed in the ratio of 4:1 in case of passenger cars and in a greater ratio in case of lorries.

(5) It enables the turning of the drive round through 90^o

(6) It enables the driving wheels to be driven at different speeds

(7) Its enables the relative movement between the engine and the driving wheels due to flexing of the road springs.

5.2 TYPES OF TRANSMISSION SYSTEMS

The various types of transmission system are classified into three main types:

(1) Mechanical transmission

(2) Hydraulic transmission:

    (a) Hydrostatic transmission

    (b) Hydrodynamic transmission

(3) Electrical and electromagnetic

Out of the above three types, mechanical transmission is the most common. The transmissions can also be classified as follows:

(a) Manually operated selective or synchromesh transmission

(b) Overdrive of semi-automatic or combined selective transmission

(c) Chrysler semi-automatic transmission

(d) Automatic transmission:

    (i) Hydromantic transmission

    (ii) Torque-converter transmission

6.0 INTERNAL COMBUSTION ENGINES

In the internal combustion engine, combustion takes place within the engine unlike in steam engine which works by virtue of the introduction of steam which has been raised externally in a boiler. All internal combustion (I.C.) engines aspirate air into which is introduced a measured quantity of fuel. This fuel burns within the engine and in such a way that it produces a high pressure, high temperature gas.

There are two principal classes of reciprocating internal-combustion engine. They are distinguished mainly by whether the combustion is initiated by spark, or spontaneously by virtue of the rise in temperature during compression process. Petrol and gas engines are referred to as spark-ignition (or SI) engines while diesel and oil engine are referred to as compression-ignition (or C.I.) engines.

In the theoretical cycles described under power cycles, there is no chemical change in the working fluid, the working fluid is assumed to be air, and the heat exchanges in the cycle are made externally to working fluid. In the practical cycle, the heat supply is obtained from the combustion of a fuel in air and thus the air charge is consumed during combustion and the combustion products must be exhausted from the cylinder before a fresh charge of air can be induced for the next cycle.

6.1 CLASSIFICATION OF I.C. ENGINES

There are many types and arrangements of engines and classification is necessary to describe a particular engine adequately. The methods of classification are as follows:

(a) Classification by the fuel used and the way in which the combustion is initiated: petrol engines and gas engines have spark ignition (S.I.). Diesel engines or oil engines have compression ignition (C.I). In the S.I. engine the air and the fuel are mixed before compression. In the C.I. engine the air only is compressed, and the fuel is injected into the air which is then at a sufficiently high temperature to initiate combustion.

(b) Classification by the way in which the cycle of processes is arranged: This is defined by the number of complete strokes of the piston required for one complete cycle. The stroke of the piston is the distance it moves from the position most extreme form the crankshaft to that nearest it. This takes place over half a revolution of the crankshaft.

In petrol engine practice the extreme positions of the piston are referred to as top dead centre (TDC), and bottom dead centre (BDC). In oil-engine practice they are referred to as outer dead centre and inner dead centre respectively. An engine which requires four strokes of the piston (i.e. two revolutions of the crankshaft) to complete its cycle is called a four-stroke engine. An engine which requires only two strokes of the piston (i.e. one crankshaft revolution) is called a two-stroke cycle engine.

In all reciprocating internal combustion (I.C.) engines the gases are induced into and exhausted from the cylinder through ports, the opening and closing of which are related to the piston position. In a two-stroke engine the ports can be opened or closed by the piston itself, but in the four-stroke engine a separate shaft, called the camshaft, is required; this is driven from crankshaft through a 2 to 1 speed reduction. The cams on this shaft operate valves, called poppet valves, either directly or by means of push rods. Modern high speed petrol engines have two camshafts, one operating the exhaust valves and the other operating the inlet valves. The timing of the valves and the point of ignition are fundamental to the engine performance, and the specified timing is a result of compromise between the many factors involved and is determined empirically. The beginning and end of each process does not coincide with the TDC and BDC positions, although nominally each process may associated with a piston stroke. The timing of the valves can be indicated on a p-v diagram.

6.2 THE WORKING OF I.C. ENGINES

Both S.I. and C.I. engines can be designed so that one complete cycle of events in the cylinder is completed during either four or two strokes of the piston. The main events occurring in a four-stroke petrol S.I. engine are illustrated in fig. 6.1, and these events are described below:

Induction stroke, 1-2: A mixture of air and petrol vapour is drawn into the cylinder, the pressure of the mixture being a little below atmospheric due to friction in the induction pipe. The inlet valve closes at the end of the stroke.

Compression stroke, 2-3: With both inlet and exhaust valves closed, the air-fuel mixture is compressed. Just before the piston reaches top dead centre, ignition is effected by an electric spark. Combustion is not instantaneous, but occupies a finite period of time. Nevertheless much of it occurs at nearly constant volume because the piston is moving relatively slowly near dead centre.

Expansion or working stroke, 3-4: Combustion is normally completed at the beginning of the expansion stroke, and the products expand until the exhaust valve opens at some point E (fig. 6.1) which is before BDC, i.e. before end of the stroke. As the valve opens, the gases blow down the exhaust duct until the pressure in the cylinder has fallen to approximately atmospheric pressure.

Exhaust stroke, 4-1: The products which have not escaped from the cylinder the blow-down are displaced by the piston. To provide the pressure difference necessary to overcome friction in the exhaust duct, the pressure in the cylinder is slightly above atmospheric. At the end of the stroke there will be some residual gases in the clearance volume, which will dilute the next charge drawn into the cylinder.

The events in a four-stroke compression ignition (C.I.) engine is illustrated in fig. 6.2. These differ from those in the S.I. engine in the following ways.

Induction stroke, 1-2: Air alone is admitted to the cylinder.

Compression stroke, 2-3: The air is compressed, and towards the end of the stroke liquid fuel is sprayed into the cylinder. The temperature of the air at the end of compression is sufficiently high for the droplets of fuel to vaporize and ignite as they enter the cylinder.

Expansion or working stroke, 3-4: Since the fuel is sprayed into the cylinder at a controlled rate, the pressure may remain fairly constant during combustion. At some point in the expansion stroke the combustion is normally complete and the pressure then falls steadily until the exhaust valve is open and blow-down occurs. This is followed by the exhaust stroke as in the S.I. engine.

6.3. TIMING DIAGRAMS

A typical timing diagram for a four-stroke petrol engine is shown in Fig. 6.3, and the angular positions in terms of crank angle position are quoted in relation to the TDC and BDC positions of the piston. The points on the diagram are as follows:

IO – Inlet valve opens. The actual position is between 10º before TDC and 15º after TDC

IC – Inlet valve closes. This occurs 20-40º after BDC to take advantage of the momentum of the rapidly moving gas.

S – Spark occurs. This is 20-40º before TDC when the ignition is fully advanced, and is at TDC when the ignition is fully retarded.

