AUTOMOBILE

ENGINEERING - 5th Sem

(Mechanical Engg)

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MOD-1

AUTOMOBILE

The automobile is defined as a self-propelling vehicle. In the past, the automobile was only required to serve as the legs for the people, but today many more things are demanded such as comfort and convenience, high mobility and maneuverability, running safety, economy and personnel safety.

The automobile has five basic components or parts:

1. The power plant or engine, which is the source of power.
2. The chassis, which supports the engine and body and includes the brake, steering and suspension systems.
3. The power train or drive train, which is the power-transmission system that carries power from the engine to the drive wheels. This unit includes clutch, gearbox, drive axle assembly, final drive, differential and the wheel axles.
4. The car body.
5. The car-body accessories, which include the heater and air conditioner, lights, radio and music player, windshield wiper and washer, power windows and seat adjusters.

VEHICLE LAYOUT

The following Fig.1.1 shows a basic structure and simplified layout of various transmission components used on a vehicle.

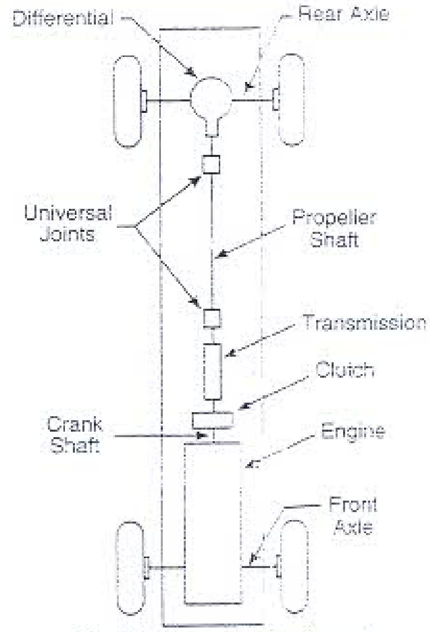


Fig. 1.1: Transmission layout

Transmission system

The transmission system covers the complete driveline between the engine and the road wheels. However, in many countries the term "transmission" refers to the gearbox unit.

Power unit

The normal source of power is provided by an internal combustion engine. The gasoline (petrol) engine is the most popular for its superior performance, but if the vehicle is used extensively, the excellent fuel economy given by a diesel engine makes this type attractive. The economy feature of the diesel engine offsets the higher initial cost and slightly reduced output.

Clutch

The gears in a manual gearbox have to be changed. This action should only be performed when the gears are not under load, so a clutch is fitted to meet this need. This enables the driver to disconnect the engine from the gearbox.

Gearbox

Gearbox consists of sets of gears that amplify the engine torque to enable the driving force at the road wheels to be increased sufficiently to overcome the resistance to movement of the vehicle. Also the gearbox enables the engine speed to be kept within its working limits irrespective of the speed of the vehicle. In addition it provides neutral, where the engine can run without moving the vehicle and a reverse to drive the vehicle backwards.

Propeller shaft

This is the long tubular shaft which links the gearbox to the final drive. Normally an open type arrangement is used in which the shaft is exposed.

Universal joints

Universal joints are fitted to each end of the propeller shaft to enable the drive to be transmitted through a varying angle. This is to allow for the flexing of the chassis components that occurs when the vehicle is traveling over a bumpy surface.

Front axle

This arrangement supports the front of the vehicle and is also used for steering.

Rear axle

This carries the wheels and supports the weight of the rear of the vehicle. The axle is tubular in section and contains two axle shafts (half shafts) to drive the road wheels in rear wheel drives.

Final drive

On the vehicle centre line the axle is enlarged to house the final drive. This pair of gears turns the drive through 90° and reduces the driving speed which is suitable for the size of the road wheels.

Differential

When the vehicle is turning a corner, the inner and outer road wheels travel at different speeds. When the two road wheels are both rigidly connected to single axle shaft, the greater distance covered by the outer wheel causes one or both wheels to slip on the road. In addition to causing excessive tyre wear, this action makes the vehicle difficult to steer. Also axle shaft may break due to twisting of the shaft because of speed difference between the outer and inner wheels. These problems are overcome by using a differential. This unit ensures each wheel can rotate at different speed that suits the cornering conditions.

Wheels

Most light vehicles run on four wheels fitted with hollow rubber tyres filled with air under sufficient pressure to support the load they have to carry. These provide grip to the road and absorb shocks caused by small road irregularities.

TYPES OF AUTOMOBILES

Light vehicles

Vehicles classified in this category have a laden mass of less than th
different body shapes and sizes come into this light vehicle category. Th
cars to personnel carriers (mini-buses) and small trucks.

Commercial vehicles

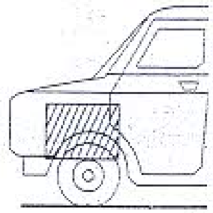
Commercial vehicles are used to transport goods and people safely a
vehicles can be divided up not only according to the position of their en
their use, their body or their trailer type.

Light commercial vehicles

These small commercial vehicles are used for the conveyance of
ally over short distances, e.g. the type of vehicles used by tradesmen to c
shopkeepers to make local deliveries to their customers. Common types
trucks and mini-buses.

a. Vans

Vans are light commercial vehicles with a maximum weight of 7.5 t. They are generally used for short-range distribution of goods and passengers. Most vans have a load-carrying capacity of about 0.5 tonnes.



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b. Pick-up

When a vehicle is required for the transportation of bulky equipment, e.g. materials carried by builders and decorators, an open body is often preferred. A light vehicle having this partly enclosed body is called a pick-up.

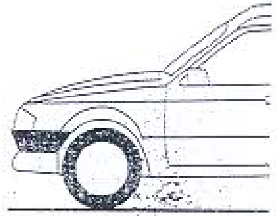

Fig. 1.3

c. Light trucks and mini-buses

Larger vehicles such as light trucks and minibuses need to carry heavier loads, so they require a stronger construction and have to be specially designed to suit the application. Since low-cost operation is an essential factor, most of these vehicles are fitted with a diesel engine.

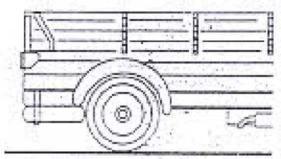

Fig. 1.4 L

Heavy commercial vehicles

Although this book concentrates mainly on light vehicles, a review o
included for comparison purposes. Common types are:

- Trucks
- Road trains (truck and trailer outfits)

e. Special-purpose vehicles

These are large vehicles for the transportation of very heavy loads. They also include fire engines and trucks with crane or concrete-pump bodies. Because of their high permissible gross weight and their unusual dimensions, special-purpose vehicles often require a special operating license.

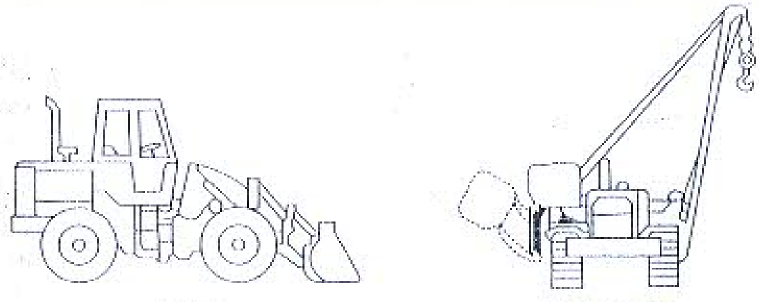

Fig. 1.9 Special-purpose vehicles

VEHICLE WEIGHTS & DIMENSIONS

Major weights and dimensions of a vehicle are explained below:

Weights

Payload

The total weight of passengers and cargo that a vehicle carries or can carry.

Gross Vehicle Weight (GVW)

GVW is the weight of the vehicle, plus the weight of all passengers the vehicle is designed to carry, plus the maximum allowable payload (passengers and cargo) or luggage load. It is also known as laden weight.

Curb Weight (CW) or Kerb Weight (KW)

CW is the weight of a vehicle wet, meaning with a full tank of fuel and all fluids filled, but without passengers or cargo (luggage).

Dimensions

(*a*) **Overall length:** The distance between the front and rear of the vehicle measured along the longitudinal centre line, including bumper guards, if the vehicle has them.

(*b*) **Overall width:** The maximum lateral distance measured between the sides of the vehicle. It includes bumpers, moldings, sheet metal protrusions, etc., measured to the outside of the metal.

(*c*) **Overall height:** The maximum vertical distance from the top of the roof to the road surface, measured with the vehicle in a curb weight condition.

(*d*) **Wheelbase:** The distance between the center lines of the front and rear axles.

(*e*) **Wheel tread (or) wheel track:** The distance between the longitudinal axes of the impressions (on the road surface) of the right and left wheels of a single axle of a vehicle.

(*f*) **Minimum running ground clearance:** The minimum clearance measured from ground with the vehicle in a gross vehicle weight condition.

(*g*) **Room length:** The horizontal distance along the vehicle's longitudinal (lengthwise) center line from the top of the instrument safety pad to the point directly above the top of the rear seatback.

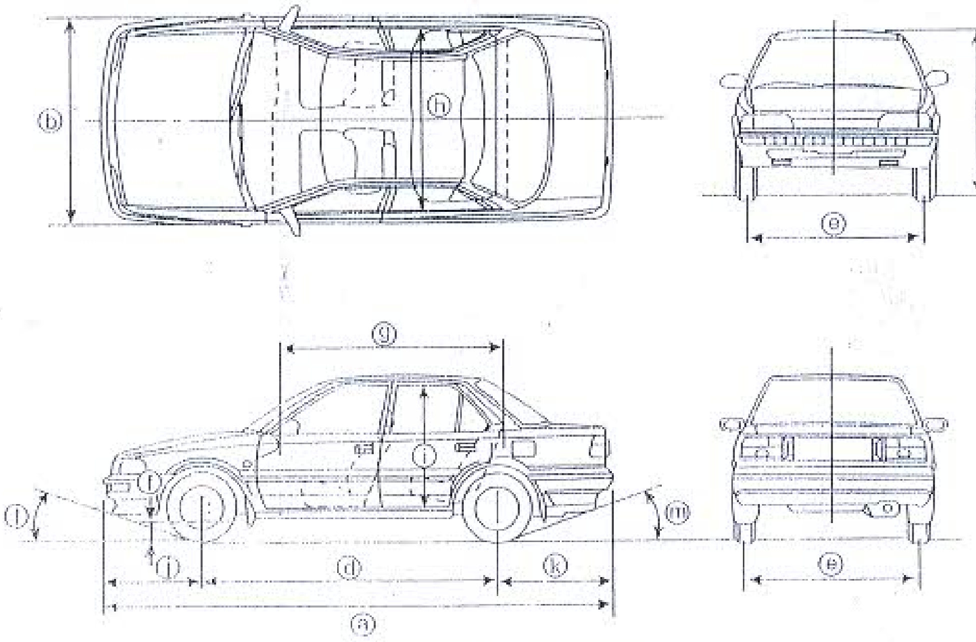

Fig. 1.10 Vehicle dimensions

(*h*) **Room width:** The maximum lateral distance between the trimmed interior body surfaces.

(*i*) **Room height:** The maximum vertical distance from the top of the floor covering to the headlining.

(*j*) **Overhang-front:** The distance from the center line of the front wheels to the front of the vehicle, including bumper guards if they are standard equipment.

(*k*) **Overhang-rear:** The distance from the center line of the rear wheels to the rear of the vehicle, including bumper guards if they are standard equipment.

(*l*) **Angle of approach:** The angle formed by the ground and the line tangent to the front tyre static loaded radius arc and the first point of interference (i.e. bumper, guard, gravel deflector, fender or other components excluding license plate).

(*m*) **Angle of departure:** The angle formed by the ground and the line tangent to the rear tyre static loaded radius arc and the first point of interference (i.e. bumper, guard, gravel deflector, tail pipe, fender or other components excluding license plate).

HISTORICAL DEVELOPMENT OF AUTOMOBILES

Development of the motor vehicle, that is to say a land based vehicle not limited to travelling on rails and driven by an engine or motor, received a decisive stimulus when the internal combustion engine was invented.

The pioneer years

1860 The Frenchman Lenoir constructs the first internal combustion engine capable of driving itself, with coal gas as a fuel. Efficiency was ~3%.

1867 Otto and Langen exhibit an improved internal combustion engine at the world exhibition in Paris. Efficiency was ~9%.

1878 Otto constructs the first gas engine using mixture compression and the four-stroke operating principle. Efficiency approx.15%. Almost simultaneously, the Englishman Clerk builds the first two-stroke gas engine.

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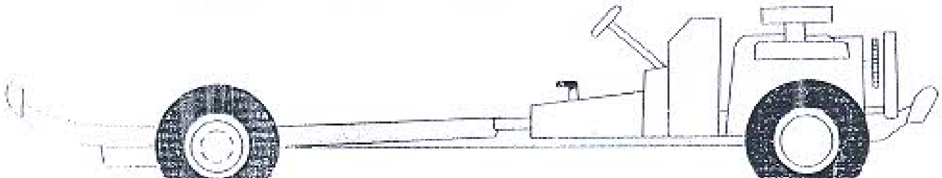
CHAPTER

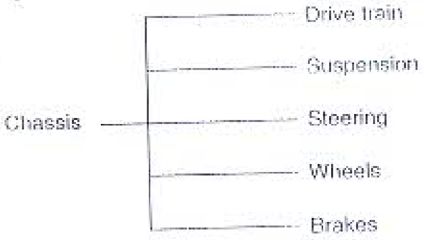
VEHICLE STRUCTURE

CHASSIS (OR) RUNNING GEAR

A VEHICLE WITHOUT BODY IS CALLED CHASSIS



The vehicle chassis includes the frame, engine, suspension system, steering system, and other mechanical parts with the body removed. These systems have direct impacts on riding comfort, the vehicle stability, steering feeling, etc, and vary widely in mechanisms and devices.



CHASSIS LAYOUT

Chassis layout refers to location of an engine and driveline components and also how power is transmitted from the engine to the drive wheels.

Chassis layout with reference to drive

Rear wheel drive

This layout has the engine in the front, mounted longitudinally, and the drive axle in the rear. The transmission is usually right behind the engine, and a drive shaft transfers power back to the rear axle. In this arrangement the rear wheels act as the driving wheels and the front wheels swivel to allow the vehicle to be steered. Spacing out the main components in this layout makes each unit accessible but a drawback is the intrusion of the transmission components into the passenger compartment. These create a large bulge in the region of the gearbox and a raised long bulge, called a tunnel, down the centre of the car floor for the accommodation of the propeller shaft. Using the rear wheels to propel the car utilizes the load transfer that takes place from the front to rear of the vehicle when the car is climbing a hill or accelerating and therefore good traction is obtained.

1997 Present Toyota Prius was launched in the Japanese market, in September 2010 reached worldwide cumulative sales of 2.0 million units, becoming the most iconic hybrid electric vehicle in the world.

1998 Present Ford Focus is one of the most popular hatchbacks across the globe, that is also one of Ford's best selling world cars.

2008 Present Tata Nano is an inexpensive, rear-engined, four-passenger city car built by the Indian company Tata Motors and is aimed primarily at the Indian domestic market.

2010 Present, Nissan Leaf and Chevrolet Volt, an all-electric car and a plug-in hybrid correspondingly, were launched in the U.S. and Japanese markets in December 2010, becoming the first mass production vehicles of their kind.

THE MOTOR VEHICLES ACT, 1988

This volume examines laws regarding motor vehicles and their operation, including traffic violations and infractions, with significant focus on two major areas of public interest: speeding, and drinking and driving. It covers laws related to victims of accidents, young drivers, licensing requirements, vehicle safety issues, helmet use laws, seat belts, child restraints, and air bags, and the Transportation Equity Act.

The first enactment relating to motor vehicles in India was the Indian Motor Vehicles Act, 1914, which was subsequently replaced by the Motor Vehicles Act, 1939. The Act of 1939 had been amended several times. Inspite of several amendments it was felt necessary to bring out a comprehensive legislation keeping in view the changes in the transport technology, pattern of passenger and freight movements, development of the road network in the country and particularly the improved techniques in the motor vehicles management. Various committees as well as the Law Commission had gone into different aspects of road transport. Several members of parliament have also urged for comprehensive review of the Motor Vehicles act, 1939. A working group was, therefore, constituted in January, 1984 to review all the provisions of the act of 1939. This working group took into account the suggestions and recommendations earlier made by various bodies and institutions and made certain recommendations. On the recommendations of the working group state governments were asked to submit their comments. The recommendations made by the working group and comments received from the state governments were discussed at a special meeting of transport ministers of all states and union territories. Based on the conclusions reached in the meeting of transport ministers and suggestions made by the Supreme Court in a case the motor vehicles bill was introduced in the parliament.

Review Questions

1. What is meant by Automobile?
2. List the components of an automobile.
3. Who invented automobile?
4. Who first commercially manufactured motor vehicles?
5. What are the different types of motor vehicles on the basis of their construction?
6. What are the main units of a motorcar?
7. Which car set the pattern for many of those in use today?
8. Define body of a car.
9. What are the nominal requirements of a body?
10. What is meant by a saloon body?
11. What is meant by a coupe in an automobile?

the body is a part of the vehicle that carries the driver or passengers or cargo. It is made of steel sheets 0.6mm to 3mm thick welded into a box shape. It's a beam supported at each end by the wheels. so it has to be strong enough not to sag in the middle

(7)

long wheels. So it has to be strong enough not to sag in the middle. A car must also have torsional stiffness i.e. the ability to resist the twisting stresses imposed by any irregular road surface. Structural strength is also necessary to cope with particular loads, such as the weight of the engine, thrust of the springs and minor impacts.

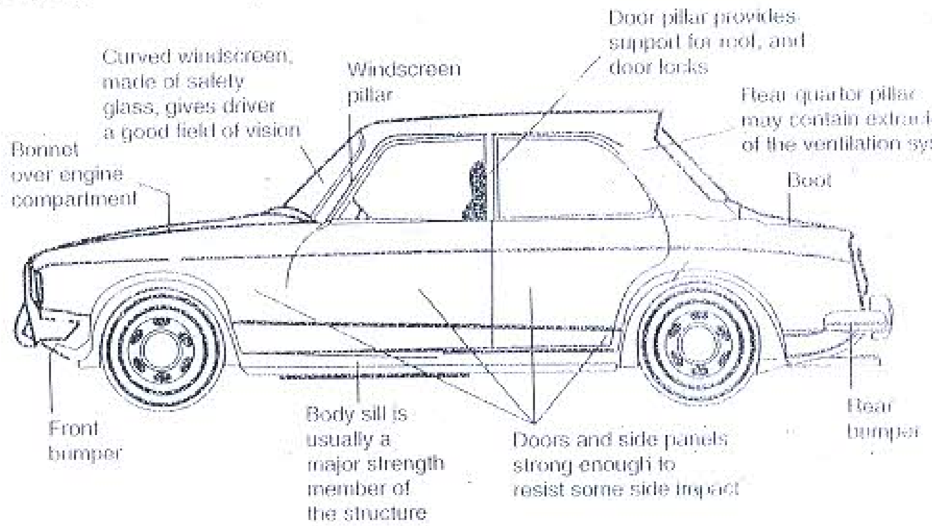


Fig. 2.14 Parts of a car body

The main parts of the car body are:

- **Bonnet** (or hood) over the engine compartment.
- Curved **windscreen**, made of safety glass, gives driver a good field of vision.
- **Windscreen pillar** provides support for windscreen glass.
- **Body sill** is usually a major strength member of the structure.
- **Door pillar** provides support for roof, and carries hinges and door locks.
- **Rear quarter pillar** may contain extractors of the ventilation system.
- **Boot** over the luggage compartment.
- **Doors and side panels** strong enough to resist some side impact.
- **Bumpers**, a horizontal bar fixed across the front or back of a motor vehicle to reduce serious damage in a collision or as a trim
- **Floor panels** ribbed for stiffness.

Bodywork materials

Steel (mild steel) is still the cheapest and the most efficient material for mass-produced separate bodies. It is strong and easily formed. The parts are stamped out by machine presses from varying thicknesses of sheet steel. Apart from steel, cast iron, aluminum, magnesium, copper, zinc, glass, and polymers are also the most commonly used materials.

Styling forms and role of stylist

Designing a form based on artistic vision is known as 'styling'. Styling enables high-volume production articles to be both attractive and functional. In fact in an age where mechanical reliability is almost automatic it is aesthetic value that provides the truly commercial success of a specific product.

Thus the stylists responsibilities in modern industry cover a very wide range. That is today's automotive stylist is required to be a combination of artist, inventor, craftsman, engineer and to some extent psychologist. He must have the ability to conceive new ideas with inventive flair and imagination and bring them to an economical reality using modern techniques and facilities, correctly selecting for the specific project in hand. To do this, he must thoroughly understand the product, its function and its appeal, have a thorough knowledge of the materials available, costs, capacities of the machinery from which the product is to be made, in an economical manner, as well as sources of supply and so on and be constantly aware of worldwide changes in customs and tastes. His responsibilities include the conception, detail design and development of all new products and the form, both visual and ergonomic, which the product must take. In the case of automobile, this constitutes the exterior form and all applied finishers, the complete interior, control instrumentation, seating, etc and colours and textures of everything visible outside and inside the vehicle.

Body styling has to accommodate passengers and luggage space, the functional power train, steering, suspension and wheels, etc. Thus vehicle design will conflict with minimizing the body surface drag so that the body shape finally accepted is nearly always a compromise. The following are some of the body styles used for cars.

Saloon (or) Sedan

The basic car body shape is the saloon, with two or four doors and a luggage compartment at the front or rear. The shape of body shell is based on three 'boxes'. The front box forms the engine compartment, the centre section the container for the occupants and the rear box a storage space, called a boot (trunk) for the luggage. This type has the features such as well designed seats, ease of entry and exit, good heating and ventilation system and better styling.

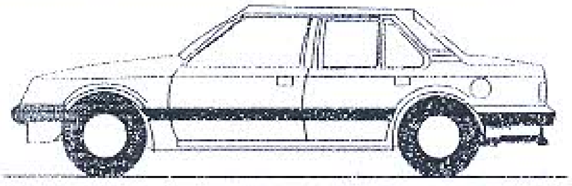
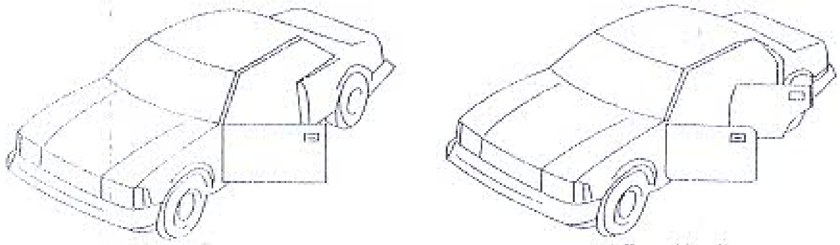


Fig. 2.15 Saloon

Hardtop

Hardtop passenger vehicles also have front and back seats and are generally characterized by their lack of door pillars or 'B' pillars. They can also be classified as either a 2 or 4-door hardtop.