EO – Exhaust valve opens. The average value of this position is about 50º before BDC.

EC – Exhaust valve closes. This occurs 0º to 10º after TDC.

There may be an overlap between IO and EC such that both valves are open at the same instant.

6.4 TWO-STROKE CYCLE

As the name implies, all the events in the two-stroke cycle are completed in two strokes. In two strokes, the crankshaft makes one revolution and hence two-stroke cycle is complete in one revolution.

Fig. 6.4 represents the cylinder of a two-stroke petrol engine with crankcase compression. As the piston ascends on the compression stroke the next charge is drawn into the crankcase, c, through the spring-loaded automatic valve, S. Ignition occurs before TDC, and at TDC the working stroke begins. As the piston descends through 80% of the working stroke, the exhaust port, E, is uncovered by the piston and exhaust begins. The transfer port, T is uncovered later in the stroke due to the shape of the piston or the position of the port in relation to the port E, and the charge in the crankcase, C, which has been compressed by descending piston, enters the cylinder through the port T.

The piston can be shaped to deflect the fresh gas across the cylinder to assist the scavenging of the cylinder; this is called cross-flow scavenge. The displacing of the combustion products out of the cylinder is called scavenging. As the piston rises, the transfer port, T, is closed slightly before the exhaust port, E, and after E is closed compression of the charge in the cylinder begins. The p-v diagram and the timing diagram for a two-stroke petrol engine are shown in Figs. 6.5 and 6.6.

6.5 CRITERIA OF PERFORMANCE

In order that different types of engines or different engines of the same type may be compared, certain performance criteria must be defined. These are obtained by measurement of the quantities concerned during bench tests, and calculation is by standard procedures. The results are plotted graphically in the form of performance curves.

6.5.1 Indicated Power (IP)

This is defined as the rate of work done by the gas on the piston as evaluated from an indicator diagram obtained from the engine. An indicator diagram has the form shown in fig. 6.7. Figure 6.7 shows both the power and the pumping loops.

The mean effective pressure has been defined under the power cycle and may be applied here.

Net work done per cycle $\oint W \propto (area\ of\ power\ loop - area\ of\ pumping\ loop)$

Therefore indicated mean effective pressure, P_i, is given by

$$P_i = \frac{net\ area\ of\ diagram}{length\ of\ diagram} \times constant$$

The constant depends on the scales of the recorder

Considering the engine cylinder

$$workdone\ per\ cycle = P_i \times A \times L$$

Where A is the area of piston and L the length of stroke.

Power output per unit time (ip) = work done per cycle x cycles per minute

or $ip = P_i AL$ x (cycles/unit time)

The number of cycles per unit time depends on the type of engine for four-stroke engines the number of cycles per unit time is N/2, and for two-stroke engines the number of cycles per unit time is n, where L is the engine speed. The formula for power output per unit time (ip) then becomes for four-stroke engines.

$$ip = \frac{P_i ALNn}{2}$$

For two-stroke engine $ip = P_i ALNn$

Where n is the number of cylinders

6.5.2 Brake Power (bp)

The net output of an engine is called the brake power. The engine is connected to a brake or dynamometer which can be loaded in such a way that the torque exerted by the engine can be measured. The torque is obtained by reading off a net load, W, at a known radius, r, from the axis of rotation, and hence the torque, T, is given by

$$T = WR$$

The brake power is then given by

$$bp = 2\pi NT$$

6.5.3 Friction Power (fp) and Mechanical Efficiency, η_m

The difference between the ip and the bp is the friction power (fp), and is that power required to overcome the friction resistance of the engine parts.

i.e. $fp = ip - bp$

The mechanical efficiency of the engine is defined as

$$\text{Mechanical efficiency}, \eta m = \frac{bp}{ip}$$

where η_m usually lies between 80 and 90%

6.5.4 Brake Mean Effective Pressure (bmep), Thermal Efficiency and Fuel Consumption

The bp of an engine can be obtained accurately and conveniently using a dynamometer. From the mechanical efficiency above:

$$bp = \eta m \times ip$$

Therefore, substituting ip from eqn. 6.2 for a four-stroke engine, we have:

$$bp = \frac{\eta m \times p_i ALNn}{2}$$

Since ηm are p_i are difficult to obtain they may be combined and replaced by a brake mean effective pressure, pb.

i.e. $$bp = \frac{p_b ALNn}{2}$$

where $p_b = \eta m \times p_i$

The bmep may be thought of as that mean effective pressure acting on the pistons which would give the measured 'bp' if the engine were frictionless. The bmep is a useful criterion for comparing engine performance. Taking the two equations for bp, eqns (6.50) and (6.6) and putting them together we have

$$\frac{p_b ALNn}{2} = 2\pi NT$$

Therefore, $P_b = K \times T$

Where k is a constant.

Therefore bmep is directly proportional to the engine torque and is independent of the engine speed.

The power output of the engine is obtained from the chemical energy of the fuel supplied. The overall efficiency of the engine is given by the brake thermal efficiency, η_{BT},

i.e. $$\eta_{BT} = \frac{brake\ work}{energy\ supplied}$$

therefore, $$\eta_{BT} = \frac{bp}{\dot{m}f \times Q_{net,v}}$$

Where $\dot{m}f$ is the mass of fuel consumed per unit time, and $Q_{net,v}$ is net calorific value of the fuel.

The specific fuel consumption (sfc) is the mass flow rate of fuel consumed per unit power output, and is a criterion of economical power production.

i.e. $sfc = \frac{mf}{bp}$

The indicate thermal efficiency, η_{IT}, is defined in a similar way to η_{BT}.

i.e. $\eta_{IT} = \frac{ip}{mf \times Q_{net,v}}$

Dividing equation (6.9) by equation (6.11) gives

$$\frac{\eta_{BT}}{\eta_{IT}} = \frac{bp}{ip} = \eta_M$$

Therefore, $\eta_{BT} = \eta_M \times \eta_{IT}$

QUESTION

A four cylinder petrol engine has a bore of 570 mm and a stroke of 90 mm. its rated speed is 2800 rev/min and it is tested at this speed against a brake which has a torque arm of 0.356 m. The net brake load is 155 N and the fuel consumption is 6.74 kg/s. The specific gravity of the petrol used is 0.735 and it has a lower caloric value, $Q_{net,v}$ of 44200 kJ/kg. Calculate for this speed, the engine torque, the bmep, the brake thermal efficiency and the specific fuel consumption.

Solution; Using eqn. (6.4)

Torque, T = WR = 155 x 0.356 = 55.2 Nm

Using eqn. (6.5)

$$bp = 2\pi NT = \frac{2\pi \times 2800 \times 55.2}{60 \times 10^3}$$

From eqn. (6.8)

$$bmep = \frac{bp \times 2}{ALNn} = \frac{16.2 \times 2 \times 4 \times 60 \times 10^3}{\pi \times 0.057^2 \times 0.09 \times 2800 \times 4 \times 10^3}$$

Using eqn. (6.9)

$$\eta_{BT} = \frac{bp}{\dot{m}f \times Q_{netw}} = \frac{16.2}{0.001376 \times 44200} = 0.266 \text{ or } 26.65$$

Where $\dot{m}f = \frac{6.74}{3600} \times 1 \times 0.735 = 0.001376 kg/s$

Using eqn. (6.10)

$$sfc = \frac{\dot{m}f}{bp} = \frac{0.001376}{16.2} = 0.000085 \text{kg/kJ}$$

It is more convenient to express sfc in terms of fuel consumption in per unit power and to express the fuel consumption rate in kilograms per hour rather than kg/s.

i.e. $\dot{m}f = 6.74 \times 1 \times 0.735 = 4.954 kg/h$

$$sfc = \frac{\dot{m}f}{bp} = \frac{4.954}{16.2} = 0.306 \text{kg/kWh}$$

6.5.5 Volumetric Efficiency, η_v

The power output of an IC engine depends directly upon the amount of charge which can be induced into the cylinder. This is referred to as the breathing capacity of the engine and is expressed quantitatively by the volumetric efficiency, which is defined as the ratio of the volume of air induced, measured at the free air conditions to the swept volume of the cylinder.

i.e. $\eta_V = \frac{V}{V_S}$

Where V = the air induced, measured at the free air conditions.

V_S = swept volume of the cylinder.

7.0 SPARK AND COMPRESSION IGNITION ENGINES

7.1 SPARK IGNITION ENGINES

Spark ignition engine is a type of internal combustion (or I.C.) engine in which the compressed air/fuel mixture is ignited by a spark. The spark ignition (SI) engine is also referred to as the petrol gasoline or gas engine from its typical fuels, and the Otto engine, after the inventor.

7.1.1 COMBUSTION IN SPARK IGNITION ENGINES

Combustion occurs either normally with ignition from a spark and the flame front propagating steadily throughout the mixture or abnormally, -ignition this can take several forms but principally through Pre-ignition and Self-ignition. Pre-ignition is when the fuel is ignition by hot sport, such as the exhaust valve or incandescent combustion deposits. Self-ignition is when the pressure and temperature of the fuel/air mixture are such that the remaining un-burnt gas ignites spontaneously. Pre-ignition can lead to self-ignition and vice versa.

7.1.2 Normal Combustion

When the piston approaches the end of the compression stroke, a spark is discharged between the sparking plug electrodes. Under normal conditions combustion begins near the spark plug after a short delay following the formation of the spark, and flame spreads through the mixture with a rapid but finite velocity.

The Delay Period during Normal Combustion in the Spark Ignition Engines

The energy released by the spark is only small, and sets off a relatively slow flameless reaction which causes delay in flame propagation. Further energy is released atom accelerating rate by the reaction, until proper flame front delay period is very hot (approximately 0.002 second) but it may correspond an appreciable movement of the crank in a high-speed engine. For example, at 3000 rev/min the crank turns through 36 degrees in 0.002 second. This is the reason why the point of ignition is always well in advance of the top dead centre.

7.1.3 Abnormal Combustion

Pre-ignition

Pre-ignition is caused by the mixture igniting as a result of contact with a hot surface, such as an exhaust valve. Pre-ignition is often characterized by running-on; that is the engine continues to fire after the ignition has been switched off.

Pre-ignition is also caused by the building-up of combustion deposits or coke even when engine is operating with the correct mixture strength, ignition timing and adequate cooling.

Effects of Pre-ignition

(i) Pre-ignition causes an increase in the compression work and this causes a reduction in power

(ii) Pre-ignition leads to higher peak pressures and this in turn can cause self-ignition.

Self-ignition

Self-ignition occurs when the pressure and temperature of unburnt gas are such as to cause spontaneous ignition. The flame front propagates away from the sparking plug, and the unburnt (or 'end') gas is heated by radiation from the flame and compressed as a result of the combustion process.

Effects of Self-ignition

(i) If spontaneous ignition (self-ignition) of the uburnt gas occurs, there is a rapid pressure rise which is characterized by a “Knocking”. The “Knock” is caused by resonances of the combustion chamber contents.

(ii) As a result of Knocking, the thermal boundary layer at the combustion chamber walls can be destroyed. This causes increased heat transfer which might then lead to certain surfaces causing pre-ignition.

7.2 CHARACTERISTICS OF PETROL

The two most important characteristics of petrol are its volatility and octane number (its resistance to self-ignition).

7.2.1 Volatility

Volatility is expressed in terms of the volume percentage that is distilled at or below fixed temperature. If a petrol is too volatile, when it is used at high ambient temperatures the petrol is liable to vaporize in the fuel lines and form vapour locks. This problem is most pronounced in vehicles that are being restarted, since under these conditions the engine compartment is hottest. If the fuel is not sufficiently volatile the engine will be difficult to start, especially at low ambient temperatures.

The volatility also influences the cold start fuel economy. Spark ignition engines are started on very mixtures, and continue to operating temperature; this is to ensure adequate vaporization of fuel. Increasing the volatility of the petrol at low temperatures will evidently improve the fuel economy during and after starting.

7.2.2 Octane Number

The octane number of a fuel is a measure of its anti-knock performance. A scale of 0-100 is devised by assigning a valve of 0 to n-heptane which is a fuel prone to knock, and a valve of 100 to iso- octane which is a fuel resistant to knock. A 95 octane fuel has the performance equivalent to that of a mixture of 95% iso-octane and 5% n-heptane by volume. The octane requirement of an engine varies with compression ratio, geometrical and mechanical considerations, and also its operating conditions. There are two commonly used octane scales, research octane number (RON) and motor octane number (MON), covered by British standard 2637:19978 and 2638:1978 respectively.

7.3 FUEL SYSTEMS

The purpose of an engine fuel system is to provide the cylinder with a mixture of air and fuel in the correct proportions for the engine requirements at any particular instant. There are basically two methods available, one is called carburetion and is used for petrol engines and the other is a type of fuel injection which is a characteristic method for diesel engines. There are many different designs of each and only the basic principles will be dealt with. The fundamentally different methods of charge ignition by spark and by compression in the petrol and diesel engines respectively have dictated different means of fuel supply for the two engines.

The petrol engine for automotive purposes has been developed on the basis of the carburetor although petrol injection system has been in used for a long time in aircraft and racing cars.

7.3.1 Comparison between Carburettors and Petrol Injection Systems

The carburettor is a simple, cheap device which has served its purpose for many years, but the trend to higher powered multi cylinder engines has shown the carburetor system to be inadequate. As a consequence several designs of petrol injection system have been introduced to meet increasingly sophisticated engine requirements. The petrol injection system, from the point of view of control, is accurate in fuel metering and has good fuel consumption characteristics in comparison with the carbureted petrol engine at has poor fuel consumption.