2-Door Hardtop 4-Door Hardtop

Fig. 2.16 Hardtop

Hatchback (or) Lift back

This type is half-way between a saloon and an estate car. The distinguishing feature of this type of vehicles is their rear luggage compartment, which is an extension of the passenger compartment. Access to the luggage compartment is gained through an upward opening hatch door from which this type of vehicle derives its name. This type of vehicles comes in 3 and 5-door versions.

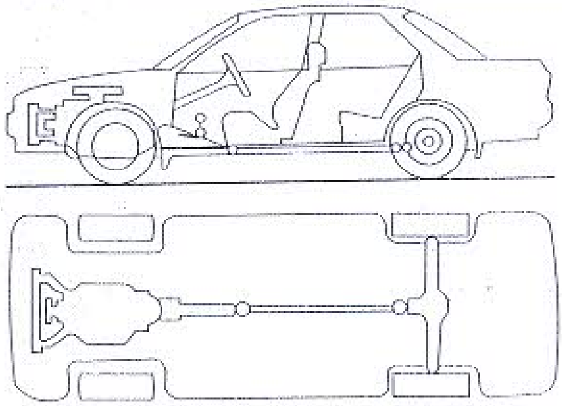


Fig. 2.1 Front engine rear-wheel drive

Front wheel drive

The compactness of the layout has made it very popular for use on cars. The vehicle has both the engine and transaxle in the front. Accommodating all the main components under the bonnet (hood) in one compartment give maximum space within the car for the occupants, also the absence of floor bulges and tunnel provides more room for the rear passengers. Transverse mounting of the engine simplifies the transmission, because the output shafts from the engine and gearbox move in a similar direction to the wheels. This avoids the need for a bevel-type final drive. Instead a simple reduction gear, incorporating a differential, transmits the power by short drive shafts to the road wheels. The heavy drive train adds weight to the front drive wheels for good traction on slippery pavement. Mounting the main units in one assembly sometimes makes it difficult to gain access to some parts.

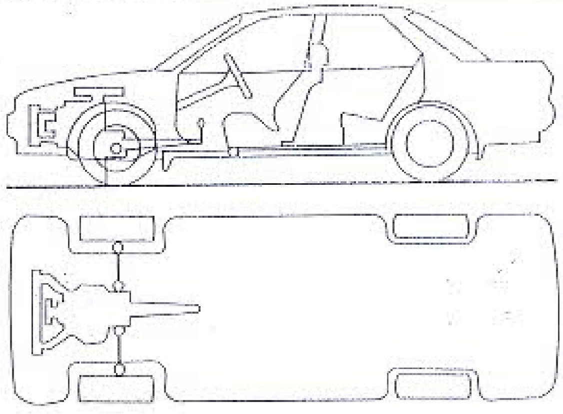


Fig. 2.2 Front engine front-wheel drive

The major criticism of front-wheel drive is that the driving wheels have less grip on the road when the vehicle is accelerating and hill-climbing. Although this characteristic can be partly corrected by placing the engine well forward to increase the load on the driving wheels, the car is then liable to become "nose-heavy". The effect of this is to make the steering of the car more difficult. For this case the car is to be fitted with power steering. Using the front wheels for steering allows the driving force to act in the same direction as the wheel is pointing. This feature improves vehicle handling especially in slippery conditions.

Four wheel drive

This arrangement is safer because it distributes the drive to all four wheels. The sharing of the load between the four wheels during acceleration reduces the risks of wheel spin. Also the positive drive to each wheel during braking minimizes the possibility of wheel lock-up. A further advantage of this layout is when the vehicle is driven on slippery surfaces such as snow and mud. When on an icy road or driven cross-country (off-highway), a two-wheel drive vehicle soon becomes undrivable because the loss of grip of one of the driving wheels causes the wheel to spin.

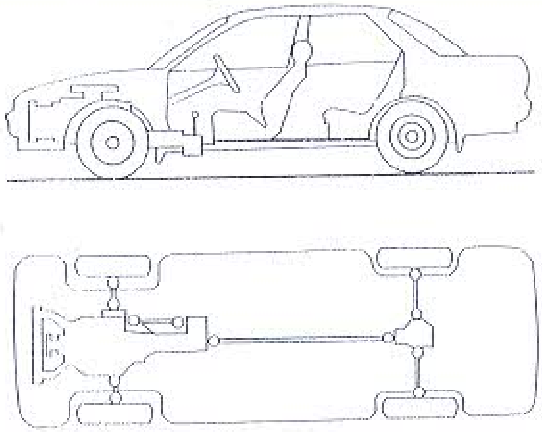


Fig. 2.3: Four-wheel drive

Chassis layout with reference to power plant location

Front engine

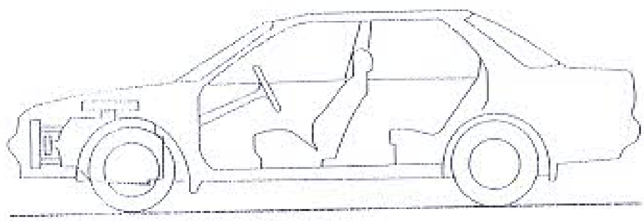


Fig. 2.4 Front-engine vehicle

Apart from tradition there are number of reasons for sitting the engine at the front of a car. The large mass of an engine at the front of the car gives the driver protection in the event of a head-on collision. Also engine cooling is simpler to arrange. In addition, the cornering ability of a vehicle is normally better if the weight is concentrated at the front. One of the main advantage is that engine can be controlled easily by the driver.

Rear engine

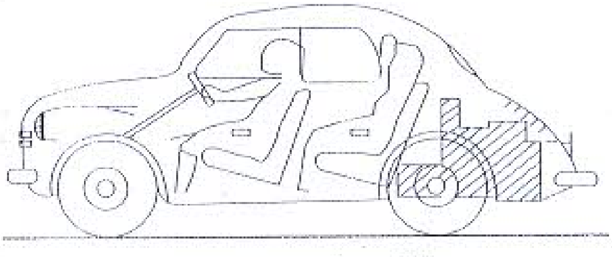


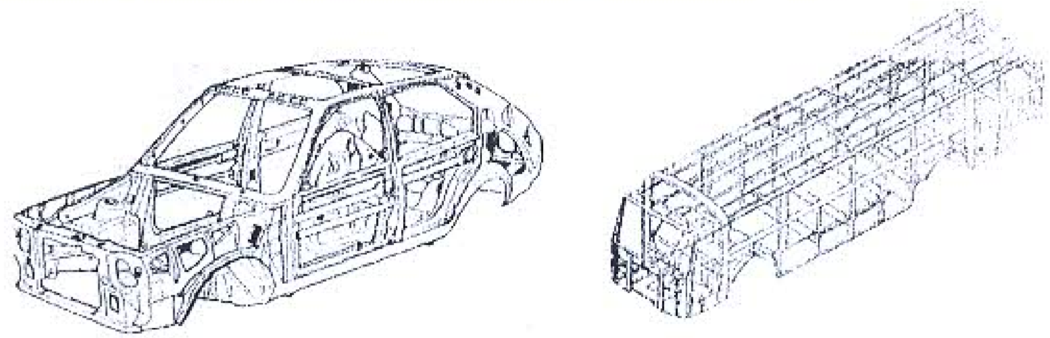
Fig. 2.5 Rear-engine vehicle

Most rear-engine layouts have been confined to comparatively small cars, because the heavy engine at the rear has an adverse effect on the 'handling' of the car by making it 'tail heavy'. Also it takes up a good deal of space that would be used on a front-engined car for carrying luggage. Most in the chassis frame than a SUV/passenger car engine and therefore there is more space available for the front road wheels to turn on the larger vehicle and the ground clearance is greater.

Unitized body design (Frameless construction)

Today, almost all passenger cars, most vanes and even some buses are of integral construction, also known as integral or monocoque construction.

In this type of construction heavy side members used in conventional construction are eliminated and the floor is strengthened by cross members and the body, all welded.



(a) (b)

Fig. 2.9 Unitized body designs: (a) passenger car and (b) bus

Most of the modern cars have this integral construction. In this body design, the frame and body are combined as one unit. All the members of a unitized body are load carrying members. Panels or members that share the load are called stressed panels. Very often their creases and bends are there to increase strength rather than change the vehicle's appearance. Unstressed panels are those that do not contribute significantly to the strength of the structure. The floor pan, roof, inner aprons, quarter panels, pillars and rocker panels are integrally joined to form an unitized body. The unitized body has a complex design that spreads collision forces throughout the body to help protect the vehicle occupants.

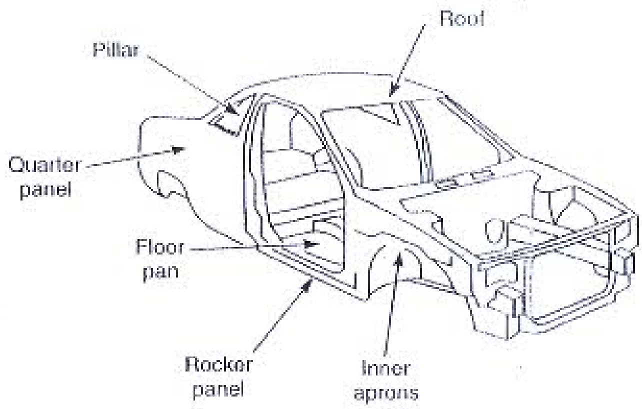


Fig. 2.10 Parts of an unitized body of a car

The strength and rigidity of the unitized body is achieved by body design rather than by having a heavy steel frame to support the body. In this body design, body sheet metal is fabricated into a box design which provides good resistance to bending and torsion.

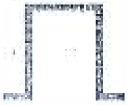
The advantages of this construction are low weight and the ability to style the outer body panels as desired.

Design and production costs are very high, which means that integral construction is used only for mass-produced vehicles. A further disadvantage of this type of construction is that the resulting box-like shape tends to amplify road and engine noise for the occupants. Special sound-deadening materials are used to minimize the transmission of noise.

FRAME SECTIONS

In order to provide a good resistance to bending and torsional effect, the frame sections are made of proper forms.

Table 2.1 Frame sections and behaviours

Frame Section	Behaviour
Flat	Offers little resistance to bending and twisting.
Channel 	Excellent resistance to bending. Resistance increases as depth of section is increased.
Tubular 	Excellent resistance to torsion. Resistance increases as diameter is increased.
Box 	Good resistance to both bending and torsion.
Top-hat 	Not commonly used due to weakness and a propensity to rust.
I 	Good resistance to both bending and torsion.

Channel section is usually employed for the side members as it provides good resistance to vertical bending loads, but with minimum weight. A further advantage of channel section is that it allows easy attachment of the cross members and mounting of other components. However, channel section provides only a limited resistance to torsion forces (i.e. poor in torsion) and is therefore unsuitable for the construction of cross members. As the cross members must be capable of resisting torsional effects, they may be formed from tubular or circular section, although for convenience a box section is sometimes employed.

Various other material sections may be used for the construction of cross members. These include the top-hat section and the I-section which is manufactured from two channel sections placed back-to-back. Provided the correct material section is used, the chassis frame can be made rigid enough to withstand the loads placed upon it.

FRAME MATERIALS

Frames are usually made of steel or aluminium and sometimes composite materials. Most frames used on light vehicles are made of low-carbon steel having a carbon content of 0.15-0.25

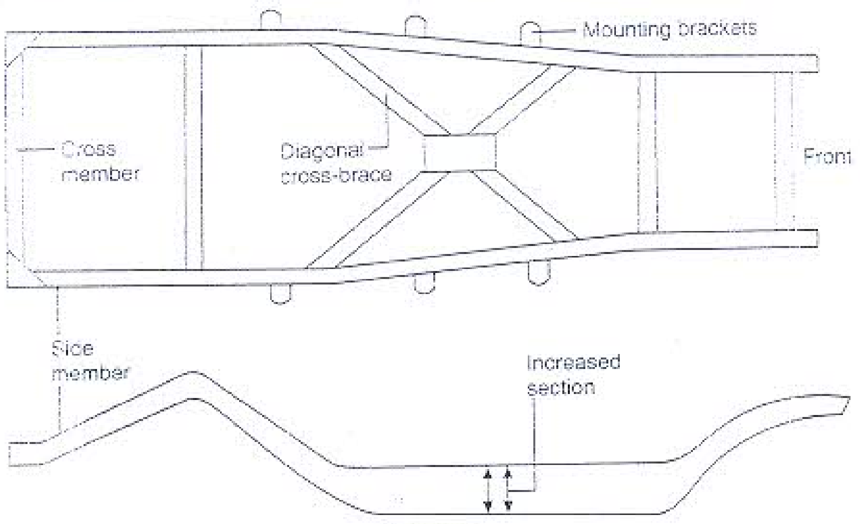
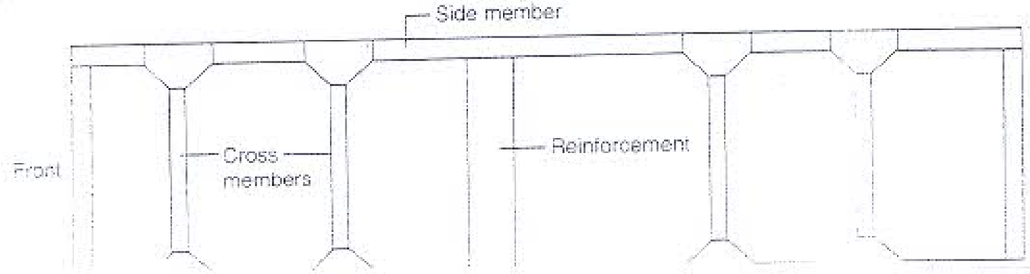


Fig. 2.7 SUV/Passenger car chassis frame

The front and rear ends of the side members are swept upwards (curved upwards) to accommodate the movement of the axle due to springing and also kept the chassis height low (lower ground clearance). This also avoids impact due to the rear axle bouncing. It is also common practice to provide the side members with an increased depth of section towards the centre, where there is a tendency for the greatest bending loads to occur. A number of brackets are attached to the main chassis members to provide a means of mounting and securing the vehicle body and components.

Although the use of a separate chassis frame is now restricted to low volume production cars it is still the main method of construction of commercial vehicle chassis.

Conventional construction for commercial vehicles

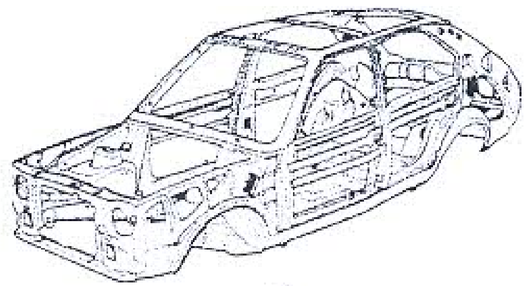
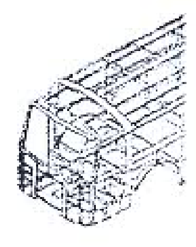


in the chassis frame than a SUV/passenger car engine and therefore there
the front road wheels to turn on the larger vehicle and the ground clearan

Unitized body design (Frameless construction)

Today, almost all passenger cars, most vanes and even some buses a
also known as integral or monocoque construction.

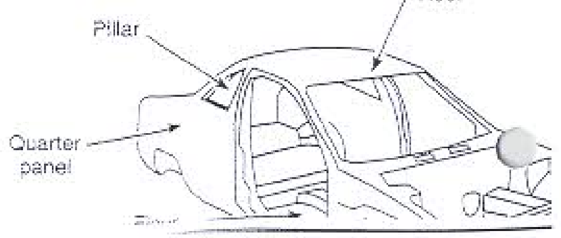
In this type of construction heavy side members used in conventio
nated and the floor is strengthened by cross members and the body, all w

(a)

Fig. 2.9 Unitized body designs: (a) passenger car and (

Most of the modern cars have this integral construction. In this body
are combined as one unit. All the members of a unitized body are load ca
members that share the load are called stressed panels. Very often their c
to increase strength rather than change the vehicle's appearance. Unstress
not contribute significantly to the strength of the structure. The floor pan,
panels, pillars and rocker panels are integrally joined to form an unitize
has a complex design that spreads collision forces throughout the body
occupants.



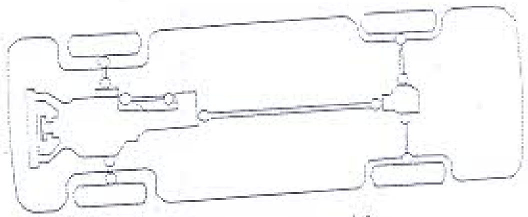


Fig. 2.3: Four-wheel drive

th reference to power plant location

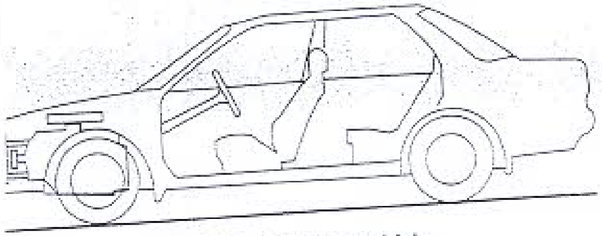


Fig. 2.4 Front-engine vehicle

on there are number of reasons for sitting the engine at the front of a car. The ıe at the front of the car gives the driver protection in the event of a head-on cooling is simpler to arrange. In addition, the cornering ability of a vehicle is weight is concentrated at the front. One of the main advantage is that engine ly by the driver.

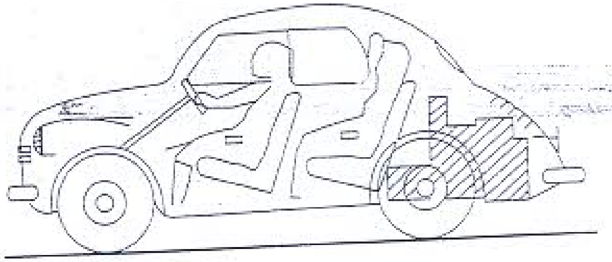


Fig. 2.5 Rear-engine vehicle

ıe layouts have been confined to comparatively small cars, because the heavy s an adverse effect on the 'handling' of the car by making it 'tail heavy'. Also it l of space that would be used on a front-engined car for carrying luggage. Most

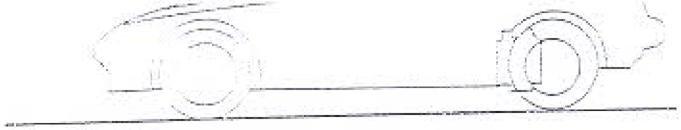


Fig. 2.5 Mid-engine vehicle

The term mid-engine is used because the engine is mounted in front of the rear axle line. This situations generally apply to sports cars because the engine sitting gives a load distribution that achieves both good handling and maximum traction from the driving wheels.

CHASSIS FRAME

The vehicle frame is a high-strength structure used to support all other parts of the vehicle. Besides bolt-on body panels, the frame holds the engine, transmission, suspension, and other parts in position. The frame can be separate from the body or integrated into the body shell as in the case of unitized body design.

Purpose of a frame

The vehicle frame is used:

- to support engine, body, road wheels and transmission assemblies.
- to withstand the accelerating and braking torque.
- to accommodate suspension system.
- to resist centrifugal force while taking a turn.
- to withstand bending and twisting stresses due to the fluctuation of rear and front axle.

Constructional details

The chassis frame is usually constructed from steel pressings which may be welded, riveted or bolted together and reinforced where necessary. There are two major types: conventional construction and unitized body construction.

Conventional construction

In this type of chassis construction the frame is the basic unit to which various components are attached and body is bolted on the frame later on. It is also known as framed construction.

Conventional construction for passenger cars

The actual chassis frame consists of two longitudinal members which are referred to as side members. These members are braced by cross members (horizontal members) at the front and rear of the frame. To improve the torsional stiffness of the frame a diagonal cross-brace arrangement is added to the centre of the frame. The side members must taper in (narrow) at the front to provide shorter turning radius of front wheel and give improved support to the engine assembly. It is widening out at the rear end to provide a bigger space for body.

springs are fitted at the rear to support the extra load. Station wagons come in 2 and 4-door versions. More luggage space and longer wheel base are a specialty. Used for touring, picnics, etc.

Limousine

Limousine is the luxury car. The term now refers to a luxury sedan or saloon car, especially one with a lengthened wheelbase or driven by a chauffeur. It is usually with high quality equipments and best finish. Cushioned seats, air conditioning system, cooling glasses, etc., are other features.

Fig. 2.21 Limousine

Racing car

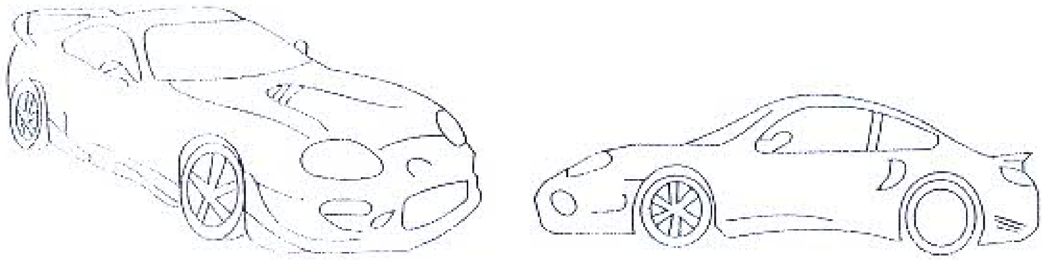


Fig. 2.22 Racing cars

Two prime criterias for racing cars are (1) lightness coupled with rigidity regardless of comfort and (2) body design must comply with the rules of the race or event such as length, width and height of car, engine capacity, fuel capacity, etc. Better aerodynamic shape reduces is the unique feature of this design.

VEHICLE BODY AERODYNAMICS

Aerodynamics is a branch of physics and is concerned with all the processes which can be observed when air flows around a body. This study deals with a solid body moving through the atmosphere and the interaction which takes place between the body surfaces and the surrounding air with varying relative speeds and wind direction.

Economy is of decisive importance in the transport sector. The most important factors in reducing fuel consumption in long distance traffic with its high average speeds are the economy of the drive train and aerodynamics.

As regards aerodynamics, the following are some of the features incorporated into the vehicle design.