In recent years the added requirement for engines to meet exhaust gas emission regulations has increased the demand for accurate fuel metering and engine control. These factors have increased the interest in petrol injection system.

7.3.2 CARBURATION SYSTEM

The term "carburettor" covers the whole process of supplying continuously to a petrol engine a mixture of vaporized fuel and air which is suitable to each engine condition of load, speed, and temperature. The function of the carburettor is to measure out the correct proportions of liquid fuel and for the particular engine condition. The liquid fuel must be "atomized" at the carburettor (i.e. broken up into a fine spray to assist in the evaporation of the fuel, so that the mixture entering the cylinders is homogeneous).

Characteristics of Ideal Carburettor

(i) Ideal carburettor would supply the air/ fuel ratio required at all speeds and throttle openings no matter what the climatic conditions or the rate at which the demand was changing.

(ii) Ideal carburettor would cope with all the factors which influence the burning of the final mixture in the cylinder.

The following are the factors which influence the burning of the final mixture in the cylinder:

(a) Engine condition required

(b) Mechanical characteristics of the engine

(c) The physical differences between the constituents of the mixture

(d) The rapid fluctuation in demand, and

(e) The temperature and humidity variation

7.3.3 TYPES OF CARBURETTOR

The two main types of carburettor are fixed jet and the variable jet types.

FIXED JET CARBURETTOR

The simplified fixed jet carburettor system is shown in Fig.7.1

(a) **Fuel supply:** In the fixed jet carburettor, the petrol pump, either electrically driven or mechanical driven by the crankshaft, pump petrol from tank to the float chamber of the carburettor.

(b) **Float Chamber:** The function of the float chamber is to maintain a constant level of petrol in the chamber by shutting off the supply from the pump when this level is about to be exceeded. The float chamber is vented to atmosphere through a small hole in the cover; hence the pressure on the surface of the petrol is constant and equal to that of the atmosphere.

(c) **Air Supply:** The air is induced by the depression created by the piston moving downward in the engine cylinder, and after passing through a filter enters the carburettor at about atmospheric pressure.

(d) **Throttle valve:** The petrol engine is quantity governed, which means that when less power is required at a particular speed the amount of charge delivered to the cylinder is reduced. This is achieved by means of a throttle valve of the butterfly type which is situated in the air inlet.

(e) **Ventura or choke Tube:** The airs on induction enters the venturi or choke tube. This is a tube of decreasing cross-section which reached a minimum at the impact or choke of the venturi, which is shaped to give the minimum resistance to the airflow. The choke or throat has a constant area and the pressure changes with throttle opening and engine speed.

(f) **Petrol Discharge Jet:** The petrol discharge jet is situated at the throat and is subject to the air pressure there. The pressure at the throat is below atmospheric since the air velocity has been increased from that at inlet to the carburetor to a maximum at the throat. Therefore, the two petrol surfaces, that in the float chamber and…………at the discharge jet are subject to different pressures. This pressure difference acting on this petrol column causes the petrol to flow into the airstream, and the rate of flow is controlled or metered by the size of the smallest section in the petrol passage.

VARIABLE JET CARBURETTOR

Fig.7.2: Variable Jet Carburetor

A cross-section of a variable jet or variable venrturi carburettor is shown in Fig. 7.2. The fuel is supplied to the jet from an integral float chamber. This has a float operated valve that maintains a fuel level just below the level of the jet. If the throttle is opened, the air flow through the venturi increases. This decreases the pressure downstream of the venturi and causes the piston to raise position of the tapered needle in the Jet or orifice vane with the piston position, therefore, controlling the air/fuel mixture. The pressure at the throat and the air velocity remains constant, but area of the throat varied. Similarly the area of the petrol orifice or Jet tapered needle, attached to a piston. The needle moves in the orifice, therefore, forming a discharge annulus for the petrol.

7.4 COMPRESSION IGNITION ENGINES

Compression ignition engine is a type of internal combustion (or IC) engine in which the air only is compressed, and the fuel is injected into the air which is then at a sufficiently high temperature to initiate referred to as diesel or oil engine, the fuel is also named after the inventor.

7.4.1 Combustion in Compression Ignition Engines

Liquid fuel is injected as one or more jets near the end of the compression stroke. The injector receives fuel at. Very high pressures in order to produce rapid injection with high velocity jet of small cross-sectional area. The fuel jets entrain air mixing which is essential if the combustions to occur sufficiently fast. Sometimes the fuel jet is designed to impinge on to the combustion chamber wall; this can help to vaporize the fuel and break up the Jet. There will be large variations in fuel/air mixtures on both a large and small scale with in combustion chamber. Since the fuel is introduced into the cylinder of a compression ignition (CI) engine only when combustion is required, i.e. toward the end of the compression stroke, pre-ignition cannot occur. Moreover, since the fuel is injected at a controlled rate, the simultaneous combustion of the whole quantity of fuel cannot occur, and the problem of detonation as in spark ignition (SI) engine does not arise.

7.4.2 Phases of Combustion In CI Engines

First Phase of Combustion

The combustible mixture in the SI engine is formed before compression, but with the CI engine this mixture has to be formed after compression and after injection begins. This leads to delay periods in the CI engine which are greater than those in the SI engine. The fuel droplets injected have to evaporate and mix with air to form a layer having an air-fuel ratio which is combustible. This delay period forms the first phase of the combustion process and is dependent on the nature of the fuel.

Second Phase of Combustion

The second phase consists of the spread of flame from the initial nucleus to the main body of the charge. There is a rapid increase in pressure during this phase and the rate of pressure rise depends on the availability of oxygen to the fuel spray, which in turn depends on the turbulence in the cylinder. However, the main factor is that of the delay period. A long delay period will result in diesel knock.

Diesel Knock : If the delay period is too long, there is time for a large fraction of the charge to enter the cylinder to enter the resulting in rough running and a characteristic noise called diesel knock.

Third Phase of Combustion

During the third phase of combustion the fuel burns as it is injected the cylinder, and this phase gives more controlled combustion than that of phase two. One of the main factors in a controlled combustion is the swirl which is induced by the design of the combustion chamber.

7.4.3 The Effect of Compression Ratio in The Compression Ignition (CI) Engine

The effect of compression ratio in the CI engine some what simpler than in the SI engine. It follows than the compression ratio can be much higher in CI engines and in fact there is a lower limit of about 12:1 below which compression-ignition of common fuel oils is not possible. Therefore, for combustion to occur at the temperature produced by the compression of the air a minimum compression ratio of 12:1 is require. The following are the effects of compression ratio on the design of CI engines.

(i) Compression ratio determines the maximum pressure that can be reached in the cylinder of CI engine.

(ii) The upper limit of compression ratio determines the strength of the cylinder, the bearings, and other parts whose stresses are determined by the peak pressure forces.