- Large corner radii on the front section
- Low-level front skirts
- Fairings above and behind the driver's cab
- Aerodynamically shaped mirrors
- Enclosed steps

In addition to optimizing the shape of the driver's cab in terms of air flow to improve fuel consumption, there are a number of other aims to be considered in aerodynamic design, namely:

- Intensive air flow around cooling units
- Optimized air-flow through the interior of cab

- Minimizing dirt deposition on visible areas
- Reducing impairment of the vision of other drivers in the wet

Importance of aerodynamic study

With proper aerodynamic design, the following advantages could be achieved

1. Drag force is reduced. So maximum speed and acceleration are obtained for the same power output.
2. Fuel consumption of the vehicle can be reduced to the maximum (about 35% of fuel cost).
3. Gives better appearance and styling.
4. By reducing the various forces and moments, good stability and safety can be achieved.
5. Helps to provide proper ventilation system.
6. Helps to understand the dirt flow and exhaust gas flow patterns.
7. Aerodynamic noise could be reduced which results in quite running of the vehicle.

AERODYNAMIC DRAG

This study concerns about the airflow around the vehicle body. Drag is caused by the movement of a vehicle in the atmosphere. This term is used to describe the resistance presented by the air to the moving object as it progresses. Aerodynamic drag is usually insignificant at low vehicle speed but the magnitude of air resistance becomes considerable with rising speed. This can be seen in Fig. 2.23 which compares the aerodynamic drag forces of a poorly streamlined and a very highly streamlined medium sized car against its constant rolling resistance over a typical speed range. A vehicle with a high drag resistance tends only marginally to hinder its acceleration but it does inhibit its maximum speed and increases the fuel consumption with increasing speed.

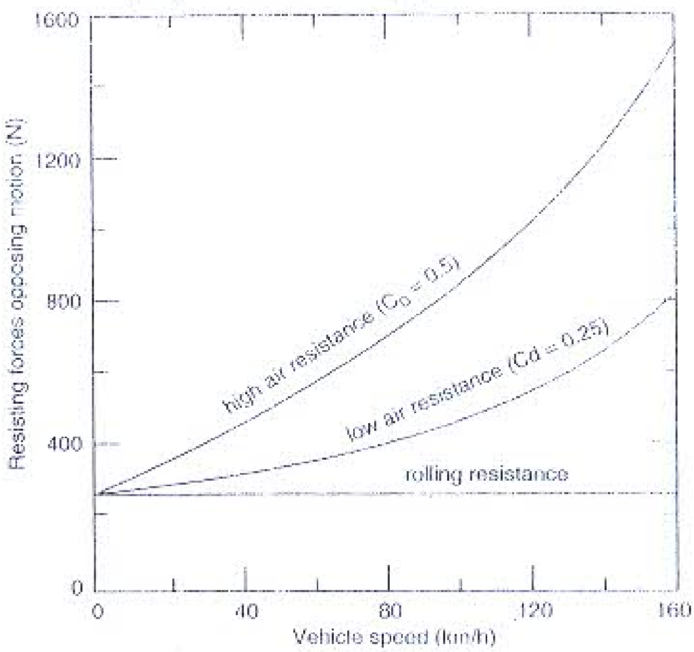


Fig. 2.23 Comparison of low and high aerodynamic drag forces with rolling resistance

Drag force depends on the following factors:

- The size and shape of the vehicle (area of nose end, vehicle super structures, shape of the loads being carried).

- Travel speed.
- Air density (air density decreases at higher temperatures and increases at higher atmospheric pressure).
- Wind direction and strength.

The aerodynamic resistance of a vehicle in air is referred to as drag force F_L. It is calculated according to the following formula:

$$F_L = \frac{1}{2} Cd\, A \rho v^2$$

Cd : Vehicle's drag co-efficient

A : Area of vehicle's nose end

ρ : Density of air

v : Velocity of the vehicle

To overcome drag, a vehicle must develop a specific amount of power. The drag power P_L is the result of drag force multiplied by travel speed v:

$$P_L = F_L\, v = \frac{1}{2} Cd\, A \rho\, v^3$$

At increasing travel speed, drag force increases by a power of two and drag power by a power of three. The increase in drag is as the square of the speed, i.e. if the speed doubles, the drag quadruples.

TYPES OF DRAG

The drag force is most easily understood if it is broken down into five constituent elements. This include:

(*a*) Pressure drag – 57%

(*b*) Induced drag – 8%

(*c*) Friction drag – 10%

(*d*) Interference drag – 15% and

(*e*) Cooling and ventilation system drag – 10%

(a) Pressure drag (or) Form drag (or) Profile drag

The most significant of the five in relation to road vehicles is the form drag which is the component that is most closely identified with the external shape of the vehicle. As a vehicle moves forward the motion of the air around it gives rise to pressures that vary over the entire body surface as shown in Fig. 2.24. If a small element of the surface area is considered then the force component acting along the axis of the car, the drag force, depends upon the magnitude of the pressure, the area of the element upon which it acts and the inclination of that surface element (Fig.2.25). Thus it is possible for two different designs, each having a similar frontal area, to have very different values of form drag.

Form drag depends upon the longitudinal section of the vehicle body. For low drag coefficient a careful choice of body profile is essential, i.e.

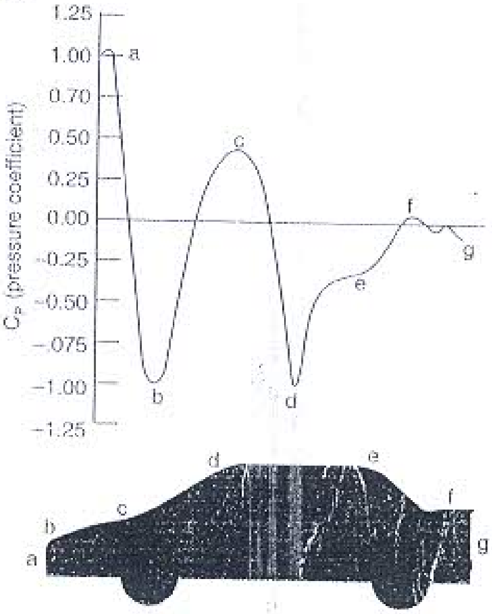


Fig. 2.24 Typical static pressure coefficient distribution

streamlines should be continuous and separation of boundary layer with its vortices should be avoided.

Body shapes that minimize positive aerodynamic forces on the front of the vehicle and minimize negative aerodynamic forces or suction on the rear of the vehicle will exhibit low form drag. The trend to lower vehicles has reduced the frontal area significantly which has reduced form drag appreciably. Constantly retarding fast back bodies may lead to passenger car shape of relatively low form drag.

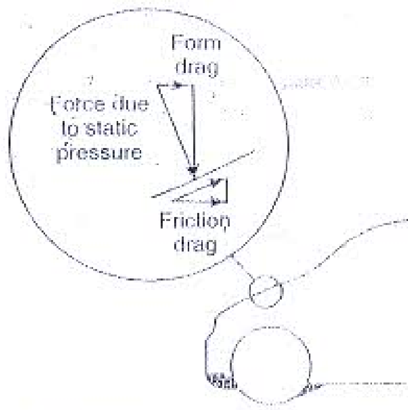


Fig. 2.25 The force acting on a surface element

(b) Friction drag (or) Surface drag

As air flows across the surface of the car frictional forces are generated giving rise to the second drag component which is usually referred to as surface drag or skin friction drag. If the viscosity of air is considered to be almost constant, the frictional forces at any point on the body surface depend upon the shear stresses generated in the boundary layer. The boundary layer is that layer of fluid close to the surface in which the air velocity changes from zero at the surface (relative to the vehicle) to its local maximum some distance from the surface.

This is caused by friction force between the boundary layer and the body surface. If this surface is kept smooth, a laminar boundary layer will be maintained. Thus a well-polished surface is not only attractive but also makes the vehicle more economical.

Body paint surface roughness has considerable effect on friction drag. Body smoothness is of the order of 0.5 to 1.0 microns.

(c) Induced drag (or) Lift drag

A consequence of the constraints imposed by realistic passenger space and mechanical design requirements is the creation of a profile which in most situations is found to generate a force with a vertical component. That lift, whether positive (upwards) or negative, induces changes in the character of the flow which the selves create an induced drag force. This is caused by vortices formed at the side of the vehicle. These vortices are in turn caused by the aerodynamic lift of the vehicle.

A car body produces accelerated air flow and the corresponding low pressure on its upper surface, especially in such areas of the lending edge of the hood, wind shield corners and the leading edge of the roof. Because of the low pressure developed on the upper surface than on the under body, aerodynamic lift results. This lift force depends on the contour of the body, underbody and ground clearance.

Lift is not a serious problem at normal speeds but it possesses a serious problem at very high speeds such as in racing cars. It also affects stability and braking performance of the vehicle. In general modification to the body so as to reduce accelerated flow and corresponding low pressure on the upper side and to reduce deceleration flow and corresponding high pressure on the underside of the body will reduce the aerodynamic lift.

(d) Interference drag

The flow over many exterior components interact with the flow over basic body shape and this lead to interference drag. Exterior components include projecting door handles, mirrors, aerials and badges which project out of the normal surface of the body. Also projectors below the vehicle such as axles, etc contribute towards the interference drag.

The various mechanical components project from under the vehicle such as an engine parts, suspension arms, exhaust system, frame rail and rear suspension also contribute to the interference drag on the vehicle under body.Exterior body ornaments must be placed where the velocity is minimum. Door handles must be placed in a close proximity and longitudinally in line with each other.

(c) Internal drag (or) Cooling and ventilation system drag

The last of the major influences upon vehicle drag is that arising from the cooling of the engine, the cooling of other mechanical components such as the brakes and from cabin ventilation flows. Together these internal drag sources may typically contribute in excess of 10% of the overall drag.

DRAG CO-EFFICIENT (Cd)

The aerodynamic drag coefficient is a measure of the effectiveness of a streamline aerodynamic body shape in reducing the air resistance to the forward motion of a vehicle. Low Cd values indicate low drag and allow a higher terminal speed and lower fuel consumption. A low drag coefficient implies that the streamline shape of the vehicle's body is such as to enable it to move easily through the surrounding viscous air with the minimum of resistance. Conversely a high drag coefficient is caused by poor streamlining of the body profile so that there is a high air resistance when the vehicle is in motion. The drag coefficient is calculated in tests carried out in aerodynamic or wind tunnels. It indicates the magnitude of a vehicle's drag as a result of its shape.

Typical drag coefficients for various classes of vehicles can be seen as follows:

Vehicle type	Drag coefficient (Cd)
Saloon car	0.22 – 0.4
Sports car	0.28 – 0.4
Light van	0.35 – 0.5
Buses and coaches	0.4 – 0.8
Articulated trucks	0.55 – 0.8
Ridged truck and draw bar trailer	0.7 – 0.9

The drag coefficient of a vehicle can be significantly reduced by rounding the front section and using a front apron, a roof spoiler and side skirts. Only a slight improvement in the drag coefficient is possible by altering the external shape of a commercial vehicle body since rounding the corners and edges reduces the load space and hence the payload. In combination with air deflectors, an aerodynamically optimized cab provides significant reductions in the drag of the vehicle as a whole.

Another measure for reducing resistance is to enclose the exposed running gear of the vehicle with fairings. This reduces the air resistance of the vehicle especially in a cross-wind.

AERODYNAMIC FORCES

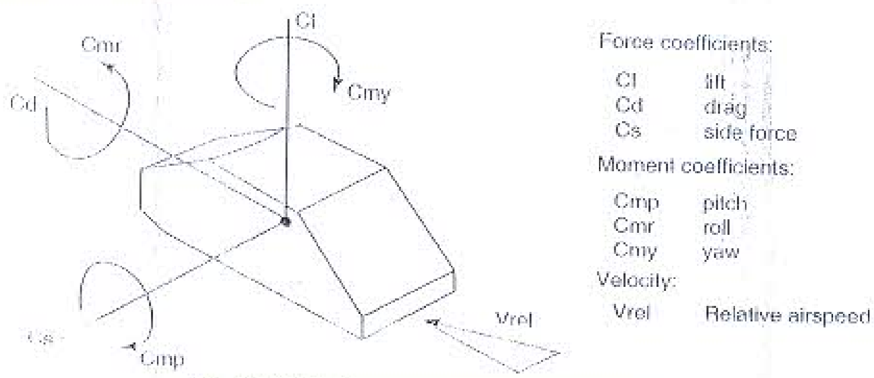


Fig. 2.26 Lift, drag, side force and moment axes

Aerodynamic research initially focused upon drag reduction, but it soon became apparent that the lift and side forces were also of great significance in terms of vehicle stability.

The aerodynamic forces and moments that act upon a vehicle are shown in coefficient form in Fig. 2.26. The forces may be considered to act along three, mutually perpendicular axes. Those forces are the drag, which is a measure of the aerodynamic force that resists the forward motion of the car, the lift which may act upwards or downwards and the side force which only occurs in the event of a cross-wind or when the vehicle is in close proximity to another. The lift, drag and pitching moments are a measure of the tendency of those three forces to cause the car to rotate about some datum, usually the centre of gravity. The moment effect is most easily observed in cross-wind conditions when the effective aerodynamic side force acts forward of the centre of gravity, resulting in the vehicle tending to steer away from the wind. In extreme, gusting conditions the steering correction made by the driver can lead to a loss of control.

In order to analyze the various aerodynamic forces and moments acting on the vehicle body, consider the vehicle as a mass having six degrees of freedom.

Now the various aerodynamic forces acting on the vehicle body can be summarized as follows:

Px – Force of air drag in the direction of motion with wind angle along the longitudinal axis

Py – Cross wind force

Pz – Aerodynamic lift

Longitudinal air drag (Px)

The longitudinal component of the resultant of pressure distribution is called longitudinal air drag. The magnitude of this component can be represented by,

$$Px = Cx\ \rho\ A\ v^2 / 2$$

Where,

Cx - Longitudinal wind force dimensionless co-efficient

ρ - Air density in kg/m³

v - Velocity of wind in m/s

A - Cross sectional area of the vehicle viewed from the front in m.

Cross wind force (Py)

It is formed by the asymmetric flow of air around the vehicle body when the wind angle is not equal to zero. The cross wind force can be given as

$$Py = Cy\ \rho\ A\ v^2 / 2$$

Where,

Cy - Cross wind force dimensionless co-efficient

Aerodynamic lift (Pz)

It is the vertical component of the resultant of the pressure distribution over the vehicle body due to flow of air around it. The aerodynamic lift can be represented as

$$Pz = Cz\ \rho\ A\ v^2 / 2$$

Where,

Cz - Lift co-efficient

The lift will tend to reduce the pressure between the wheels and the ground, which causes losses of steering on the front axle and the loss of friction on the rear axle. The magnitude of this lift and its distribution over the front and rear is a function of ground clearance, the contours of the body and the underbody and the angle of attack of the air on the vehicle body.

Since these factors are not acting at the CG of the vehicle body but at the centre of pressure, they create the following three aerodynamic moments:

Mx - Rolling moment

My - Pitching moment

Mz - Yawing moment

Rolling moment (Mx)

This moment is caused by the cross wind force Py about the longitudinal axis. This magnitude of this rolling moment is given by

$$Mx = Py\ a = Cmx\ \rho\ A\ L\ v^2 / 2$$

Where,

a - Height of centre of thrust above CG

Cmx - Rolling moment coefficient

L - Reference length

The rolling moment effects the weight distribution on the wheels. This effect is dangerous for tall vans where the side force acts much above the CG. The only near solution to reduce rolling moment is to increase the wheel track.

Pitching moment (My)

This moment is caused about Y-axis by cross wind force Py or the longitudinal force Px. The pitching moment My is given by

$$My = Px\ b = Cmy\ \rho\ A\ L\ v^2 / 2$$

Where,

b - Distance between CG and CP

Cmy - Pitching moment coefficient

L - Reference length of the wheel base

The pitching moment is usually negative i.e., nose down and this moves. The rear axle lifts off the ground and further reduces the available traction.

Yawing moment (Mz)

This moment is caused about Z-axis by cross wind force Py. The yawing moment Mz is given by

$$Mz = Py\ c = Cmz\ \rho\ A\ L\ v^2 / 2$$

Where,

c - Distance between CG and CP

Cmz- Yawing moment coefficient

L - Reference length

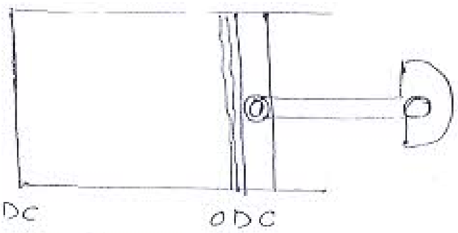
These moments adversely affects the directional stability of the vehicle at high speed. The use of stabilizer fins at the rear of the vehicle gives a very good reduction in yawing moment.

Both aerodynamic lift and pitching moment have undesirable effects. The lift will tend to reduce the pressure between the wheels and the ground, which causes loss of steering on the front axle and loss of traction on the rear axle. Pitching moment is usually negative that is nose down and this makes the rear axle lift off the ground and further reduce the available traction.

> Note:
>
> **CG – is the point where the whole mass of a system is assumed to be act.**
>
> **CP – is the point where the total pressure acts on the system.**

Engine performance

when the ~~cylinder~~ piston moves from one end of the cylinder to the other, it displace air equal to the volume of cylinder.



piston displacement volume or swept volume

$$V = \frac{\pi}{4} D^2 \times L \times N$$

V = piston displacement volume

D = cylinder bore

L = stroke length

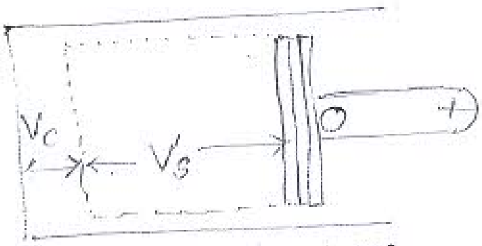
N = no of cylinders.

mean effective press (P_m)

It is defined as the hypothetical pressure which is acting on the piston ~~dur~~ throughout the power stroke.

$$\text{W.D/cycle} = P_m \times V_s$$

compression ratio (r)



Let V_c = clearance volume

V_s = stroke volume

V_{Total} = Total volume = $V_c + V_s$

r = comp ratio

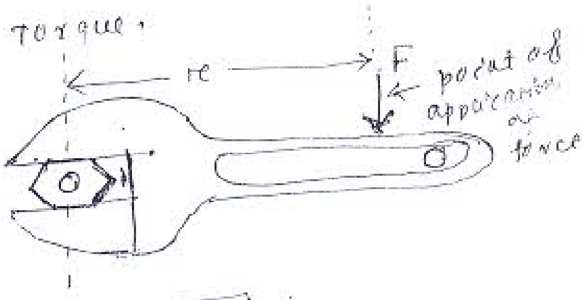
It is defined as the ratio between total volume and clearance volume

$$r = \frac{V_c + V_s}{V_c}$$

Engine Torque:-

Defn of Torque.

exp:- For tightening a bolt with the wrench, the force used to turn the bolt is Torque.



$$T = F \times r \quad Nm$$

Torque tending to turn the bolt is the product of the force and the distance from the centre of the bolt to the point where the force is applied. therefore if greater Torque is required a longer wrench should be used or more force applied

I.P (Indicated power):-

the power developed inside the engine cylinder

Indicated power per cylinder

$$I.P = \frac{P_m A L N}{n}$$

$P_m = N/m^2$

$A = m^2$

$L = m$

N = Rotational speed of the engine in rev/...

n = no of revolutions required to complete one engine cycle.

n = 1 for 2 stroke engine

= 2 for 4 stroke engine.

B.P (Brake power):-

the power available at the engine crankshaft is called brake power. It is called brake power because some types of brake (dynamometer) ... used to measure it

$B.P = \frac{2\pi NT}{60}$ watt

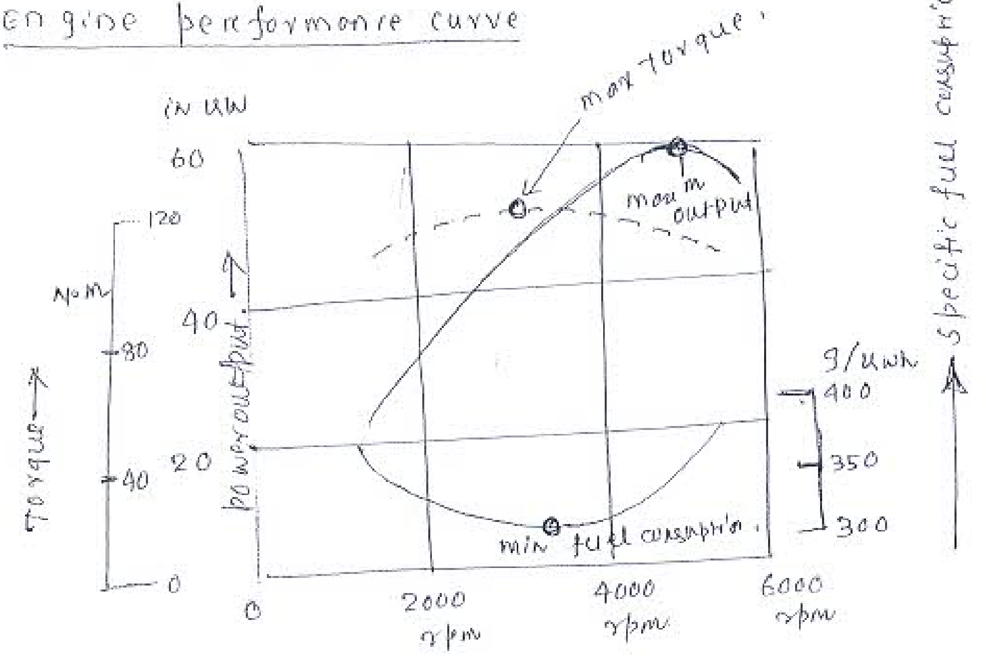
N = R.P.M

T = Braking Torque.

Frictional power (FP) :- Some power is lost in the cylinder, piston, connecting rod, crankshaft, gears, bearings, valve mechanisms, combustion chamber, fuel feed pump, injection pump, Atomiser, cooling system, lubricating system. This lost power is called friction power.

$$F.P = I.P - B.P$$

Engine performance curve



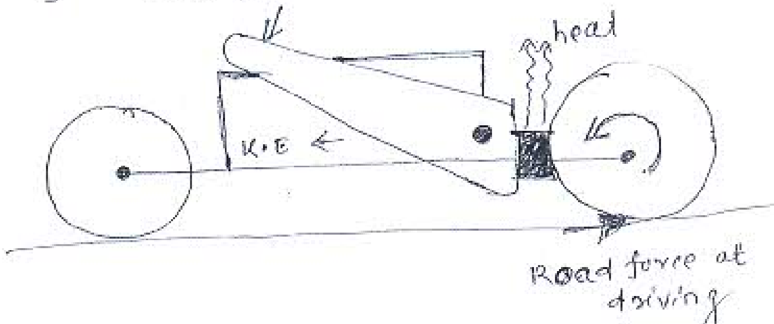
power torque and fuel consumption can be said as being important factors of engine performance. In regard to these three factors curves are plotted to determine how they vary with the engine speed. These curves are known as engine performance curve.

Brake system

Brakes are designed to

1) Decelerate or slowdown the vehicle
2) to stop the vehicle
3) allow the vehicle to be parked on slope

Principle:- A moving vehicle cannot stop immediately when the engine is disconnected from the power train, due to inertia (the tendency of a moving object to continue moving). This inertia must be reduced inorder to bring the vehicle to a halt. This engine converts heat (thermal energy) into kinetic energy (energy of motion) to move the vehicle. In contrast, the brakes change this kinetic energy back into heat energy to stop the vehicle. Generally brakes work by causing a fixed object to be pressed against a rotating object. The braking effect is obtained from the friction that is generated between the two objects. The heat formed at this time is dissipated to the atmosphere.



Types of Brake

Brakes that are used on motor vehicles can be grouped into several types depending on their purpose

1. The service brakes, operated by a foot pedal, which slow or stop the vehicle.
2. The parking brakes, operated by a foot pedal or hand lever which hold the vehicle stationary when applied.
3. Auxiliary brakes are used in combination with the ordinary service brakes by diesel trucks and other heavy duty vehicles.

- Brakes
  - Service (foot) brake
    - Hydraulic brake
    - Pneumatic brake
    - (Hydraulic and pneumatic brake) — Wheel brake
  - Parking brake
    - Mechanical brake
      - Centre brake
      - Rear wheel brake
  - Auxiliary brake

Service brakes (foot brake or foundation brake)

Different types of service brake systems are used in different vehicles, depending on the application

1) mechanical brake 2) Hydraulic brake 3) air brake.

There are two main types of service brake

1) drum brake 2) disc brake.

Drum brake :- The drum brake consists of following components :

(i) Backing plate
(ii) Wheel cylinder
(iii) Brake shoe and lining
(iv) Brake drum

Backing plate:- The backing plate is a pressed steel plate bolted to the rear axle housing or rear axle carrier. Since the brake shoes are fitted to the backing plate, all of the braking force acts on the backing plate.

Wheel cylinder:- It is used to expand the brake shoes against the brake drum, one or two wheel cylinders are used for each wheel. Some systems have two pistons (operated by hydraulic press) to operate two shoes, one at each side of the wheel cylinder.

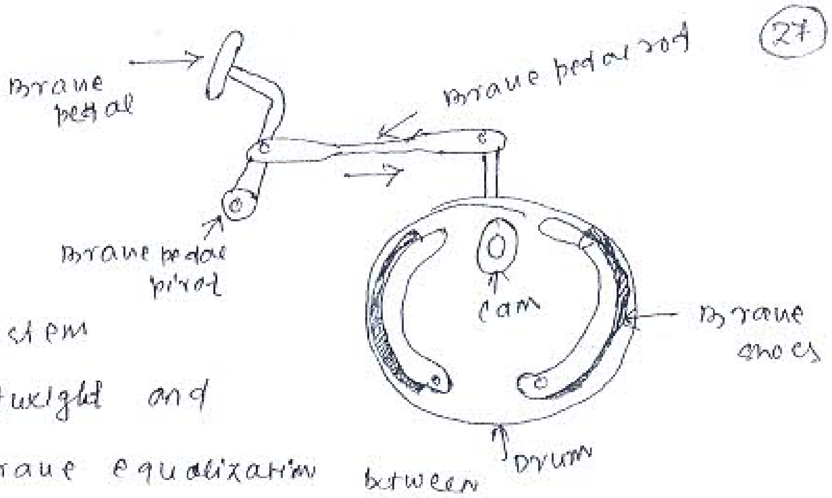
Brake shoe and brake lining:- The brake shoe is semi-circular in shape. Brakes shoes are usually made of steel plates. The brake lining is attached to the shoe by rivets (on large vehicle) or by adhesives (on small vehicles). The material used for lining must have the following qualities.

- Good frictional properties
- wear resistance
- Heat resistance

Lining were once largely made of asbestos, but the health risks associated with this substance have brought about its replacement with synthetic materials.

Brake drum:- It is made of gray cast iron. It is positioned very close to brake shoe without actually touching it and rotates with the wheel. As the lining is pushed against the inner surface of the drum when the brake is applied, friction heat can reach as high as 200°C to 300°C.

Mechanical braking system



mechanical brakes are usually limited today to the parking brakes on vehicles fitted with a hydraulic brake system or the service brakes of lightweight and medium weight motorcycles. Brake equalization between the left and right wheels on an axle can be assured by incorporating a balance beam in the linkage or by means of a pulley. lengthy brake rods must be guided halfway along to avoid vibration or buckling. the linkage can be arranged to generate additional force by incorporating levers at the appropriate points.

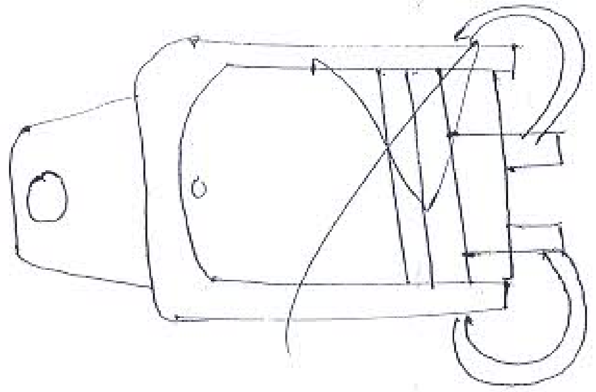
Hydraulic brake system :- fluid is not compressible. Any effort applied at one place will be transmitted without loss of press or movement. anywhere in the systems. so the hydraulic brakes can respond much faster than other types and are simpler in design. hydraulic brakes also have superior design flexibility. Due to the advantages, hydraulic brakes are most commonly used with passenger cars and light-duty trucks today.

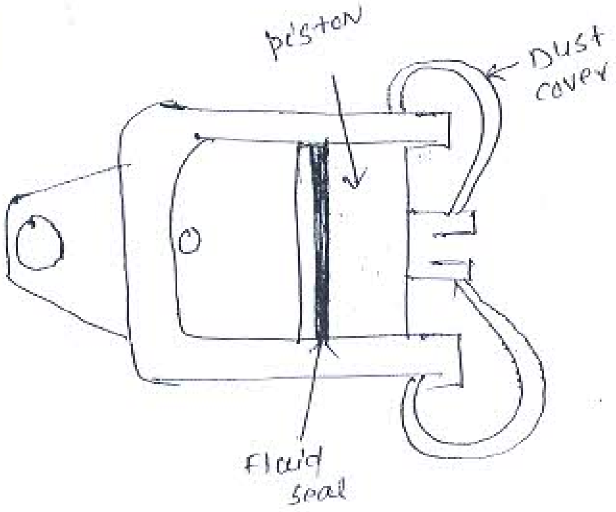
Operating mechanism :-

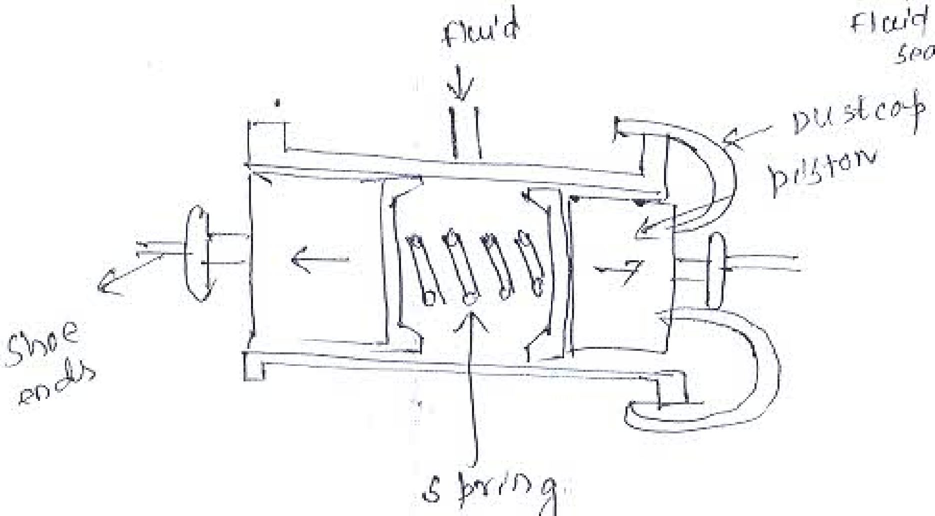
master cylinder :- the master cylinder converts the motion of the brake pedal into hydraulic press. It consists of the reservoir tank which contains the brake fluid as well as the piston and cylinder which generates hydraulic press. there are two types of master cylinder :- the single type and tandem type. the tandem type master cylinder is used more commonly than the single type. the tandem master cylinder has separate hydraulic systems for front and rear wheels so that if one of these systems becomes inoperative, the other system can still function properly. the tandem master cylinder is basically two single master cylinders mounted end the cylinder contains two pistons, dividing it into two chambers. the first piston is operated by the brake pedal and a pushrod. the second piston is normally operated by the fluid press created by the first.

Wheel cylinders (slave cylinder)

These are sometimes called expanders or actuators. It is the purpose of the wheel cylinder pistons to force the brake shoes into contact with brake drum. the wheel cylinder consists of a cylindrical casting made from castiron or aluminium alloy. It is rigidly attached to the back plate, but is sometimes free to slide slightly to centralize it's position. there are two basic types: single acting and double acting. Internally both have a machined bore but in a single acting cylinder one end is blind and contains only one piston. A double acting system is open at both ends and contains two pistons separated by a spring. the pistons are free to move inside the cylinder.

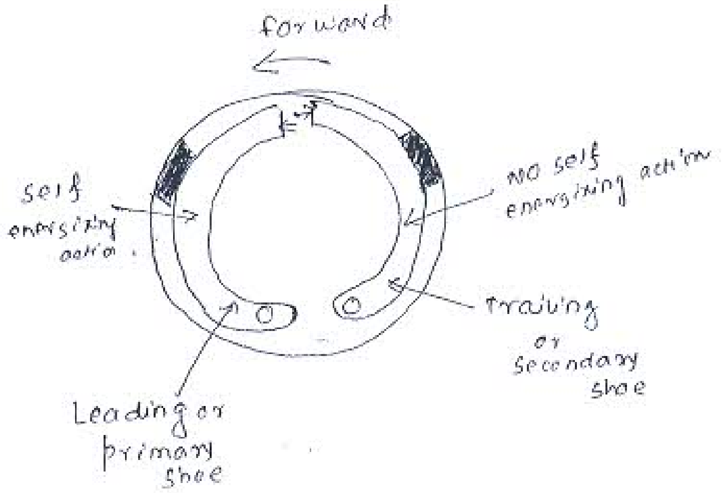






Self energizing action:-

In the drum type brake, braking power is obtained by causing non-rotating shoes to be pushed against the innersurface of a drum that rotates together with the wheel. There are two types of brake shoe: the leading (primary) shoe and the trailing (secondary) shoe. The shoe facing the front of the vehicle is called the leading shoe and the shoes facing the rear of the vehicle is called the trailing shoe. The action of the drum, in which it tries to force the leading shoe to rotate with it, is called self energizing or self servo action. Self-energizing action creates a greater breaking force results from a relatively small pedal effort. Although leading shoes provide more braking power, there is a disadvantage to this in that they wear faster than trailing shoe.



Disc brake:- A disc brake basically consists of a castiron disc (disc rotor) that rotates with the wheel and fixed friction material (disc pads) that are pushed against the disc rotor. Braking force is generated by friction between the disc and the disc pads.

Advantages over drum brake

- Not as effective at slow speed
- Need more press to work affectively
- Size of the disc pad is limited
- Pads weare faster than drum brake shoe lining.

Disadvantages:

- Has the same stopping power in forward or reverse
- Has progressive action. The greater the effort applied to the pedal the more effective the brake will be.
- Self adjusting.
- High braking effeciency.
- High stability
- Because the ...

to the air, good heat radiation is ensured. this minimized fading.

- Good water recovery. water that splashes onto the discs can be removed by centrifugal force.
- simpler design facilities easy maintenance and pad replacement

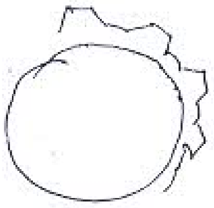
components of disc brake

1. cast iron disc rotor
2. Brake pad
3. caliper

the purpose of gear box

- To multiply engine torque
- To provide a definite break in the transmission system so that the engine may run with the vehicle stationary.
- To provide a means of reversing the drive to the road wheels, thus enabling the vehicle to move backwards.

Gear ratio



A Gear ratio is a measure of the relationship between two or more gear wheels that are meshed contact with each other.

$$\text{Gear ratio} = \frac{\text{Number of teeth on driven gear wheel}}{\text{Number of teeth on driver gear wheel}}$$

For exa:- two gear wheels are meshed in contact with each other. the driver gear has 8 teeth and driven gear wheel has 24 teeth.

$$\text{Gear ratio} = \frac{24}{8} = 3:1$$

To provide a vehicle with a suitable set of gear ratios, manufactures ues gearboxes that contain several set of gears. these are called compound gears. To calculate a compound gear ratio or overall gear ratio, we use the formula

$$\text{overall gear ratio} = \frac{\text{Product of number of teeth on driven gear wheels}}{\text{Product of number of teeth on driver gear wheels}}$$

the engine produces very little power at low speeds. If the engine were permanently connected through the clutch directely to the propeller shaft, it would not be possible to move easily from stationary posn. A vehicle requires a large torque to start off or to climb a hill or to pull a heavy load. However a large torque is not necessary during high speed travel when the wheels need to be driven at a high speed. It should also be noted that any increase in engine speed by the engine and in turn, the torque at the road wheels. the transmission is provided to handle this problem by changing gear combinations (gear ratios) to change the engine output into a torque that suits the travel conditions of the vehicle.

Manual gear box :- there are two types of gear box, manual and automatic, the Latter often being called Automatic transmission. manual gear boxes depend totally on the driver to select and change gear. Automatic gear boxes can change gear according to engine load, road speed, driver's demand and the latest computer controlled units, according to the style of driving. there are three types of manual gear box

1. sliding mesh gear box
2. constant mesh gear box
3. synchronous gear box.

today the synchronous is the most common type in use.

Sliding mesh gearbox :- It is the oldest type of manual transmission used in automobiles. Among the manual gear transmission, this sliding mesh type is the simplest in construction. However in this type mechanical efficiency is very low and noise level is quite high. Moreover the driver required considerable skill in changing the gears.

Construction :- It has three forward and one reverse speed. There are two gears (6 and 5) attached on the main shaft and four gears (2, 3, 4 and 7) on the countershaft. The two gears on main shaft can slide and can mesh with the gears on countershaft. Therefore it is called sliding mesh gear box. In this gear box spur gears are used because of the sliding action. A separate gear is mounted on the idler shaft (8). The gears 1 and 6 are mounted on the splined main shaft. These gears can be slided by a shifting yoke.

Power flow of 3-speed sliding mesh gearbox.

(i) Gears in neutral (ii) First or low speed gear (iii) Second gear (iv) Third or top gear (v) Reverse gear.

Constant mesh gear box :- In this type of gearbox, all the gears are in constant mesh having dog clutches for engaging and disengaging the gears. The gears on the splined mainshaft are free. The dog clutches are provided which are free to slide on mainshaft. The gears on the countershaft are fixed. Only reverse gears are spur gear type and all other are helical gears. As the gears are always in mesh, helical gears are used which are quiter running.

Power flow of 3-speed constant mesh gear box

(i) Neutral (ii) First gear (iii) Second gear (iv) Third or topgear (v) Reverse gear.

Synchromesh gearbox :- This is similar to constant mesh gearbox and dog clutch is replaced by synchronizer unit. Here the gears were synchronized by double de-clutching i.e engaging the clutch with the gearbox in neutral and accelerating the engine to speed-up the input component, then disengaging the clutch again and engaging the appropriate gear. Drivers today are relived from the need for double de-clutching by a synchronizing device built into the sliding collars in the gearbox. This synchromesh device is ...

(36) Synchronizers:- It equalize the speed of the shaft and gear before they are engaged. They use friction to synchronize the speed of the gear and the shaft before the connection is made.

Automatic Transmission :- When a driver is driving a vehicle with a manual transmission, it is necessary for the driver to be constantly aware of the engine load and vehicle speed and to be shifting gears accordingly. With an automatic transmission this type of driver judgement is unnecessary, shifting by the driver is not necessary and shifting up or down to the most appropriate gear is accomplished automatically at the most appropriate time for the engine load and vehicle speed.

Advantages

1) It reduces driver fatigue. Two pedal control i.e the elimination of the clutch pedal togethere with automatic gear selection reduces driver fatigue because it overcomes the need for tedious clutch and gear change operations.

2) It automatically and smoothly shifts gears at speeds appropriate to the driving condition, thus relieving to the driver of the need to mastere difficult and troublesome driving techniques such as clutch operation.

3) It prevents the engine and drive line from becomming overloaded, because it connects them hydraulically (via the torque converter) rather than mechanically.

Automatic transmission can be basically divided into two types, those used in FF (Front engine, Front wheel drive) vehicles (automatic transaxle) and those used in FR (Front engine, Rear wheel drive) vehicles.

gearboxes can change gear according to engine load, road speed, driver's demand and in the latest computer controlled units, according to the style of driving. There are three types of manual gearboxes:

1. Sliding mesh gearbox
2. Constant mesh gearbox
3. Synchromesh gearbox

Today the synchromesh is the most common type in use.

Sliding mesh gearbox

Sliding mesh type gearbox is the oldest type of manual transmission used in automobiles. Among the manual gear transmission, this sliding mesh type is the simplest in construction.

However, in this type the mechanical efficiency is very low and the noise level is quite high. Moreover the driver required considerable skill in changing the gears.

Construction

The Fig. 9.5 below shows the construction of a sliding mesh type transmission having three forward and one reverse speeds. There are two gears (6 and 5) attached on the main shaft and four gears (2, 3, 4 and 7) on the counter shaft. The two gears on the main shaft can slide and can mesh with the gears on counter shaft. Therefore, it is called sliding mesh gearbox. In this gearbox, spur gears are used because of the sliding action. A separate gear is mounted on the idler shaft (8). The gears 1 and 6 are mounted on the splined main shaft. These gears can be slided by a shifting yoke.

Power flow of 3-speed sliding mesh gearbox

(i) Gears in neutral

When the engine is running and the clutch is engaged, the counter shaft is driven by the clutch gear. The low speed and high speed gears are fitted on the transmission main shaft which does not rotate.

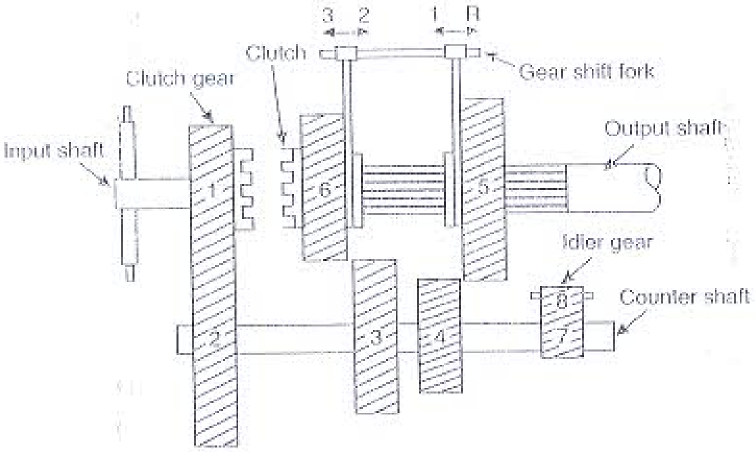


Fig. 9.5 Gears in neutral

At the same time, they are not engaged with any driving gears. Therefore, there is no motion transmitted from engine to the wheels. Hence, the vehicle is stationary.

(ii) First (or) Low speed gear

When the gear shift fork moves towards direction (1) by operating the gear shift lever, the sliding gear (5) on the output shaft will be shifted forward to mesh with low speed gear (4) on the countershaft. It results the rotations of input shaft being transmitted in the order (1) ⇒ (2) ⇒ (4) ⇒

(5) to turn the output shaft. This gear combination is the one that produces the lowest speed from the input shaft and low transmission. In this case the torque output from the gearbox will be as geart as that applied at the input.

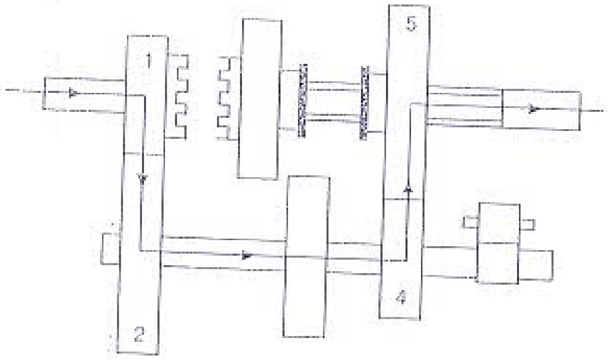


Fig. 9.6 First gear

(iii) Second gear

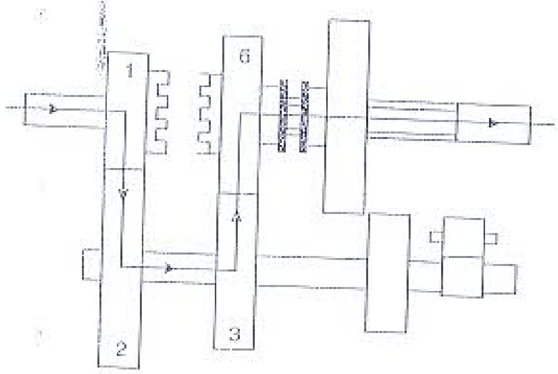


Fig. 9.7 Second gear

When the gear shift fork is moved toward direction 2, the second sliding gear (6) will be shifted backward to mesh with the second speed gear (3) but (5) and (4) are unmeshed. The rotation of input shaft is transmitted in the order (1) ⇒ (2) ⇒ (3) ⇒ (6) to turn the output shaft. This is the transmission in the second speed.