(iii) The efficiency of the cycle increases with higher values of compression ratio (i.e. the higher the value of compression ratio the higher the efficiency of the cycle).

(iv) The designer must reach a compromise between high efficiency and low weight and cost.

7.4.4 Characteristics of Diesel Fuel

The most import characteristic of diesel fuel is the cetane number, as this indicates how readily the fuel is ignitable. Viscosity is also important, especially for the lower-grade fuel used in the large engines. Sometimes it is necessary to have heated fuel lines. Another problem with diesel fuels is that, at low temperatures, the high molecular weight components can precipitate to form a waxy deposit; this is defined in terms of the cold filter plugging point.

Volatility: In CI engine the volatility of the fuel influences the time taken for a combustible envelope to form round the fuel droplets, and hence influences the delay period.

Flashpoint: The flashpoint is the temperature to which the liquid has to be heated for the vapour to form a combustible mixture with air at atmospheric pressure. The flashpoint of diesel fuel is at least 55°C; this makes it a safer fuel to store than petrol is about 40°C.

Cetane Number: The ignitability of a fuel oil is indicated by its cetane number. A scale of 0-100 is constructed by assigning a value of 0 to α-methylnaohthalene, $C_{10}H_7CH_3$, (this is a naphthenic compound with poor self-ignition qualities), and a value of 100 is assigned to n-cetane, $C_{16}H_{34}$, (this is a straight- chain alkane with good self-ignition qualities.)

The mixture is made by volume and the ignitability of the test fuel is quoted as the percentage of cetane in the reference mixture which has the same ignitability. For the example a 65 cetane fuel would have ignition delay performance equivalent to that of a blend of 65% n- cetane and 35% α-methynapthyalene by volume. For higher- speed for engine the cetane number required is about 50, for medium- speed engine about 40, and for low- speed engines about 30.

Effect of Low Cetane Number

If an engine runs on a fuel with too low a cetane number, there will be diesel knock. Diesel knock is caused by too rapid combustion and is the result of a long ignition delay period, since during this period fuel is injected and mixes with air to form a combustible mixture. Ignition occurs only after the pressure and temperature have been above certain limits for sufficient time, and fuels with high cetane numbers are those that self-ignite readily.

Relationship between Cetane number and Octane number.

The fuels with high cetane number have low octane number and the fuels with low cetane number have high octane number.

Ignition Acceleration: additives in diesel fuel to improve the cetane number are referred to as ignition acceleration. Their concentrations are greater than those of anti-knock additives used in petrol.

7.4.5 FUEL INJECTION FOR DIESEL ENGINES

The function of a fuel injection system is to meter the fuel accurately and uniformly to the engine cylinders under all operating conditions from idling to full load. The timing of the injection should be accurate enough to give the required combustion characteristics. The fuel from the tank is filtered before passing to the pump, and the metered fuel is than passed to the injector which is fitted in the engine cylinder.

8.0 STEERING AND BRAKING SYSTEM

8.1 Steering System

The function of the steering system is to enable the driver to control accurately the direction taken by the vehicle under all operating conditions. The system must be light and easy to operate, free from shock and vibration and be as direct as possible.

The steering system also helps to convert the rotary motion of the drive's steering wheel into the angular turning of the front wheels as well as to multiply the driver's effort with leverage or mechanical advantage for turning the wheels.

8.1.1 Steering Gear

Steering gear is a device for converting the rotary motion of driver's steering wheel into the straight line motion of the linkages or angular turning of the front wheels. It consists of mainly two parts: a worm on the end of the steering shaft and a pitman-arm shaft. There is gear sector, toothed roller or stud fitted on the pitman-arm shaft.

The steering gearbox is mounted on the chassis at the correct angle for the steering wheel and operates in such a way that the rotation of the steering wheel produces a forward and backward, or transverse, motion of the drop arm and drag link. The motion is transferred to the track rod and stub axles and results in the steering road wheels being swivelled about their kingpins.

(a) Reduction gears

All steering gearboxes employ reduction gears in which a large steering wheel movement under a small torque is converted into a smaller drag link movement under a much larger torque. The usual reduction is about 14:1 but, as the drop arm needs only a small arc of motion, 3 or 4 complete revolutions of the steering wheel will turn the road wheels fully from one side to the other, i.e. from lock to lock. Commercial vehicles, with their much bigger tyres and heavier wheel loadings, may require 8 to 10 turns of the steering wheel to move the road wheels from one lock to the other.

(b) Steering lock

This is related to the smallest radius of turn which the vehicle makes to either the left or right. A large lock resulting in a small radius of turn, is essential for easy manoeuvring, and large locks are always provided for taxis and small delivery vehicles. These can usually turn inside a circle of about 7 m in diameter. Small cars are usually able to turn in a 9 m diameter circle, while the larger cars and commercial vehicles may have turning circles of between 9 m and 15 m in diameter. The longer the vehicle the larger its turning-circle.

8.1.2 Types of Steering Gears

There are different types of steering gears used on different vehicles. Depending upon the method of coupling the steering tube with the cross shaft, different types of steering gears are as follow:

(1) Worm and roller

(2) Worm and sector

(3) Cam and roller

(4) Cam and peg

(5) Screw and nut

(6) Recirculating ball

(7) Worm and ball bearing

(8) Rack and pinion

8.1.3 Worm and Roller Gear

This gear consists of a two toothed roller fastened to the cross shaft known as roller shaft, sector shaft and pitman shaft. At the end of the steering tube it meshes with the thread of the worm gear or worm shaft. As the worm shaft is turned by the steering tube roller is moved in an arc for rotating the roller shaft as well as turning on the pin connected to the shaft. The roller is generally mounted on the ball bearings or on some anti-friction type of bearing.

8.1.4 Worm and Wheel & Worm and Sector Steering

(a) Worm and Wheel

In almost all steering gearbox assemblies the steering wheel is attached to the upper end of a strong steel tube, or column, by means of splines and is secured with a locknut. At the lower end of the column a rigidly secured worm engages with a worm-wheel, so that rotation of the worm causes the drop arm and shaft to move in an arc of between 60º and 80º. The column is enclosed by a light steel tube which is riveted to the box at its lower end while its upper end is supported by a body bracket.

(b) Worm and Sector

This is similar in arrangement and operation to the worm and worm wheel type, the sector being a part of a wheel. The sector is often mounted above the worm with the drag link end of the drop arm being below the worm. This type is smaller, cheaper and easier to install than the complete wheel type. Provision is made to compensate for the wear of the teeth and for the end-float adjustment of the worm and of the sector shaft.

Fig 8.2 worm and sector

8.1.5 Cam Roller

This steering consists of cam rotating in a housing, roller, rocker shaft and a drop arm. By moving the steering wheel and steering shaft the cam is rotated. Due to this rotation, the roler is compelled to follow the helix of the groove. By this the rocker shaft is caused to rotate as well as the drop arm is moved.