(iv) Third (or) Top gear

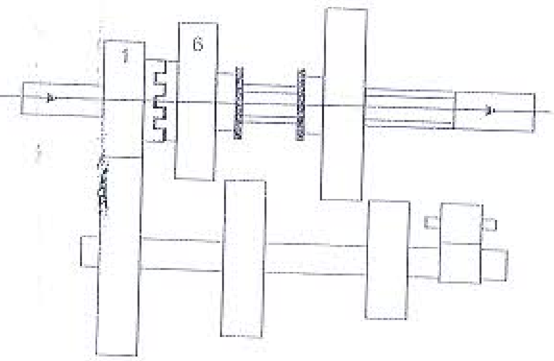


Fig. 9.8 Third gear

When the gear shift fork is moved toward direction 3, the clutch will be meshed but gears (6) and (3) are unmeshed. Due to this, both the input and output shafts are coupled and rotated together with the same speed. This is the transmission in the third or top speed that gives a ratio of 1:1.

(v) Reverse gear

When the gear sh
...d to mesh with th
...der (1) ⇒ (2) ⇒ (7)
... in reverse speed.

This is the same
... seen that the ratio
...rection, but does n

Constant mesh

In this type of ge
...engaging the gear
...hich are free to slid
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...sed which are quite

Power flow of 3

(i) Neutral

When the gear le
...ny of the gears and

(ii) First gear

The dog clutch
...through the gear (1)
...first gear speed is ob

(v) Reverse gear

When the gear shift fork is moved toward direction R, the sliding gear (5) will be shifted backward to mesh with the reverse idler gear (8). Then the rotation of input shaft is transmitted in the order (1) ⇒ (2) ⇒ (7) ⇒ (8) ⇒ (5) to turn the output shaft in reverse direction. This is the transmission in reverse speed.

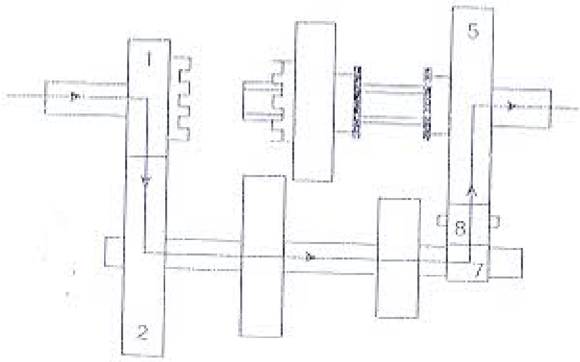


Fig. 9.9 Reverse gear

This is the same ratio as for the first gear and irrespective of the size of the idler gear it will be seen that the ratio always remains the same. For this reason it is called an idler – it changes the direction, but does not alter the ratio.

Constant mesh gearbox

In this type of gearbox, all the gears are in constant mesh having dog clutches for engaging and disengaging the gears. The gears on the splined main shaft are free. The dog clutches are provided which are free to slide on the main shaft. The gears on the counter shaft are fixed. Only reverse gears are spur gear type and all other are helical gears. As the gears are always in mesh, helical gears are used which are quiter running.

Power flow of 3-speed constant mesh gearbox

(i) Neutral

When the gear lever is in neutral position, the two dog clutches D_1 and D_2 are not in contact with any of the gears and cannot transmit torque to the main shaft.

(ii) First gear

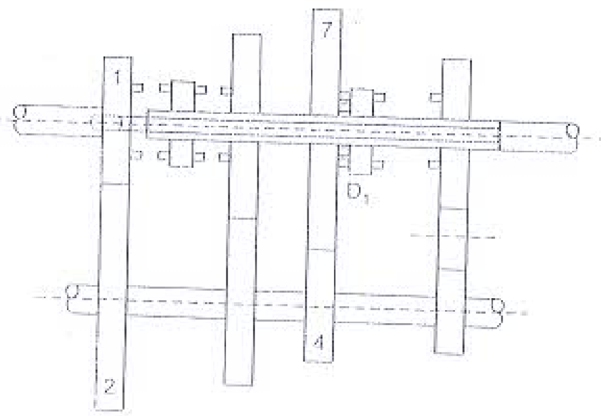


Fig. 9.10 First gear

The dog clutch (D_1) is shifted to left to make engage on (7). Now the power is transmitted through the gear (1) ⇒ (2) ⇒ (4) ⇒ (7) and dog clutch D_1, transmits to the main shaft. Hence, the first gear speed is obtained.

(iii) Second gear

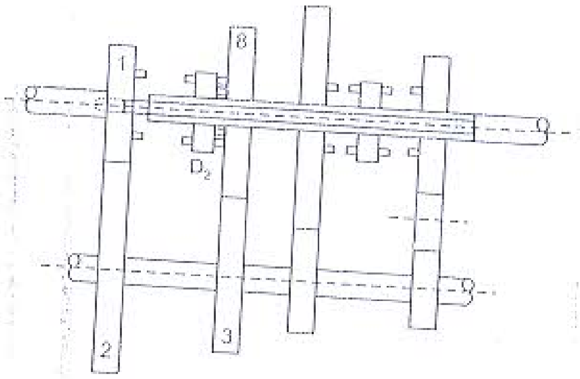


Fig. 9.11 Second gear

Now, the dog clutch (D_1) is disengaged. The dog clutch (D_2) is shifted to right to lock with the gear (8). Therefore, the power is transmitted from clutch shaft through (1) ⇒ (2) ⇒ (3) ⇒ (8) and dog clutch (D_2) to the main shaft. So, the main shaft rotates with the second gear speed.

(iv) Third (or) top gear

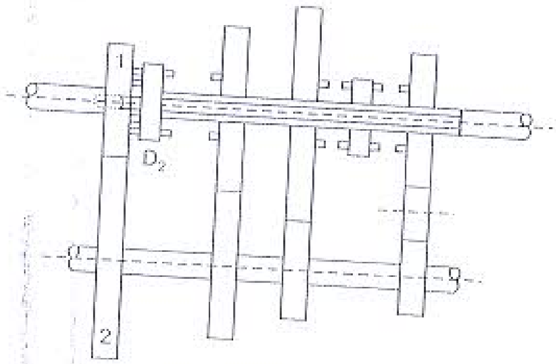


Fig. 9.12 Third gear

In this layout, third gear is a direct drive; namely a gear that gives a ratio of 1:1. The dog clutch (D_2) is moved left to engage with the gear (1) on clutch shaft. Now the engine speed is directly supplied to the main shaft. This is called as top gear speed. In this gear the power flow is not transmitted through any gear teeth so the energy loss is small, i.e., the efficiency is high.

(v) Reverse gear

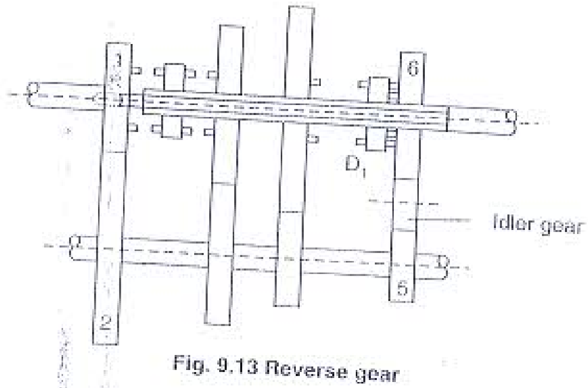


Fig. 9.13 Reverse gear

First the dog clutch D_2 is disengaged. Then the dog clutch D_1 is shifted to right to engage with the gear (6). The idler gear causes the main shaft to rotate in the opposite direction.

Synchromesh gearbox

This is similar to constant mesh gearbox and dog clutch is replaced by synchronizer unit. In the simplest type of constant mesh gear box, which is now absolute, gears could be engaged by snatching the gear lever from one position to the next as fast as possible. This was noisy and jerky. There will still be noise if the dog teeth are not rotating at the same speed when the engagement is made. To do the job more quietly and smoothly without clashing, the gears were synchronized by ***double de-clutching*** i.e., engaging the clutch with the gearbox in neutral and accelerating the engine to speed up the input component, then disengaging the clutch again and engaging the appropriate gear. Drivers today are relieved from the need for double de-clutching by a synchronizing device built into the sliding collars in the gearbox. This synchromesh device is usually fitted to all forward gears.

Synchronizers

Synchronizers equalize the speed of the shaft and gear before they are engaged. They use friction to synchronize the speed of the gear and the shaft before the connection is made.

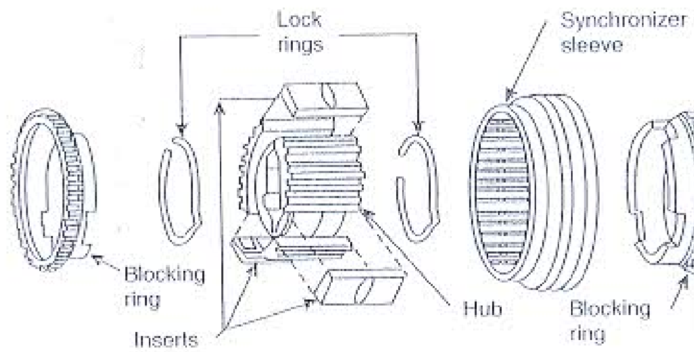


Fig. 9.14 Components of synchronizer

Neutral position

When the gearbox is in neutral, the synchronizers are in their neutral position and are not rotating with the main shaft.

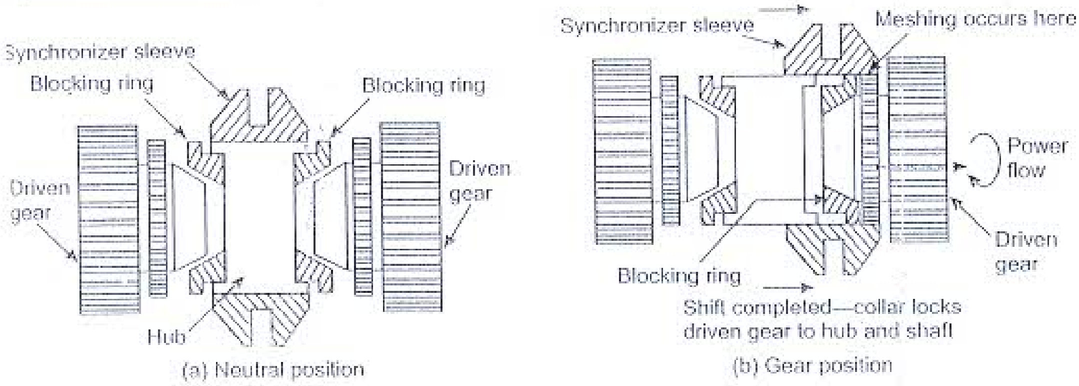


Fig. 9.15 Synchronizer operation

Gear position

When a gear is selected, the shifting fork forces the sleeve toward the selected gear. As the sleeve moves, inserts also moves because they are locked in the sleeve. The movement of the inserts pushes the blocking ring into contact with the shoulder of the gear. When this contact is made, there is a metal to metal contact and begins to rotate.

As the components reach the same speed, the synchronizer sleeve can now slide over the external dog teeth on the blocking ring and then over the dog teeth on the gear's shoulder. This completes the engagement of the synchronizer and the gear is locked to the main shaft. Power now flows as follows:

Input gear ⇒ Counter gear ⇒ Gear selected ⇒ Synchronizer ⇒ Main shaft

Power flow of 3-speed synchromesh mesh gearbox

(i) First gear

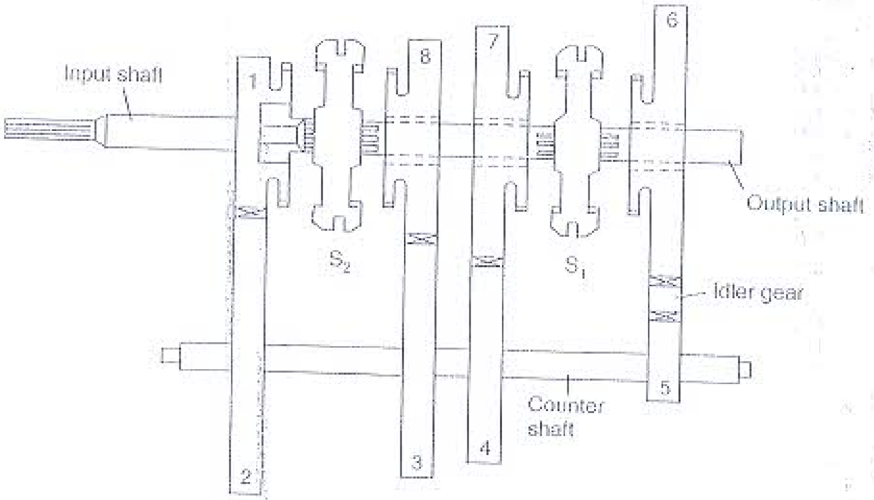


Fig. 9.16 Synchromesh gearbox

The synchronizer (S_1) is shifted to left to make engage on (7). Now the power is transmitted through the gear (1) ⇒ (2) ⇒ (4) ⇒ (7) and synchronizer S_1, transmits to the main shaft. Hence, the first gear speed is obtained.

(ii) Second gear

Now, the synchronizer (S_1) is disengaged. The synchronizer (S_2) is shifted to right to lock with the gear (8). Therefore, the power is transmitted from clutch shaft through (1) ⇒ (2) ⇒ (3) ⇒ (8) and synchronizer (S_2) to the main shaft. So, the main shaft rotates with the second gear speed.

(iii) Third (or) Top gear

The synchronizer (S_2) is moved left to engage with the gear (1) on clutch shaft. Now the engine speed is directly supplied to the main shaft. This is called as top gear speed. The top gear provides a 1:1 ratio between the input shaft and the main shaft by locking the two shafts together.

(iv) Reverse gear

First the synchronizer S_2 is disengaged. Then the synchronizer S_1 is shifted to right to engage with the gear (6). The idler gear causes the main shaft to rotate in the opposite direction.

GEAR SELECTOR MECHANISM

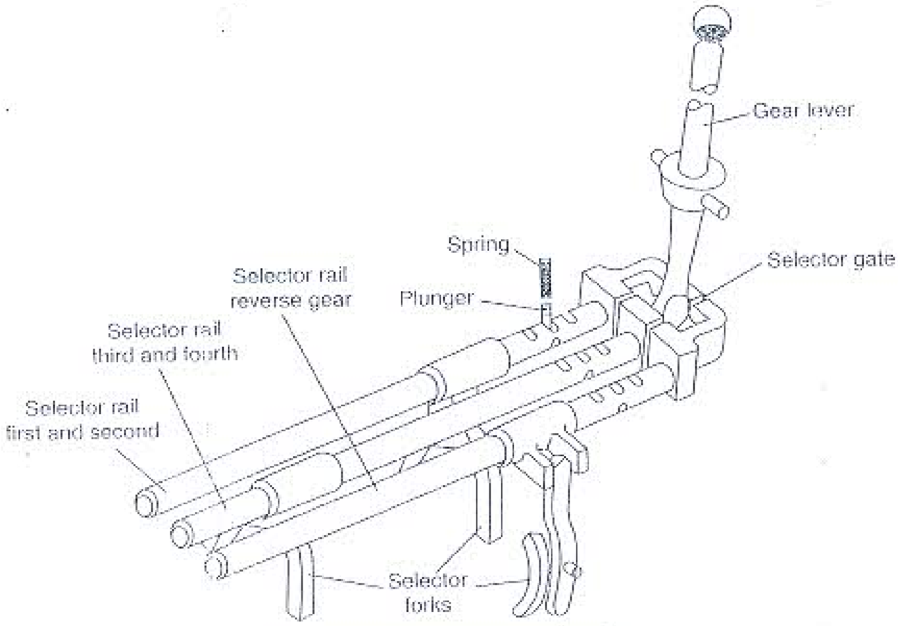


Fig. 9.17 Gear selector mechanism

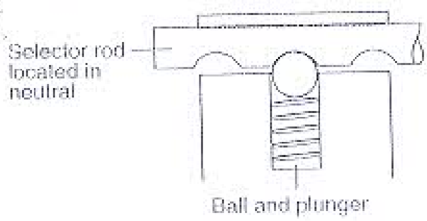


Fig. 9.18: Gear Locating Device

To allow the driver to select the most suitable gear ratio, manual gearboxes are fitted with a gear lever and selector mechanism. The main components of such a selector mechanism are shown in Fig. 3.4. When the driver uses the gear lever to select a particular gear, the movement is transmitted along the appropriate selector rail to the gearwheel. Selector-locking or gear-locating device hold a gear engaged when it has been selected as shown in Fig. 9.21.

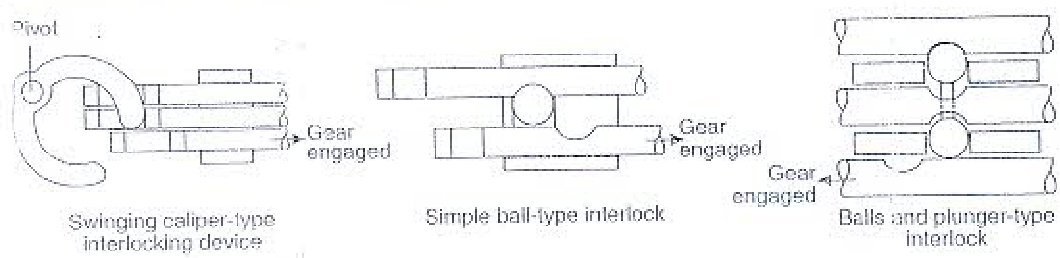


Fig. 9.19 Interlocking mechanism

To ensure that only one gear can be selected at a time, an interlocking mechanism is incorporated into the gearbox selectors. A selection of interlocking mechanisms is shown in Fig. 9.22.

AUTOMATIC TRANSMISSION

When a driver is driving a vehicle with a manual transmission, it is necessary for the driver to be constantly aware of the engine load and vehicle speed and to be shifting gears accordingly.

With an automatic transmission, this type of driver judgement is unnecessary, shifting by the driver is not necessary and shifting up or down to the most appropriate gear is accomplished automatically at the most appropriate time for the engine load and vehicle speed.

Advantages

Compared to the manual transmission, the automatic transmission has the following advantages

- It reduces driver fatigue. Two pedal control, i.e., the elimination of the clutch pedal together with automatic gear selection reduces driver fatigue because it overcomes the need for tedious clutch and gear change operations.
- It automatically and smoothly shifts gears at speeds appropriate to the driving conditions thus relieving to the driver of the need to master difficult and troublesome driving techniques such as clutch operation.
- It prevents the engine and drive line from becoming overloaded, because it connects them hydraulically (via the torque converter) rather than mechanically.

Types of automatic transmission

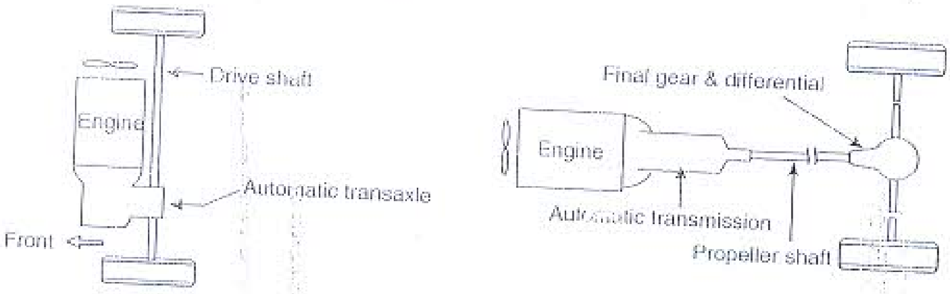


Fig. 9.20 Automatic transmission

Automatic transmissions can be basically divided into two types, those used in FF (Front-engine, Front-wheel drive) vehicles (automatic transaxle) and those used in FR (front-engine, Rear-wheel drive) vehicles.

MAJOR COMPONENTS

Most modern automatic transmissions consist of two main units: a fluid clutch and a main gearbox. The functions of these main parts are as follows:

Fluid clutch

Fluid clutch automatically disconnects the drive when the engine speed is low and gradually connects it as the vehicle is moved from a stationary position. It is either a fluid coupling or torque converter

Fluid coupling

The fluid coupling serves to transmit the engine torque to the gearbox, same as the friction clutch, but does it automatically and more smoothly. It is comprised essentially of the pump impeller (drive side) and turbine runner (driven side). These parts have the appearance of a hollow doughnut sliced vertically into to equal halves.

Both of these parts are provided with radiating out from the center. These parts are contained in a housing filled with oil and installed facing each other, with very little clearance provided between

...n. The pump impeller is installed on the engine crankshaft and the turbine runner coupled to ...smission input shaft.

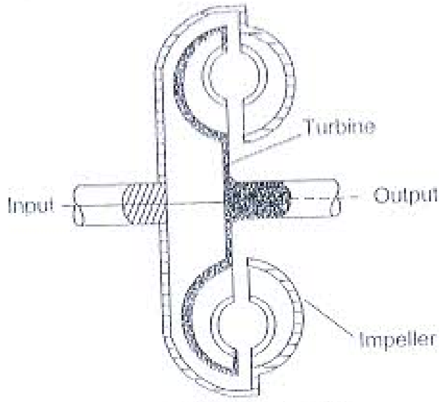


Fig. 9.21 Fluid Coupling

When the engine rotates, the pump impeller provides motion to the oil in between the blades to ...n the turbine runner and transmit the engine power to the transmission. When the engine speed ...ps, the turbine runner will turn faster than the pump impeller so that the turbine runner will now ... working as a pump impeller and exert a braking action to the engine.

At idling, the pump impeller is rotating slowly and since the oil pressure is low, the turbine run-... receiving the oil does not turn. The oil merely circulates between the opposing blades and there ...no transmission of engine power to the propeller shaft. This is because the oil pressure generated ... the pump impeller is not large enough to overcome the resistance of the drive wheels.

Torque converter

Torque converters, in its simple form, can double the output torque from the engine. In addition ...e converter is able to reduce the torque amplification gradually as the output speed of the converter ...creases.