8.1.6 Cam and Peg

The steering gear consists of a tapered peg in the rocker arm engaging with a special cam formed on the inner column. By rotating the cam through the steering shaft. The peg is moved along the groove for rotating thee rocker shaft. Shims control the end float of the column.

8.1.7 Screw and Nut Gear

This gear consists of a phosphor-bronze of steel nut, screwed on to a multi-start Acme thread formed on the inner column. A ball fitted in the rocker arm prevents the rotation of the nut. A single ball race fitted at the top end of the rocker shaft takes up the axial thrust of the column while the lower end is supported by the nut sliding in the housing. The nut at the top end is used to adjust the end float of the inner column.

8.1.8 Recirculating Ball Gear

This design resembles that of the worm and nut but the square threads are replaced by coarse pitch helical grooves of semi-circular cross-section. The half nut and the transfer tube contain the balls. It feeds the balls back to the nut by employing the half nut with the transfer tube. A peg on the nut is located in the rocker arm. The balls pass from one side of the nut through the transfer tube to the other side by rotating the cam of worm. Any movement of the balls along the track of the cam carries the nut along with it because the nut cannot turn. The rocker shafts get rotated by this movement. Due to very small frictional losses in gear, this type of steering is quite efficient.

8.1.9 Rack and Pinion Gear

The rack consists of a cylindrical steel bar which has gear teeth machined on one side. The steel pinion is meshed with these teeth and is attached to the lower end of the column so that rotation of the steering wheel causes the rack to move bodily along its axis. In one modern arrangement the box, or case, is cylindrical and is mounted across the chassis. Each end of the rack is connected to the steering track arms by short, ball-joined shafts.

Independent front suspension is fitted and torsion bars are used for springs. The lighter versions of this design make no provision for wear compensation, but the heavier versions have a shim adjustment which forces the pinion into closer contact with the rack.

8.2 POWER STEERING

Power steering has become necessity in most of the vehicles because of the increased demand for light control aligning tyre torque for keeping vehicle loads acceptable. Power steering is used in order to reduce the steering wheel turning effort; turn sharp corner easily, negotiate winding roads and manoeuvre the vehicles in confined space as well as to offer some resistance to make the driver feel and retain some road feel or vehicle steering response.

8.3 WHEEL ALIGNMENT

Alignment of automobile wheels is defined as the correct adjustment of pivot axes controlling the movement of the wheels. The wheel alignment, therefore, refers to the positioning of the front wheels and steering mechanism for promoting ease of steering, reduce tyre wear to minimum as well as to provide directional stability to the vehicle. Excessive tyre wear, vibration, stability to the vehicle. Excessive tyre wear, vibration, hard steering, shimmy etc. are caused due to incorrect alignment of wheels. For making wheel alignment, the following checking, inspection and adjustment should be made.

(i). Wheel bearing adjustment should be checked and made if required according to specifications.

(ii). The kingpins and their bushing must be checked and inspected for excessive play.

(iii). Spring to be checked for breaks or sags.

(iv). Checking the bent of the steering arms because it causes incorrect toe out on turning in the wearing away of the tyres.

(v). Checking factors like frame frame alignment, spring conditions position of the rear axle, condition of the shock absorbers etc.

8.4 WHEEL BALANCING

In order to maintain good steering, proper balancing of the front wheel is necessary. Unbalanced front-wheel assembly results in tramp or high-speed shimmy while the unbalanced rear wheels producing variations in the vehicles also affect the front suspension system. The unbalanced wheels also result in uneven tyre wear and rough ride. For ensuring the rotation of wheel free from vibration, balancing of the wheel assembly is necessary. By adding small weights on the rim of the wheel, an unbalanced wheel assembly gets balanced. A special machine known as wheel balancing machine is used to balance and determine the location of balancing weights on the rim.

8.5 THE BRAKING SYSTEM

The most vital factor in the running and control of the modern vehicle is the braking system. In order to bring the moving motor vehicle to rest or slow down in a shortest possible time, the energy of motion possessed by the vehicle must be converted into some other form of energy. Brake is a friction device for converting the power of momentum or kinetic energy of the moving vehicle into heat.

8.2.1 Basic Requirements of a Brake

(i). The brake must be strong to stop the vehicle during emergency within the shortest distance without skidding.

(ii). The effectiveness of the brakes should remain constant even with prolonged application, as in hill descending.

Purpose of brakes

There are two purposes of fitting brakes on motor vehicle: to help in speed control of the vehicle as well as to stop it when and where desired quickly and efficiently, without skidding. These purposes are accomplished by providing two independent braking system in a motor vehicle: a service brake or foot brake operated by foot pedal and a parking emergency or hand brake operated by a hand lever.

8.2.2 Brake Assembly

Brake assemblies are mounted at the end of the axles and each consists of a non-rotating back-plate and shoe assembly which is enclosed by a drum. The drum rotates with the road wheels, and the back-plate are bolted rigidly to the stub axles and to the ends of the rear axle case.

Two shoes are mounted on each back-plate and each carries a friction lining of an asbestos material. Some linings are riveted to the shoes by copper or brass rivets, while others are secured by means of a chemical bonding process. The shoes may be thin steel pressings or aluminium alloy castings but they must be rigid and they must absorb and dissipate heat quickly.

8.2.3 Hydraulic Brake System

The pedal force in this system is transmitted to the brake shoes for its actuation through a confined liquid known as brake fluid. The fluid pressure acting upon positions in the wheel brake operating causes the brake shoes to expand. A system of force transmission based on Pascal's law helps to multiply and transmit the force applied on the pedal to the brake shoes (fig. 8.5).

A hydraulic braking system essentially consists of:

(i) A fluid supply tank for storing the fluid necessary for operating the system.

(ii) A master cylinder and piston connected by steel tubing to hydraulic wheel cylinders at each of the four wheels and brake pedal.

(iii) Pipelines and houses for conveying the fluids under pressure to the wheel brake shoe operating units.

(iv) The wheel cylinders whose position moves out for applying the pressure to the wheel brakes.

Advantages of hydraulic brake over mechanical brake

1) Due to the absence of brake rods, joints etc, which are present in mechanical, hydraulic system is very simple in construction.

2) As compared to mechanical breaking system, this system provides equal braking effort at all the four wheels due to the fluid exerting equal pressure everywhere in the circuit.

3) In this braking system, all the wheel brakes are forced to act together without any consideration to their individual adjustments.

4) It provides an increased braking effort.

5) It provides equal pressure at all points.

6) It is self compensating system.

7) The wear rate is quite low because the system is self-lubricating.

8) Unlike mechanical brakes, they can easily be made to follow almost any desired path under the chassis.

9) They provide a high mechanical advantage without the use of long levers.

Disadvantages

1) Complete braking system is liable to be affected if any fault causing pressure loss or the breakage of a pipe to one wheel occurs.