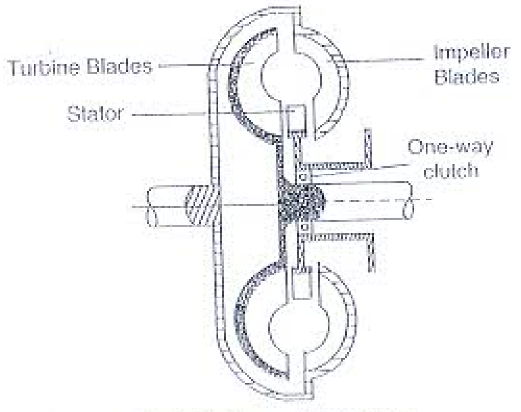
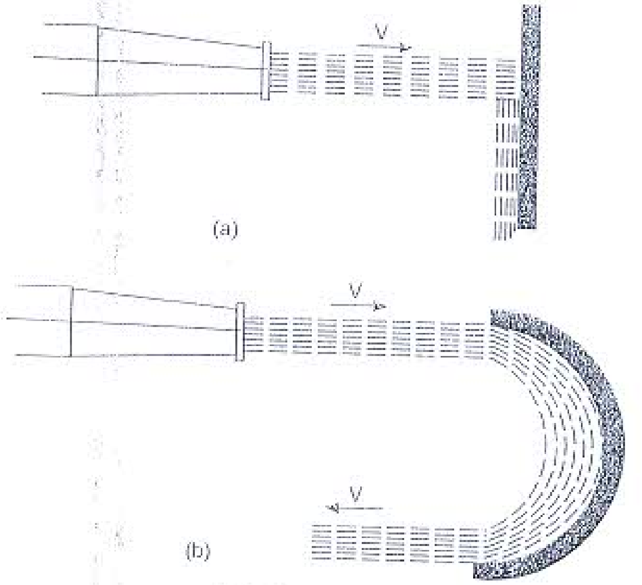


Fig. 9.22 Torque Converter

Principle

A moving fluid possesses energy and this means that it is capable of doing work. Directing a ...uid from a nozzle on to a plate causes the fluid direction to change and exerts a force on the plate. The force of impact can be varied by moving the plate with the fluid direction. During this move-...ent the speed of the fluid relative to the plate is slower than in the previous case, so the impact force will be less. If it is possible to move the plate at the same speed as the fluid is moving, then no impact will take place, consequently no force will be produced on the plate.



Velocity changes
(a) When fluid strikes a flat plate
(b) When fluid strikes a curved plate

Fig. 9.23 Principle of a torque converter

In the case of curved plate, the fluid strikes the plate with a velocity V and the curved surface redirects the fluid back at a velocity –V towards its source. Double the force is obtained with this arrangement, since the plate not only stops the fluid but also has to send it back at the same speed. Mounting a series of these plates on to a shaft forms a simple turbine. Each plate, which is now called a vane, will extract the energy from the moving fluid to produce a turning action on the shaft.

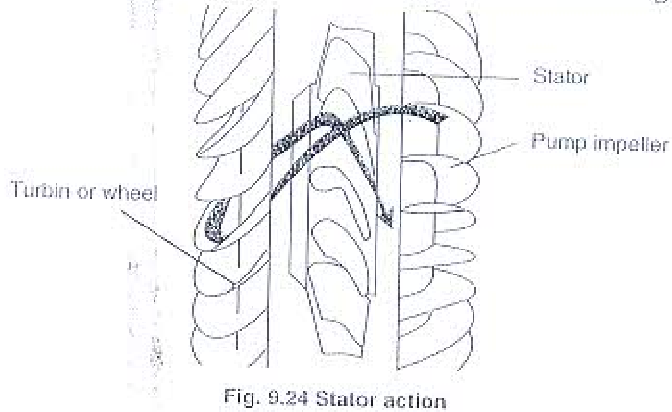


Fig. 9.24 Stator action

Applying the analogy of the nozzle-plate would indicate that when the turbine is turning slower than the pump, the force of impact of the fluid striking the turbine vanes should give a torque increase. This would be true if the fluid did not have to return to the pump, but since this fluid has to recirculate then the speed of the fluid compared to the speed of the pump vane must be considered. To give a high impact force on the output member, the pump must be turning at a higher speed than the turbine, so when the fluid is returned to the pump it is travelling slower than the pump vane. In

...ndition the vane wil
...ng against the motio
...r the speed differenc
...e but this will also re
...this braking action m
...or (stationary membe
...which are shaped in
...the pump at a suitab

...les of a torque co

The roles of a torque c
- Multiplying the to
- Serving as an auto the transmission.
- Driving the oil pu

...rque converter op

When the engine is run ...entrifugal force and de ... blades attempts to rota ... this movement is preve ...tes such that it now ent ...cuit.

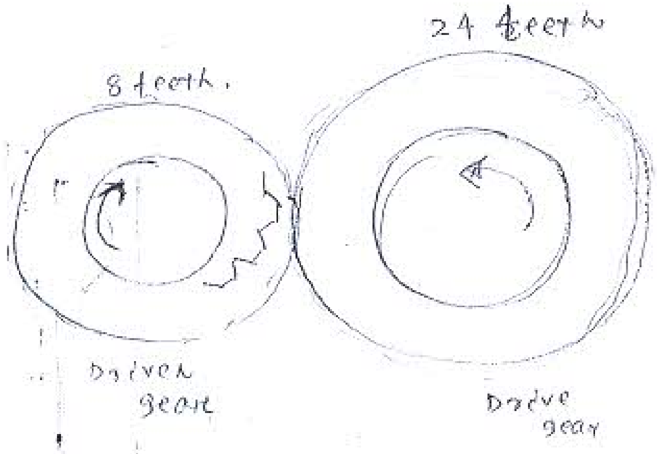
As the turbine speeds ... the oil flow strikes the s ... the turbine blades, so tha

The stator then begins ... almost identical, the oil ... turbine is almost the sa ...nversion takes place at th

At this stage in vehicle ...his is described as the *coup* ... the other two wheels and

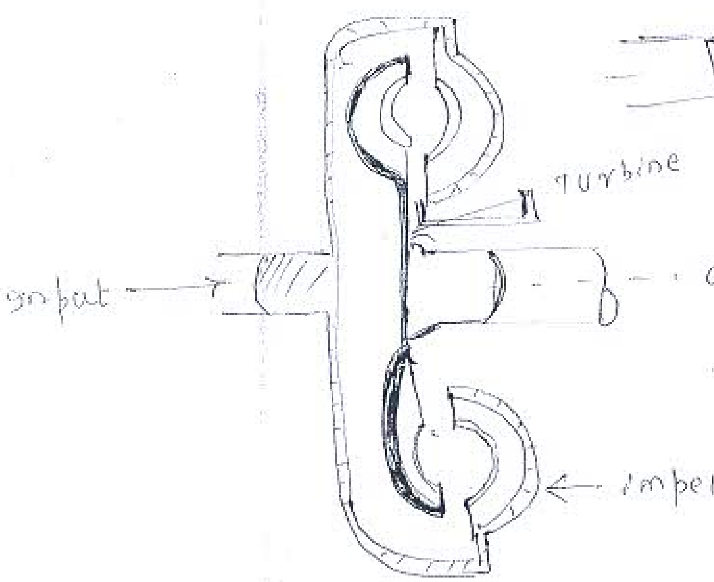
Depending on the desig ...ultiplied by between 2 and

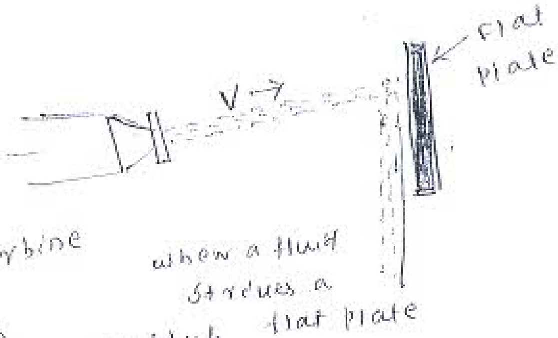
Overdrive :- An overdrive is a gear ratio in which the speed of the output shaft is greater than the speed of input shaft. This principle is put to good use on motor vehicles to reduce engine wear and fuel consumption. Almost all early cars had four speed gear boxes with a straight through 1:1 drive in fourth gear. Nearly all modern cars have five speed gear box, with fifth gear being an overdrive ratio. Similarly, most modern automatic transmission units have their epicyclic gearing so arranged that their top gear, usually fourth is an overdrive. There are however some vehicles still in use that fit a four speed manual gear box, but with a separate overdrive unit fitted behind or in an extension to gear box. Such separate units normally use an epicyclic gear train to provide the overdrive ratio. When the overdrive is selected, hydraulic press forces the cone clutch against the casing, which prevents the sunwheel from rotating. The planet carrier and planet gears rotate around the stationary sun wheel which drives the annulus and output shaft at a higher rotational speed.

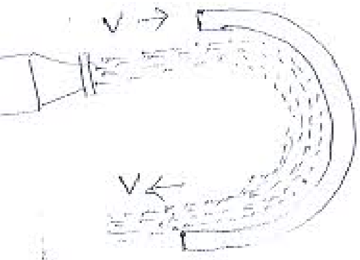


Torque converter :- In its simplest form, can double the output torque from the engine. In addition the converter is able to reduce the torque amplification gradually as the output speed of the converter increases.

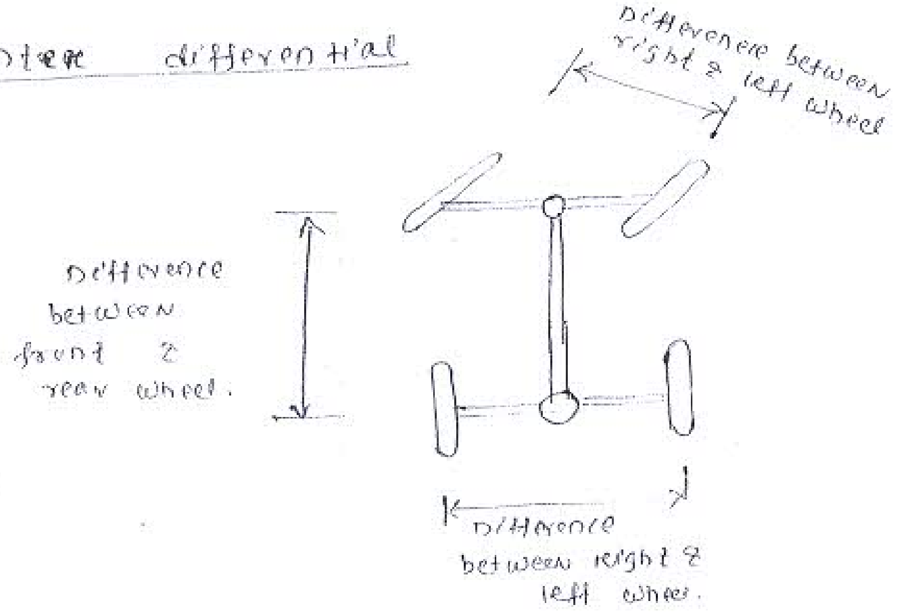
Principle :- A moving fluid possesses energy and this means that it is capable of doing work. Directing a fluid from a nozzle on to a plate causes the fluid direction to change and exerts a force on the plate. The force of impact can be varied by moving the plate with the fluid direction. During this movement the speed of the fluid relative to the plate is slower than in the previous case, so impact force will be less. If it is possible to move the plate at the same speed as the fluid is moving, then more impact will take place, consequently, no force will be produced on the plate.







Center differential



Front differential absorbs rotational speed difference between front right and left wheels.
Center differential absorbs rotational speed difference between front and rear wheels.
Rear differential absorbs rotational speed difference between rear right and left wheels.

Advantages

- Excellent drive-through performance on snowy roads.
- Excellent drive-through performance on rough roads.
- Excellent drive-through performance on hill climbing
- Excellent cornering stability.
- Excellent starting and acceleration performance.
- Excellent straight line stability.

Disadvantages

- Construction is complex
- Weight is increased
- Cost is increased
- Sources of vibration and noise increase.

10

CHAPTER

PROPELLER SHAFT ASSEMBLY

In the front-engine rear-drive automobiles, the gearbox rotations are transmitted to the rear axles means of the propeller shaft assembly. It consists of propeller shaft, universal joints, slip joint, etc.

DRIVING THRUST AND TORQUE REACTION

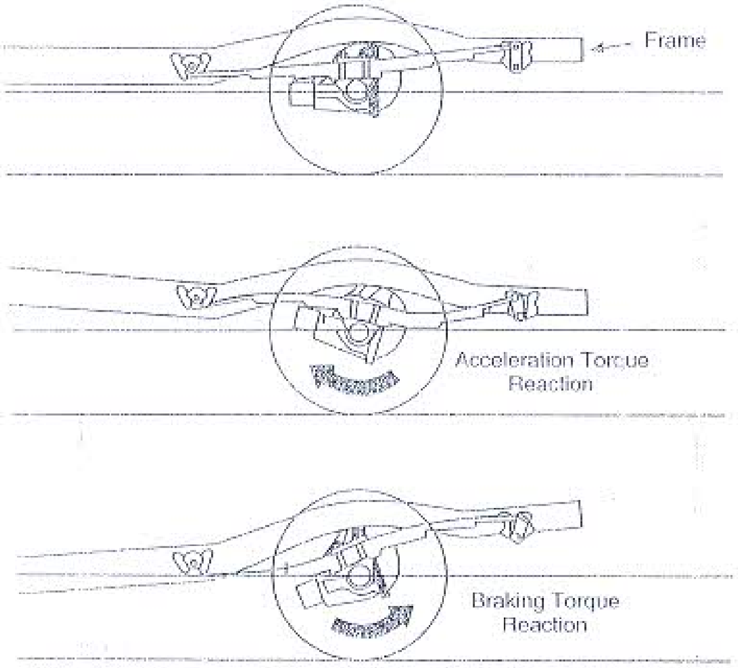


Fig. 10.1 Effect of torque reaction

Driving thrust

Driving torque produced in the engine causes the thrust to be produced in the road wheels, hich has to be transmitted from the axle housing to the frame and the body of the vehicle. This is ost conveniently done by some form of member connecting the axle casing and the frame or body f the vehicle in the longitudinal direction. Such members are either leaf springs or radius rods (or rut rods).

Torque reaction

If the road wheels are prevented from rotation with the propeller shaft rotating, it is seen that the evel pinion will tend to roll round the crown wheel. This tendency is also present when the vehicle is running so that the bevel pinion always tends to climb round the crown wheel. Thus there is a force on the axle casing to rotate. This is called torque reaction. In the same way, the braking torque on the axle casing is opposite in direction to the torque reaction.

PROPELLER SHAFT

Where the engine and axles are separated from each other, as on four-wheel-drive and rear-wheel-drive vehicles, it is the propeller shaft that serves to transmit the drive force generated by the engine to the axles.

The propeller shaft is normally a carbon steel tube having a high resistance against torsional and bending forces. A balance weight is installed outside the tube to balance out rotational weight. The duties of the propeller shaft assembly are:

- to transmit torque
- to allow different drive shaft angles
- to allow changes in length
- to reduce rotary vibrations

Construction

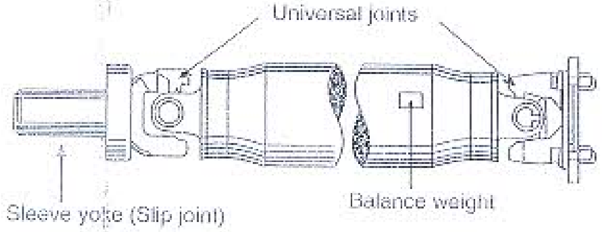


Fig. 10.2 Propeller shaft assembly

The propeller shaft is normally made by seamless steel tubing method with universal joint yokes welded to both ends of the shaft. Some drivelines have two propeller shafts and three universal joints and use a center support bearing. Four wheel-drive wheels use two propeller shafts, one to drive the front wheels and the other to drive the rear wheels.

In practice, propeller shafts should always be short and as stiff as possible, this enable the shaft to resist the bending loads and torque reactions which are imposed during operation. If the shaft cannot be made in a short length, then its stiffness can be improved by making the diameter larger. Propeller shafts are either solid or tubular in construction. A tubular shaft is stronger than a solid shaft of the same weight and therefore offers advantages of reduced weight and low manufacturing cost.

Components

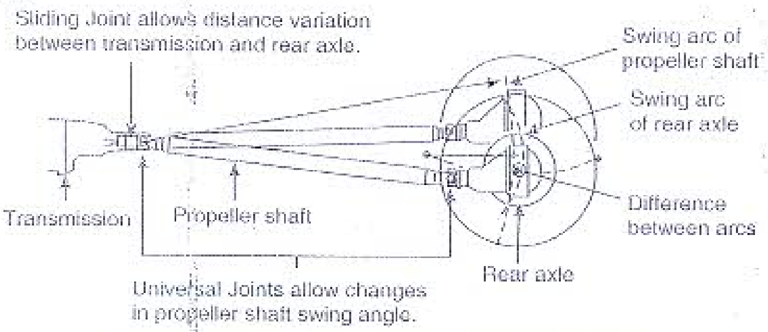


Fig. 10.3 Components of a propellershaft assembly

Universal joint

A universal joint, sometimes called a Carden joint, forms a mechanical connection between the two shafts and allows angular movement of one or both shafts. Also it transmits power smoothly from the gearbox to the differential.

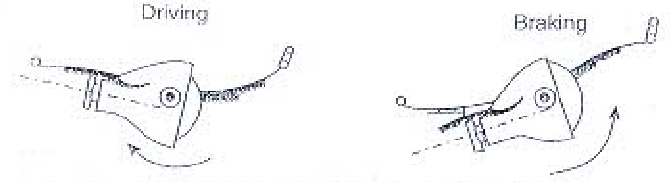


Fig. 10.4 Deflection of spring due to road shocks

Road shocks will deflect the springs to the position shown in Fig. 10.4. This will alter the angle of the propeller shaft, relative to the gearbox and final drive and unless a universal joint is fitted to each end of the propeller shaft, the shaft will bend and fracture.

Slip joint (or Sliding joint)

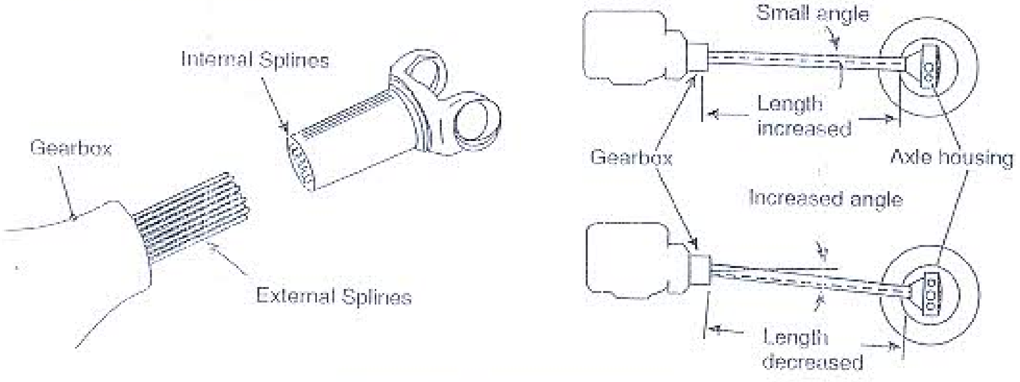
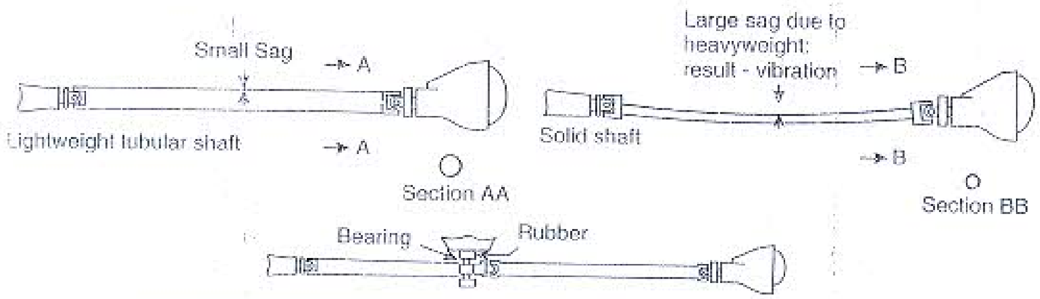


Fig. 10.5 Slip Joint and its function

Propeller shafts use a slip joint at one end, which allows it to lengthen or shorten. It permits the effective length of the propeller shaft to change due to the up and down movement of the wheels.

Center bearing



Long or high-speed shafts require a center bearing to avoid vibration due to whip

Fig. 10.6. Centre bearing

Long-wheelbase vehicles (trucks) often have a propeller shaft in two sections; a two-piece, three-joint type propeller shaft incorporates a rubber-mounted center bearing which is designed to support the shafts at the middle and to reduce torsional vibration and noise. For its usage, the optimal shaft is a short, bar-like product. The longer the bar, the more liable it is to sag and sagging is further promoted when rotation is applied. Sagging causes vibration and results in an increase in noise ... such an extent that the shaft is likely to break when the critical speed is exceeded.

It consists of a rubber collar contained within a steel casing, which is mounted on the vehic... chassis. The centre bearing normally uses self-aligning bearings, which allow for slight misalig... ment of the shaft caused by the gearbox moving on its mountings.

UNIVERSAL JOINTS

Requirements

A modern universal joint is expected to meet the following requirements:

1. **Strength:** High torque must be transmitted with the minimum energy due to friction.
2. **Compactness:** Space is limited so the joint must be small and robust.
3. **Large drive angle:** Modern road springs allow large wheel deflections so the joint must ... able to accommodate the large drive angle given by this movement.
4. **Shaft balance:** Severe vibration occurs if the shaft runs out-of-true, so the joint must ma... tain good alignment.
5. **Operating speed:** The joint must operate efficiently at higher speed under the conditions ... high torque and variable drive angle. This requirement must be combined with the need for the j... to have a long life and minimum maintenance.

Construction

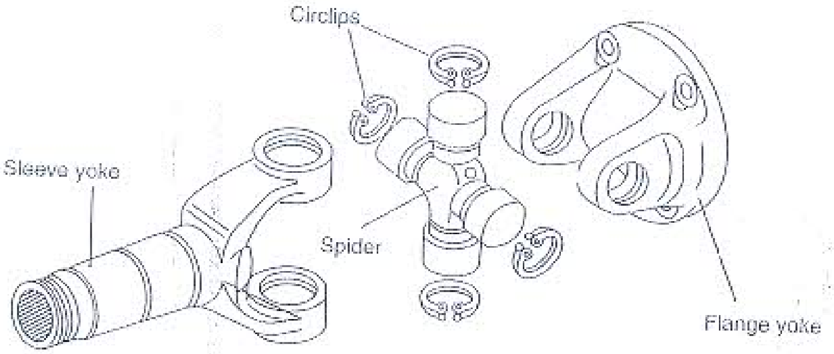
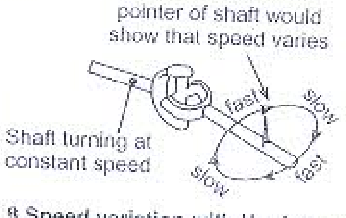


Fig. 10.7 Parts of a universal joint assembly

...sal joints are made from heat-treated steel. Fork-type joints are connected together by ... The journals of these joints normally run in fully-enclosed needle roller bearings ... no maintenance. Normal patterns of universal joint can bend to an angle of abo... ...rsions providing an angle of up to 25° are also available.