2) The brake shoes are liable to get ruined if the brake fluid leaks out.

8.2.4 Master Cylinder

Master cylinder is the central unit in the hydraulic braking system. The hydraulic pressure required to operate the system is produced here. The pressure of the driver's foot on brake pedal through different linkage arrangements is transmitted to the master cylinder piston. It can be considered as the heart of the hydraulic braking system.

Purposes of a master cylinder

1) The hydraulic pressure required to operate the system is built up in the master cylinder.

2) Due to the reservoir provided with it, it serves to maintain a constant volume of fluid in the system.

3) To bleed or force air out of the brake line and wheel cylinders, it acts as a pump.

9.0 AUTOMOBILE ELECTRICAL SYSTEM

An elaborate mechanism known as electrical system is provided within the framework of the modern automobile which helps to change energy easily in an automobile from one form to another. For the normal running of the automobile, the satisfactory operation of the electrical equipment and system is very essential. Due to its failure, the automobile becomes immobilized or it cannot be started.

9.1 VARIOUS ELECTRICAL ELEMENTS IN AN AUTOMOBILE

The electrical equipment f an automobile as a whole consist of the following six elements:

1) The generating circuit
2) The starting circuit
3) The ignition circuit
4) The lighting circuit
5) Battery circuit and
6) Branch circuit

The generating circuit, the starting circuit, the ignition circuit, and the lighting circuit are the four main circuits and they are connected together and linked to the battery.

9.1.1 The Generating Circuit

The generating circuit or the charging circuit consists of a generator and its control equipment. It is connected to one end of the vehicle ammeter which registers the charge direction while sending current to the battery. The other end of the ammeter or the generator is connected directly to the cable leading to the underground pole of the battery. Its purpose is to generate electricity for refilling or re-charging the battery when the motor vehicle is running. The battery is liable to become run down due to continual use of charge by other equipment if the generating or the charging circuit is not provided.

9.1.2 The Ignition Circuit

The ignition circuit provides accurately timed high voltage sparks for igniting the gases of fuels in the engine cylinders. The ignition equipment consists of a ignition coil powered from the battery, a distributor unit and sparking plugs. The ignition circuit, the lighting circuit and the branch circuits are connected to the generator circuit through ammeter. The current is received by them directly from the generator without going through the ammeter when the generator is operating. These circuits draw current directly from the battery directly or through the ammeter when the requirements exceed the generator.

9.1.3 The Starting System

The starting system helps to turn the engine over until it fires for running under its own power. It eliminates the tiresome operation of swinging the engine by hand.

9.1.4 The Lighting System

The lighting system is used for units like the head, side and rear light, fog lamps, number plate illumination lamps, interior lights and indicator flashers.

9.1.5 The Battery Circuit

The battery circuit is the nerve centre of the whole installation. Most of the units except the charging device are operated by this. The engine cannot be started with the starting motor without it since the battery circuit can only supply the required amount of currents for the purpose.

9.1.6 The Branch Circuit

The branch circuit serves the special purpose of operating different accessories and special purpose units like horns, windscreen wipers, electric petrol pumps and gauges, radio sets, gasoline gauge, cigar lighter, heater, wind screen defroster and other accessories.

9.2 THE AUTOMOBILE BATTERY

The battery is in reality the heart of the electrical system of a motor vehicle. It supplies current for cranking motor and the ignition system. The function of the battery is to store electrical energy which can be sued whenever required. Battery may be called nerve-centre of the whole installation. Because it supplies electrical energy for operating all the electrical devices and other units except the charging device. It also supplies electricity for operating the various electrical devices when vehicle is not operating or running slowly and generator speed is insufficient to meet the full load requirements.

The capacity of the battery depending upon the amount of chemicals it contains, limits amount of current it can supply. 64,000km on the average is life of the battery based mainly on the attention it receives during service.

9.2.1 Battery Voltage

The battery voltage is not affected by the number and sizes of the battery plates. A fully charged battery cell has voltage of bout 2.2 volts which goes on decreasing to 1.9, 1.8 to 1.7V (fully discharged). Therefore, a 6-volt battery is made up of three cells connected in series. The voltages add up in series. Similarly a 12-volt battery contains 6-cells while a special purpose 24-volt battery is of 12 cells.

9.2.2 Battery Efficiency

It is the ability of a battery to deliver current. Depending upon the temperature and rate of discharge, it varies within wide limits. The chemical activity is greatly reduced at low temperature because the sulphuric acid cannot react actively on plates resulting in lesser supply of current and thus lesser efficiency of the battery. Since the chemical activities take place on the surface of the plate without utilizing the materials formed below the plate surface because they cannot penetrate the plates, therefore, the current produced by high rate of discharge will be lesser than that produced by low rate of discharge.

9.2.3 Battery Capacity

It is defined as the maximum amount of current that a battery can deliver based on the area of the plate surface in contact with the electrolyte as well as on the number of plates and amount as well as the quality of the electrolyte. It decreases with the decrease of temperature. It is measured in ampere hours. It also depends on the rate of discharge with 10 hour assumed rate. A battery having 75 ampere capacity provides 7.5A for 10 hours without the voltage falling below 1.80.

9.2.4 Battery Charging

The battery gets a charge best suited to its condition from a generator under normal running condition by means of output control systems like compensated voltage control and current voltage control. But sometimes happens that unusual running conditions like frequent use of starter or longer period of vehicle parking with parking lights on or the use of other accessories like radio, heater, air conditioner may discharge a good condition battery to such an extent that the generator is unable to make good the deficiency.

9.2.5 Causes of Battery

(i). Low level of the electrolyte in the battery.

(ii). Over filling of battery with electrolyte, which makes battery top to get corroded.

(iii). Terminal corrosion on the top of the battery which can cause current leakage between its cells.

(iv). Cracks in the top of the battery, which may result in escape of electrolyte or the vapour.

(v). Formation of lead-sulphate on the plate surface when the battery is kept without use for sometimes in a discharged or semi-discharged state.

9.2.6 Battery Maintenance and Care

The following are necessary maintenance and cares needed to prolong battery life:

1) Container and cover surface should be kept clean and dry because electrical leakage and the risk of electrolyte contamination is caused by dirt, fluid and grease.

2) Terminals posts and cable clamps should be kept clean otherwise corrosion will occur resulting in high resistance to the passage of starting current. They should be smeared with petroleum jelly to prevent corrosion.

3) Cable clamps should fit roughly around the terminal post.

4) Battery cable connections should be in good condition with their clean and tight vehicle connections. Starting current will be limited by frayed cables.

5) To stop the battery vibration, the battery hold down clamp should be tight enough without much strain on the cover and container.

6) The vent plug should be kept in position to avoid escaping of electrolyte resulting in damage to car and the battery.

7) Top up the battery only with distilled water and only when the electrolyte has fallen to just below the top edges of the separators.