...8 Speed variation with Hooke type joint

...th only one universal joint, the shaft will only run uniformly ... away from a straight line, the section of shaft after the j... ...evolution in relation to the section of shaft before the joi... ...nitting a drive through an angle, the output shaft does not rota... Instead the speed varies every 90° of rotation and the rate of mo...

ment for one revolution is fast, slow, fast and slow. This cyclic speed variation and its associated vibration is insignificant when the drive angle is less than about 5°. This vibration increases with increasing angle.

Two universal joints on a shaft have the effect of cancelling out non-uniform rotation. The front and rear sections of the shaft then run at a uniform speed and only the center section varies in speed.

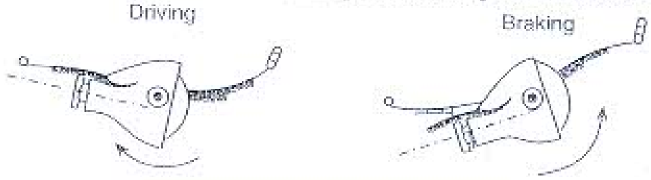


Fig. 10.9 Need for rear universal joint

Another reason for using two universal joints is shown in Fig.10.9. Due to torque reaction, the spring deflects. Thus torque reaction is taken up by the springs. Similarly, to take up the braking torque the springs would deflect in the opposite direction. When the springs deflect, the bevel pinion shaft also changes its position. Therefore if there is only one universal joint at the front end of the propeller shaft, it will bend under this condition. To avoid this, another universal joint at the rear end of the propeller shaft is used.

Universal joints are usually pre-greased by the manufacturer whereas some are having a nipple for further greasing. In case of failure the spider and all collars with needle rollers have to be replaced.

The merits of this type of joint are:

1. Compactness.
2. High mechanical efficiency.
3. Ability to drive through a large occasional bump angle (maximum about 25°).
4. Accurate centering of shaft, hence the joint is suitable for high speed operation.

CONSTANT VELOCITY (CV) JOINTS

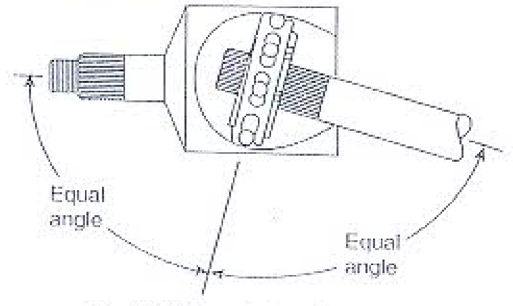


Fig. 10.10 Constant velocity joint

A constant velocity joint is a type that provides an output shaft speed equal to that of the input at all shaft positions within the working range of the joint. Constant-velocity conditions are achieved when the connecting device between the driving and driven yokes is positioned in a plane that bisects the angle of drive.

Constant velocity universal joints

One method of achieving a constant speed output from the propeller shaft is to mount two universal joints back-to-back (double Carden type) or positioned in a certain way at each end of the propeller shaft. In both configurations the relative positions of each joint must be arranged so that the speed change of one joint is counteracted by the other.

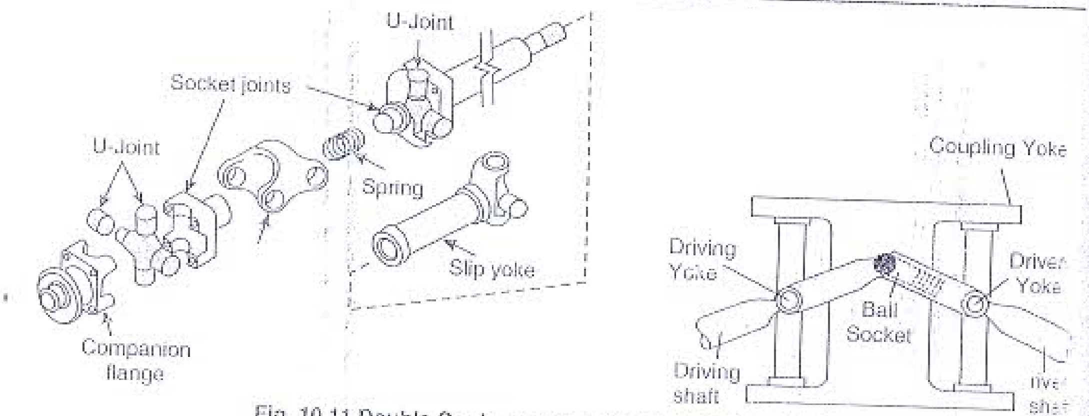


Fig. 10.11 Double Carden constant velocity universal joints

A constant velocity universal joint (double Carden type) used in front engine rear wheel dri... is shown in Fig. 10.11. It consists of two universal joints linked by a ball and socket. The ball ... socket splits the angle of the drive and driven shafts between the two universal joints of the consta... velocity unit. Because the two universal joints operate at the same angle, the speed-up and slo... down action is cancelled out. The speed-up resulting at any instant from the action of one univers... joint is cancelled out by the slow-down of the other. Therefore no speed change occurs between the two shafts connected to a constant-velocity universal joint.

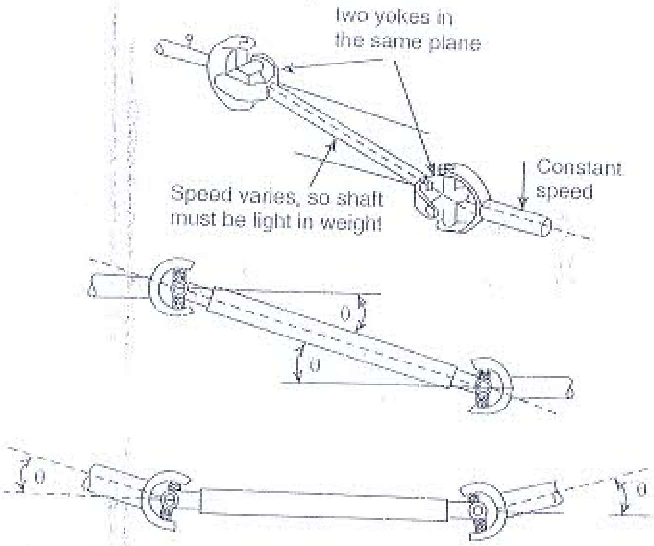


Fig. 10.12 Driving through an angle. Both angles are equal and giving no variation between input and outpu...

The phasing of universal joints, as applied to two separate driveline layouts, is shown in Fig. 10.12. This diagram shows that to restore a constant speed, two conditions must be satisfied:

- yokes at each end of the propeller shaft must be positioned in the same plane.
- drive angle of each coupling must be equal.

Constant velocity joints

In the front-wheel drive vehicles, one end of the driveshaft is connected to a fixed transaxle assembly and the other end is attached to a wheel hub that moves up and down with the suspension

With the load on the wheels, total chain slack should not exceed approximately 15 to 20 mm above and below the theoretical run of the chain. Chain slack can be taken up at the tensioning or adjusters.

DIFFERENTIAL

The differential is a device that enables two drive shafts to be driven at different speeds, with equal torque.

Need for differential

The right and left wheels do not always rotate at the same speed because of road conditions, especially during cornering. There is a need for a special device that allows the wheels to rotate at different speeds while continuing to transmit torque.

In comparing the path of the inside wheel (A) with the path of the outside wheel (B) of a vehicle when it turns along a curve, as illustrated in Fig. 10.23*a*, the outside wheel (B) draws an arc whose radius is the distance O-B, while the inside wheel (A) draws an arc whose radius is the distance O-A. Therefore, the distance of travel of the outside wheel is longer than that of the inside wheel. For this reason, the outside wheel is forced to move faster and rotate more than the inside wheel.

If one of the wheels is on a flat surface and the other on a rough surface, as illustrated in Fig. 10.23b, the wheel (A) on the rough surface naturally must run at a higher rpm than the other wheel on the flat surface (this is not necessarily so, however, if both wheels are on equally rough surfaces).

Furthermore, it is extremely rare for both wheels to run at an identical rpm even on ordinary roads, because the two wheels contact the road surface differently even if the road appears to be flat.

Another reason for this difference in rpm between the right and left wheels is the difference in the amounts of tyre inflation and wear. In most cases, therefore, if both wheels were forced to run at the same rpm, one of them would slip. Tyres would, therefore, wear faster, and the driving performance of the vehicles would be affected as a result. To solve these problems, there is needed a differential device that allows differences in rpm to occur while transmitting equal torque.

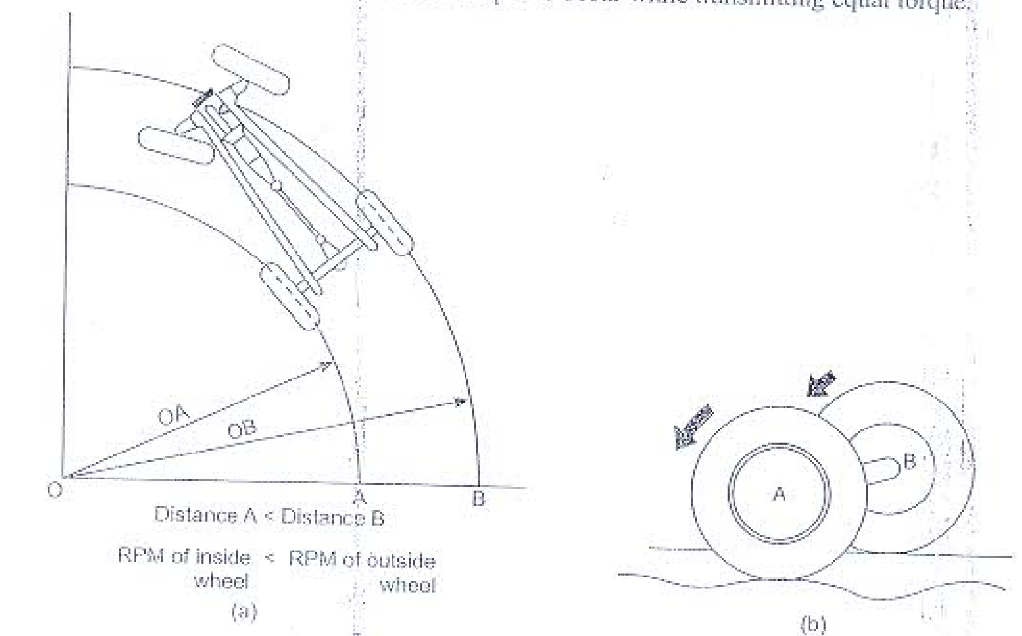


Fig. 10.23 Need for differential unit

Construction

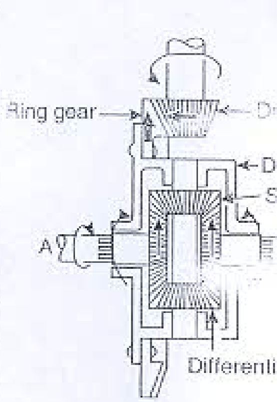
The general construction

The ring gear (crown wh
-type gear pinions all f
pinions opposite each
opposed pair of pinions
shaft which acts as a
by the ring gear. Ther

The final drive
they will be transmittin
is located in the axle

Operation

Straight-ahead travel



The rolling resistances
straight ahead on a level
themselves do not rotate
this case, the differen
two sun gears rotate as a
wheels to turn at an equal rpm

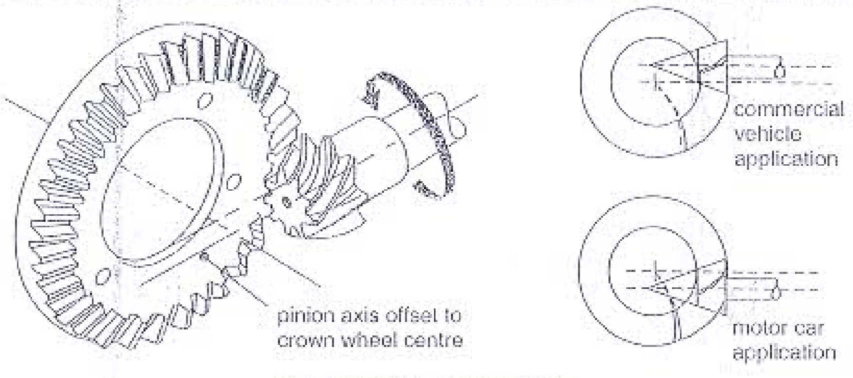


Fig. 10.21 Hypoid final drive

Since these gears are constantly sliding and rolling against each other, the hypoid bevel gear ...ust be lubricated with hypoid gear oil (extreme pressure oil), which has a high oil film strength. ...dditives such as chlorine and sulphate prevent the gear teeth from 'scuffing' as well as providing ...dequate lubrication at all likely temperatures.

Chain-sprocket final drive

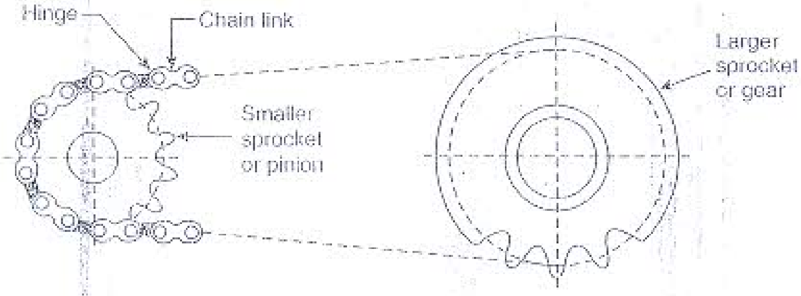


Fig. 10.22 Chain final drive

Chain final-drive is perhaps motor cycling's most common system used for transferring me...anical energy to the rear wheel.

Power is transmitted from the engine via a roller chain and a pair of toothed wheels, or sprock... one each on the countershaft and on the rear wheels. As the chain is drawn around the counter...aft sprocket by that sprocket's rotation, the gear teeth mesh with each link. This action pulls the ...ain, which rotates the sprocket on the rear wheel in the same fashion. That is, the chain meshes ...th the rear wheel sprocket's teeth, turning it, and the entire rear wheel, around.

These days, there are two types of roller chains for motorcycles: O-ring and non O-ring. O-ring ...ain can be a bit of a misnomer. Rather than O-rings, manufacturers are using X and Z shape rings ...at help keep special, installed at the factory lubricant inside the chain and water, dirt and other nas...s out. Note that most high-quality chains used on motorcycles are O-ring (or X or Z ring) chains.

There are several good reasons why motorcycles prefer chain drives. To begin with, chain final-...ive systems are lighter than their other two counter parts, belt and shaft drives. They are more ...ficient, too, than big, heavy, power-snapping shaft final drives and narrower than belt final drives. ...oreover, chain drives allow owners to alter their overall gearing with relative ease.

Chain drive has its disadvantages too. Chain drive is noisy. It requires the most maintenance ...ch as periodic cleaning, lubrication and adjustment, as well as replacement. Indeed, when a chain ...d/or sprockets are worn out, you need to replace all three-chain, countershaft sprocket and rear ...heel sprocket. Otherwise the remaining part(s) will wear out the new one(s) quickly.

Construction

The general constructional detail of the final drive and differential assembly is shown in Fig.10.24.

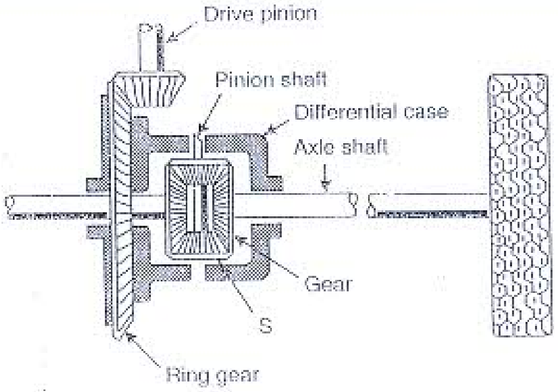


Fig. 10.24 Differential assembly

The ring gear (crown wheel) of the final drive is attached to a differential case which contains four bevel-type gear pinions all facing inwards, meshing with each other in the form of a box. Two of the bevel pinions opposite each other are splined to the half shafts and are referred to as the sun gears. The other opposed pair of pinions are free to rotate upon a pinion shaft and are known as pinion gears. The pinion shaft which acts as a pivot for the pinion gears is mounted in the differential housing which is driven by the ring gear. There is no direct connection between the ring gear and the half shafts.

The final drive gears must function precisely in correct relationship with each other. At the same time they will be transmitting very high torque. For this reason, the final drive and differential assembly is located in the axle casing and supported on taper roller bearings.

Operation

Straight-ahead travel

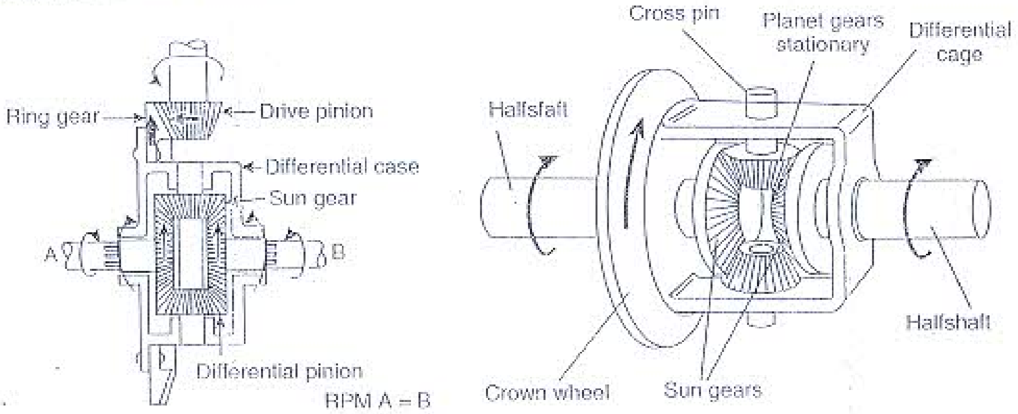


Fig. 10.25 Straight-ahead

The rolling resistances of the two drive wheels are almost identical when the vehicle is travelling straight ahead on a level road. When resistance is equal in both axle shafts, the differential pinions themselves do not rotate but turn as a unit with the ring gear, differential case and pinion shafts. In this case, the differential pinions only function to connect the right and left sun gears. As a result, the two sun gears rotate as a unit with the revolution of the differential pinions, causing both drive wheels to turn at an equal rpm.

Turning

When the vehicle is turning, the inside wheel travels less distance (i.e., in a shorter arc) than the outside wheel in comparison with when the vehicle is travelling in a straight line.

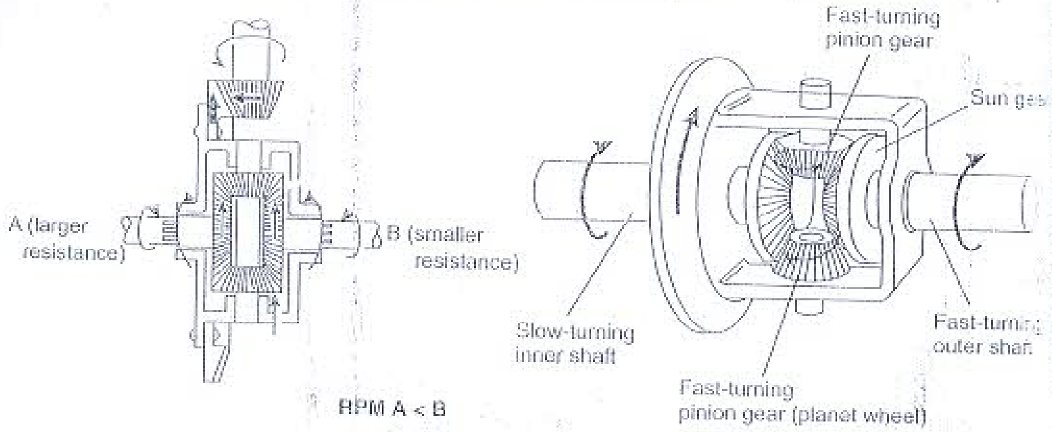


Fig. 10.26 Cornering

Since a resistance is therefore applied to the left-hand sun gear, as illustrated above in Fig. 10.26, each differential pinion rotates around its own shaft and also revolves around the rear axle. The rpm of the right-hand sun gear increases as a result.

One wheel on a muddy surface

The differential described above is a standard or open differential. It delivers the same torque to each wheel. If one tyre begins to slip and spin, the open differential divides the rotary speed unequally. The tyre with good traction slows and stops. This may also stop the vehicle or prevent it from moving.

If one of the wheels gets in the mud it will start to spin if the accelerator pedal is pressed. This is because of the extremely low friction resistance of the muddy surface. This makes it very difficult to get that wheel out of the mud, because it merely spins (at an rpm twice as much as that of the ring gear) instead of moving.

DIFFERENTIAL LOCK

A differential lock is a mechanical device that, when fitted to a differential, prevents the driving wheels from rotating at different speeds.

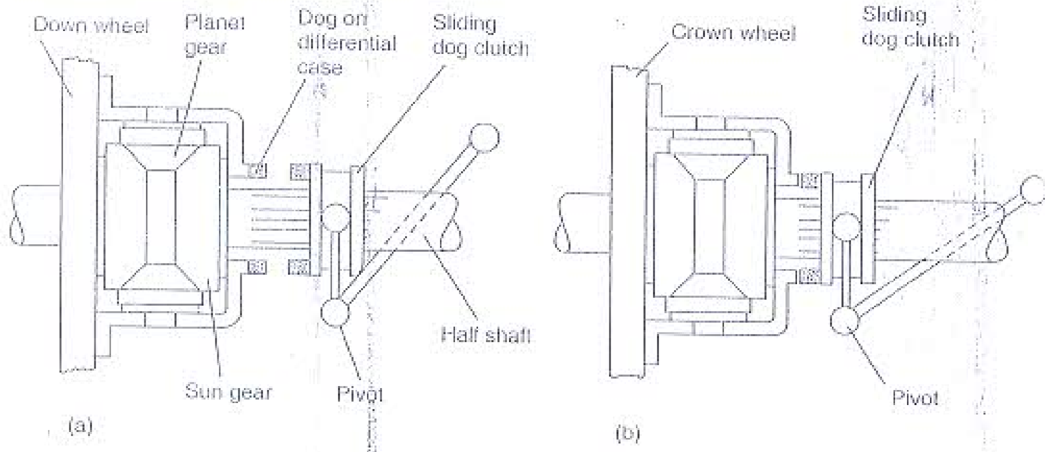


Fig. 10.27 Differential lock: (a) disengaged and (b) engaged

12 CHAPTER

WHEEL ALIGNMENT

WHEEL ALIGNMENT (OR) STEERING GEOMETRY

The driver can turn the automobile in any direction he desires by turning the steering wheel. However, if the driver manipulates the steering wheel continuously to keep the vehicle running in a straight line when travelling on a straight road or if he is required to expend a lot of energy to turn the vehicle on curves, he would be under a great physical and mental strain.