8) When topping up, do not allow over filling of the battery otherwise the car will be damaged by overflow when charging.

9) Check the specific gravity of the electrolyte occasionally so that it is never below 1.17. The vehicle wiring is liable to get short circuited by a discharged battery.

9.3 GENERATOR AND THE CHARGING SYSTEM

9.3.1 Generator

Generator is one of the important components of the electrical system of a motor vehicle. Its main function is to maintain the charge of the battery when the engine is running as well as to replace the electrical energy consumed and taken by the starter, ignition, lighting etc. from it. It converts mechanical energy into electrical energy to be used for reversing the chemical action of the cell material. The potential difference maintained between the terminals of battery is sufficient to supply current for the different components. The generator is usually driven by means of a belt from the engine.

9.3.2 Commutator Type Generator

It consists of a laminated iron core having coils of insulated wire wound on it to make up the armature. Commutators made up of copper bars are separated from each other by mica with coil ends soldered to it. By means of bearing the steel shaft running through the armature and commutator is supported. This will result in turning by an engine-driven belt the pulley and the fan mounted on the front end.

9.3.3 Alternator Type Generator

This generator is quite different from the commutator type generator. It uses an induced current generated in the stationery stator windings by a revolving electromagnet. In order to change the alternating current to direct current required for the electrical system of the motor vehicle, silicon diodes are employed by this generator.

Difference between alternator and commutator

The main difference between alternator type generator and the commutator type generator is in the method of voltage and current control as well as in design. It does not require any cut-out to prevent the battery from discharging through it because the current is allowed to flow by the diode rectifiers only in one direction. The maximum current output of the generator is controlled without the use of a vibration current control using inductive reactance provided by special design of the stator windings.

9.3.4 Starting System

The piston engines are not self-starting. They are incapable of running below a certain minimum speed. Therefore, it is necessary to provide certain system in the engine circuit to overcome the stand-still resistance and crank it to a speed at which it is self-supporting and self-starting. For this purpose a starting system or circuit which consists of a series wound motor with manually operated switch is provided. It is mounted on the side of the engine.

The different components of the system are the container, the armature, commutator and the field winding with current supplied by the battery driving the system. Certain forms of drive mechanism are usually provided at the end of the armature shaft. It helps the motor to start the engine.

9.3.5 Starter

The starter drive are mainly concerned with the method of linking the starting motors to the engine flywheel for cranking the engine until it starts and disconnecting it automatically when the engine has started running. Now when the engine has started turning, it is necessary that the starting motor should be disengaged form it otherwise the engine will rotate it at a high speed. This will result in flying away at the commutator segments and windings due to centrifugal forces because the starting motor is unable to take up such high speed.

Therefore, in order to disconnect the starting motor from the engine flywheel when the engine has started it is necessary to employ certain device. Generally four types of starting devices are used:

(a) Bendix drive

(b) Over-running clutch drive

(c) Solenoid starter switch

(d) Dyer drive

But only Bendix drive is commonly used on most of the motor vehicles.

9.3.6 Bendix Drive

In order to engage starter pinion with the flywheel gear the method of the Bendix drive is used. For fastening this unit with the starting motor armature shaft, the drive head is usually keyed to the end of the armature shaft. With the passage of electric current into the starting motor the armature will begin to turn at full speed. The starter pinion and the flywheel gear do not remain in mesh but are automatically disengaged by the Bendix drive as soon as the engine starts.

9.4 IGNITION SYSTEMS

Ignition system is an important part of electrical systems that provides a succession of accurately timed high voltage sparks for igniting the explosive mixture in the engine cylinders. It supplies high voltage surges of volume up to 20,000 volts for igniting the compressed air fuel mixture by producing spark at the spark plug gap.

In order to produce the necessary high voltage for jumping a set gap, two methods based on principle of mutual electromagnetic induction are generally employed:

(a) Battery or coil ignition system, it can be conventional or transistor assisted.

(b) Magneto ignition systems, it can be low tension or high tension.

9.4.1 Coil Ignition System

This system includes a battery supplying current via the ignition switch to the ignition coil, low-tension or primary winding. The current flow from primary winding terminal of the coil flows to an engine operated the contact breaker thereby induced current in the high tension or secondary winding of the coil due to electromagnetic action in the coil windings. This current flowing to the sparking plug jumps the air gap. The circuit break to the coil through the battery and low tension windings is completed.

In order to prevent arcing causing the low tension current flowing even when the contact breaker points open, a condenser is fitted in parallel with the contact breaker points. This also helps to increase the spark at the sparking-plug gap. The sparking plug gap and the pressure in the cylinder effect the voltage required ate the plug points.

9.4.2 Ignition Coil

It is simply a form of a transformer having a primary as well as a secondary winding. It is less efficient in comparison to a transformer except for certain characteristics making it suitable for a particular use. Generally two types of ignition or induction coils are used in modern ignition systems: core type and metal clad or cane type ignition coils.

9.4.3 Condenser

It is a type of elastic container which stores the energy due to the inertia of the current flowing during the contact period. The condenser usually connected across the contact breaker is used to reduce arcing and pitting of the contact breaker points as well as to intensify the spark. The excess energy during "make' period is absorbed by it while at the "break" it gives out the energy. In this way it intensifies the spark as well as protects the contact points. In order to produce a spark at the sparking plug, the voltage supplied by the battery or generator should be increased to about 20,000 volts. It is done with the help of a condenser used for the purpose, in the ignition system of a motor vehicle.

9.4.4 Contact Breaker

The main purposes of the contact breaker is to provide the make and break of the primary ignition circuit. There are in general two types of contact breakers: single arm type and the double arm type.

A good contact breaker must have the following essential requirements:

(i) Opening and closing of the contact must take place at the correct time.

(ii) The closing of the contacts must take place without a bounce.

(iii) Flinging should not occur while opening the contacts

(iv) The contacts should not get oxidized excessively.

(v) The contact points should not be allowed to corrode excessively.

Setting of contact breaker gap

It is necessary that the contact breaker gap between the contact points should be set within the permissible values. A very small gap between the points will cause them to burn rapidly and will result in mis-firing of the engine at all the speed. A very large gap on the other hand will reduce the closing time of the contact breaker, will decrease the maximum voltage produced and will also cause the ignition failure. A gap of 0.35mm to 0.45mm is usually provided between the contact breaker points.

Different methods employed for setting contact breaker gap are:

(i). Feeler gauge method

(ii). Dial gauge method

(iii). Dwell meter or synchronoscope method

9.4.5 Distributor

Both the contact breakers as well as the distributor are mounted together in the distributor housing or distributor unit. At the upper end of the distributor, a cam having as many lobes as there are cylinders in the engine is provide. The main function of a distributor is to distribute the high voltage impulses in the sequence of the engines firing order to different sparking plugs at regular time intervals.