The wheels are installed on the body (or chassis) at certain angles in accordance with certain requirements to eliminate these problems, as well as to prevent early wearing of tyres. These angles, in combination, are called "wheel alignment".

Steering is easy as long as the wheels are aligned properly, because the steering wheel will remain in a straight-ahead position on straight roads with little help from the driver and will require little efforts to turn on curves. But if even one of these angles is incorrect, the following problems can occur:

- difficult steering
- poor steering stability
- poor recovery on curves
- shortened tyre life

Wheel alignment refers to positioning of the front wheels and steering mechanism in such a way that the geometry may impart:

- good directional stability
- steering ease
- minimum tyre wear
- reversibility of steering, and
- durability of the component parts

FRONT-WHEEL GEOMETRY

The term 'front-wheel geometry' or 'steering geometry' refers to the various angles between the front wheels, the frame, and the attachment parts. The angles include:

1. Camber
2. Steering Axis Inclination (SAI)
3. Caster
4. Toe angle, and
5. Turning radius

CAMBER

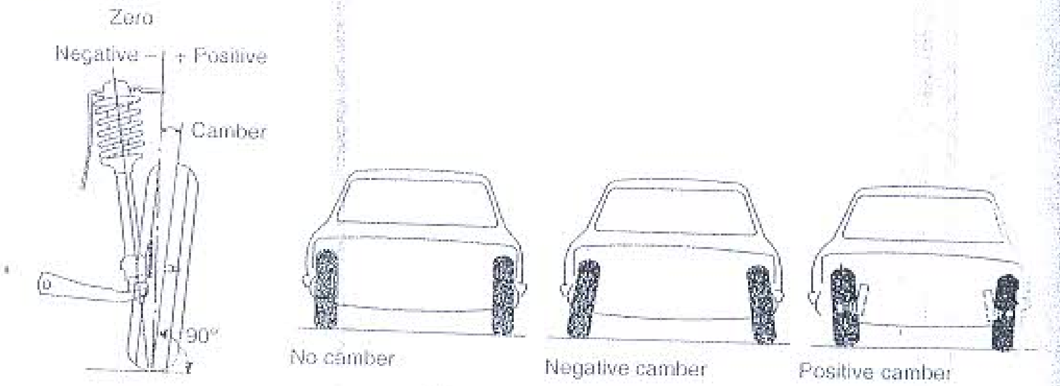


Fig. 12.1 Camber angle

Camber is the tilt of the car wheels from the vertical when viewed from the front of the ve... Camber is "positive" if the tilt is outwards at the top and is "negative" if it tilts inwards at the ... If the top of a wheel is not tilted in either direction, it is called "zero camber". Camber is also ca... wheel rake and is measured in degrees which is normally up to 2°.

If the camber on the two front wheels is not equal, the vehicle will try to pull towards the ... where the camber is higher.

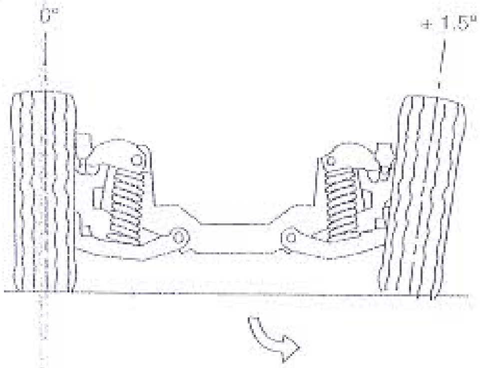


Fig. 12. 2 Unequal camber angle

On the conventional rigid axle, the camber remains almost fixed.

Effects of positive camber

The effects of positive camber are as follows:

- Reduction of vertical load
- Prevention of wheel slip-off
- Prevention of undesirable negative camber due to load
- Reduction of steering effort

Effects of negative camber

Some vehicles (frequently travel in hills) are being given negative camber to improve corner... performance.

Effects of zero camber

The main reason for adopting zero camber is that it prevents uneven wear of tyres. It is alw... desirable that tyres should roll on the ground vertically so that the wear is uniform. The tyre life w... be maximum when the camber angle in running condition is zero with average load.

...while running, the tyres
... one side than the othe

...STER AND CASTER T

...aster is the forward or b
...sured in degrees from the

The distance from the inte
... tyre-to-road contact are
Backward tilt from the ve
... centerline) is called "po
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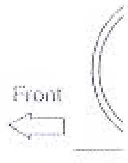


Fig. 1

If the caster on the two fr
...ere the caster is least.

Excessive caster provides

If while running, the tyres are inclined from the vertical either inward or outward, they will wear more on one side than the other.

CASTER AND CASTER TRAIL

Caster is the forward or backward tilt of the steering axis as veiwed from the side. Caster is measured in degrees from the steering axis to vertical.

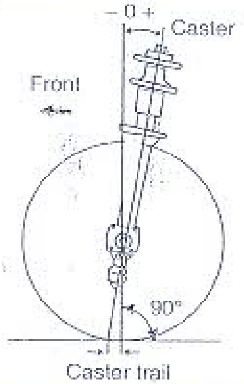


Fig. 12.3 Caster and caster trail

The distance from the intersection of the steering axis centerline with the ground, to the center of the tyre-to-road contact area is called "caster trail".

Backward tilt from the vertical line (steering axis meets the ground at a point in front of the wheel centerline) is called "positive caster", while forward tilt (steering axis meets the ground at a point behind the wheel centerline) is called "negative caster".

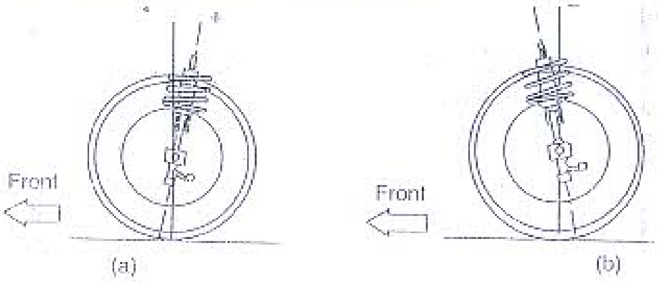


Fig. 12.4 (a) Positive caster and (b) Negative caster

If the caster on the two front wheels is not equal, the vehicle will try to pull towards the side where the caster is least.

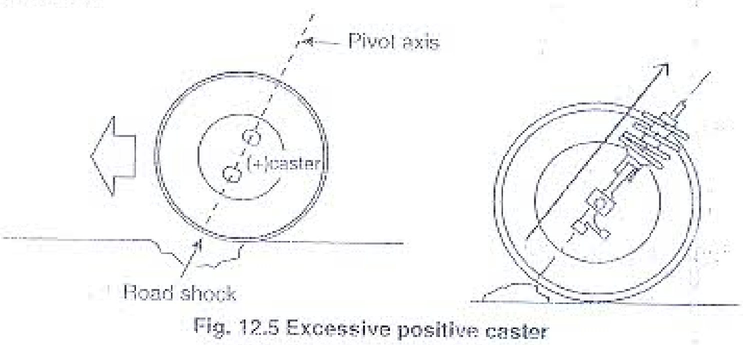


Fig. 12.5 Excessive positive caster

Excessive caster provides a road shock path to the vehicle.

Effects of caster

Caster angle is the stability angle. It provides directional stability while taking a turn or ... cruising in straight ahead position.

Positive caster puts the point of intersection (lead point) of the steering axis and the road surface a little ahead of the tyres point of contact. While going straight straight ahed, the wheel follows ... lead point which always lies in front of it.

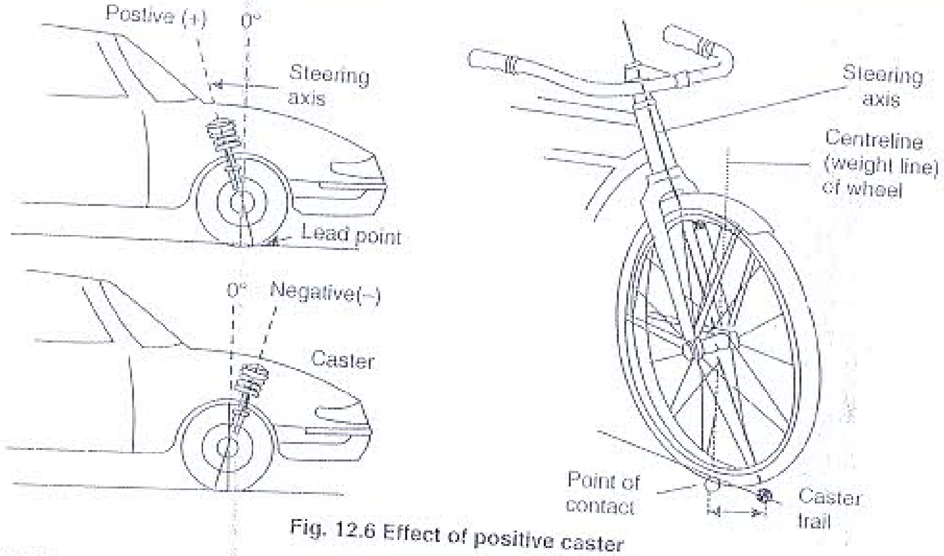


Fig. 12.6 Effect of positive caster

STEERING AXIS INCLINATION (SAI) (or) KING PIN INCLINATION (KPI)

Steering axis

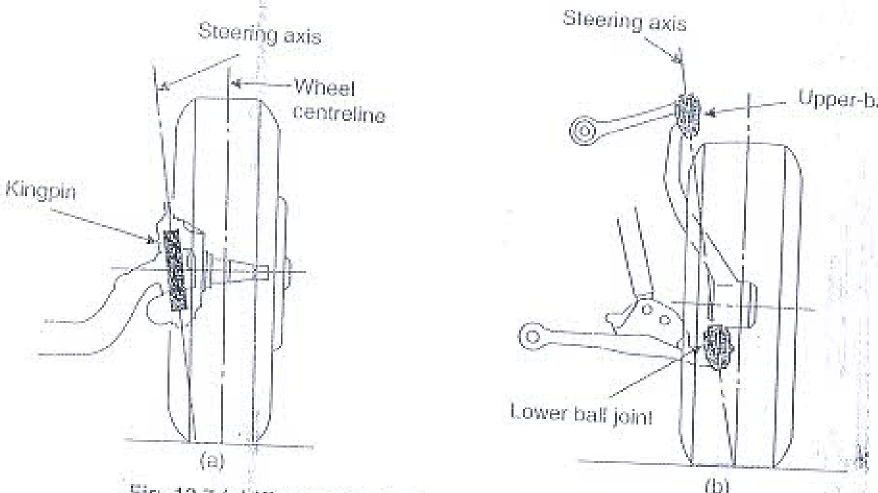


Fig. 12.7 (a) King pin inclination and (b) Steering axis inclination

The axis around which the wheel rotates as it turns to the right or left is called the "steering axis". The steering axis is found by drawing an imaginary line between the top of the shock absorber's upper support bearing and the lower suspension arm ball joint in the case of strut type suspensions. With rigid-axle suspensions, a part called a kingpin is included at each end of the axle. The kingpin axis is equivalent to the steering axis of other types of suspension. In the case of ...

...ble wishbone suspension, the line connecting the upper ball joint and the lower ball joint forms the steering axis.

Steering Axis Inclination (SAI)

The steering axis is tilted inward as viewed from the front of the car and is called the "steering axis inclination (SAI)" (for an independent suspension) or "kingpin angle" (for a rigid axle suspension). This angle is measured in degrees.

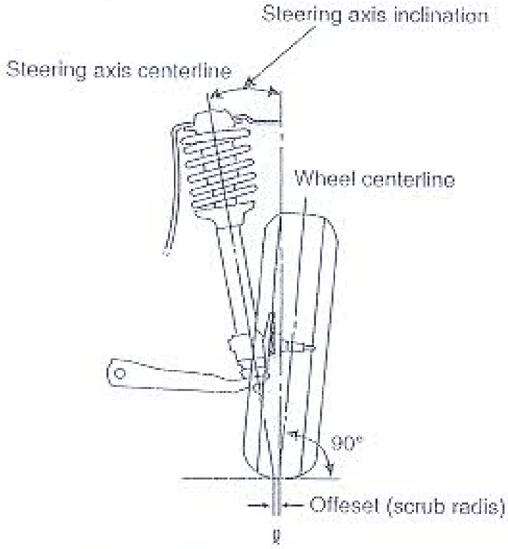


Fig. 12.8 Steering axis inclination

Furthermore, the distance "*l*" from the intersection of the steering axis with the ground to the intersection of the wheel centerline with the ground is called the "offset" or "scrub radius".

SAI is non-adjustable, since it would change only if the wheel spindle or steering knuckle is bent.

Effects of SAI

The effects of SAI are as follows:

- Reduction of steering effort
- Reduction of kickback and pulling to one side
- Improving straight-line stability

TOE-ANGLE (TOE-IN (or) TOE-OUT)

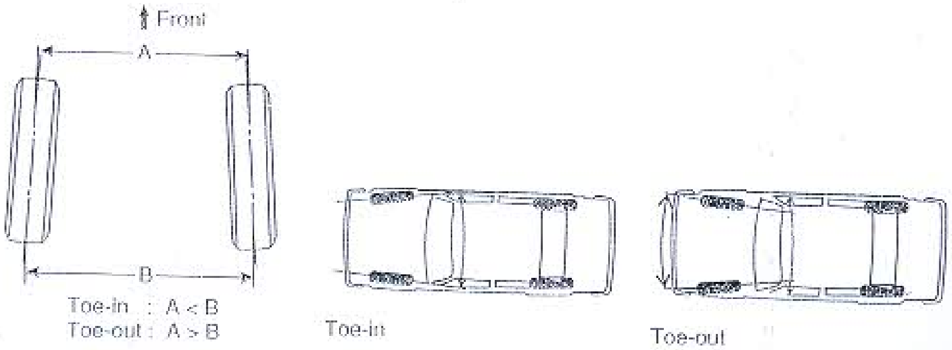


Fig. 12.9 Toe-angle: toe-in and toe-out

It is the difference in distance between the front wheels of a car as measured at the front and a… the rear as viewed from the top when the vehicle is stationary. Toe angle is usually expressed b… distance (B-A). Toe-in is amount by which the front wheels are set closer together at the front th… at the rear. On the other hand, the wheel may be set closer at the rear than at the front in which ca… the difference of the distances between the front wheels at the front and at the rear is called toe-ou…

Effect of toe-angle

The main function of toe angle is to cancel out the camber thrust generated when camber … applied.

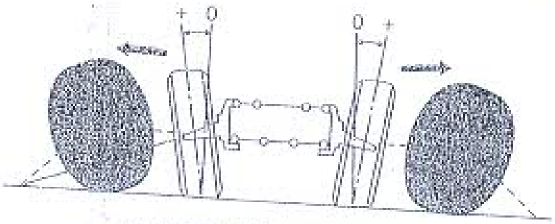


Fig. 12.10 Effect of toe-angle

When the front wheels are given positive camber, they tilt outward at the top. This causes the… to attempt to roll outward as the car moves forward and therefore to side-slip. This subjects the ty… to wear. Therefore, toe-in is provided for the front wheels to prevent this by cancelling outward ro… ing due to camber.

Front-wheel drive vehicles normally require toe-out, because the wheels pull inwards to a par… allel position under power. Toe-in adjustment rarely exceeds 3/16 in. Conversely, rear-wheel dri… vehicles commonly use a toe-in setting, because the wheels pull back when the vehicle moves fo… wards. This adjustment is similar to that for toe-in, which rarely more than 3/16 in.

INCLUDED ANGLE

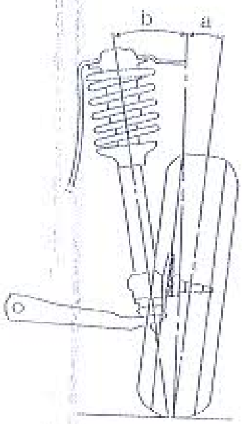


Fig. 12.11 Included angle

The included angle refers to the sum of the camber and steering axis inclination. If the measure… ment of the camber and/or steering axis inclination is outside of the inspection standards, the caus… of the problem can often be found by checking the included angle, as shown in the table 12.1.

S.A.I.	Cam…
Correct	Less
Less than specification	Grea…
Greater than specification	Less
Less than specification	Grea…

…URNING RADIUS

When a car turns a corne… …side. This increases the dis… …spect to each other.

If the right and left front… …ould have the same turning… …d O_2). Smooth turning wou… … that, irrespective of correc… …usual wear.

Turning radius in act…

Table 11.1

ALIGNMENT ANGLES			PROBLEM
S.A.I.	Camber	Included Angle	
Correct	Less than specification	Less than specification	Bent spindle
Less than specification	Greater than specification	Correct	Bent lower control arm
Greater than specification	Less than specification	Correct	Bent upper control arm
Less than specification	Greater than specification	Greater than specification	Bent lower control arm and spindle

TURNING RADIUS

When a car turns a corner, the wheel on the inside must always turn more than the wheel on the outside. This increases the distance between the wheels at the front so that they actually toe-out with respect to each other.

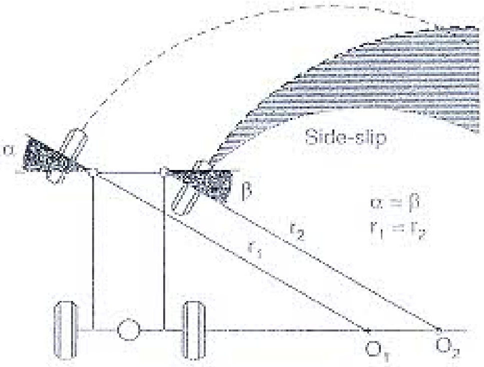


Fig. 12.12 Side slip

If the right and left front wheels were both to turn by exactly the same amount (*i.e.* $\alpha = \beta$), they would have the same turning radius ($r_1 = r_2$), but each wheel would turn around a different center (O_1 and O_2). Smooth turning would therefore be impossible due to side slipping of the tyres. The result is that, irrespective of correct tyre inflation and wheel alignment factors, the tyre would undergo unusual wear.

Turning radius in actual cases

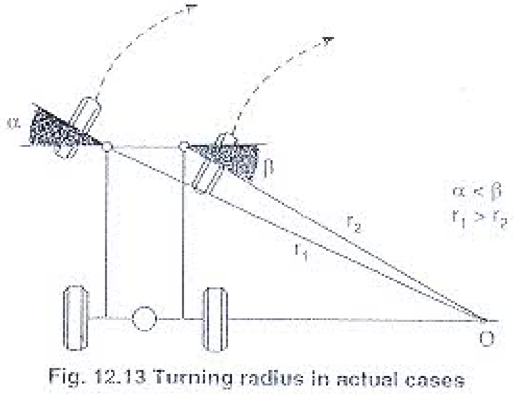


Fig. 12.13 Turning radius in actual cases

In an actual vehicle, the steering linkage is modified in such a way that the inner road whe... move through a greater angle than the outer ($\alpha < \beta$) to achieve the desired turning radii. The ... ence between them is called toe-out on turn which is normally between 2° and 3°.

Side-slip

Side-slip is the total distance that the right and left tyres slip to the side while the vehi... in motion. Side-slip is measured with a side-slip tester during staright-ahead driving at a ver... speed.

Side-slip is generally expressed as the amount of sideway slippage, in mm, per 1 m of for... motion. The general guideline is 0-3 mm (0-0.118 in).

The cause of side-slip is mainly incorrect camber or toe-in, but it is also important to pay ... tion to caster and steering axis inclination.

Centre-point steering and scrub (or roll) radius

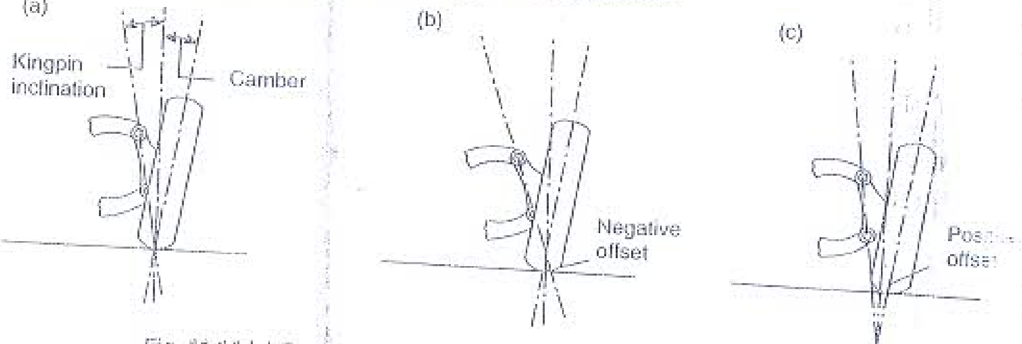


Fig. 11.14 (a) Center-point steering (b) negative offset (c) positive offset

To reduce steering effort, especially on large commercial vehicles, the steering geometry ca... arranged to give centre-point steering. In the 12.14 (a) layout the axes of the road wheel and of ... steering axis intersect where the tyre touches the road.

In the layout 12.14b, the axis of the road wheel and the steering axis intersect slightly ab... ground level. It has been found that this arrangement improves stability and reduces the pull on ... steering wheel if there is a tyre blow-out or front brakes become unbalanced. It is now widely ... on cars. It is called negative scrub radius.

In another layout, the axis of the road wheel and the steering axis meet below ground leve... shown in Fig. 12.14c. It is called positive scrub radius and gives plenty of "feel" to the steering, ... can make it heavy.

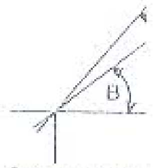
ACKERMANN & DAVIS STEERING

The perfect steering is achieved when all the four wheels are rolling perfectly under all con... tions of running *i.e.*, free from tyre 'side slip' when the vehicle is negotiating a bend. While tak... turns, the condition of perfect rolling is satisfied if the axes of the front wheels when produced m... the rear wheel axis at one point. Then this point is the *instantaneous centre* about which all ... wheels must rotate.

To achieve this condition, two types of mechanisms have been devised: the Davis and ... Ackermann steering mechanisms. Out of these Ackermann mechanism is almost universally ... because of its simplicity. Further this has the advantage that it employs pivots and not sliding ... straints, due to which reason its maintenance is easier. That is why it is universally employed.

...e Ackermann princi...

... motor vehicle is steered ... control of the steerin... ... rolling motion.



Centre of turn

...hen the vehicle is makir... ...each road wheel should rol... ... to a radius drawn to this ... ... must be on a line drawn ... ... as they are fixed at 90... ... to their radius of turn, th... The front wheel on the in... ... the outer wheel and this i...

...kermann linkage

The differnce in moveme... ... In the straight-ahead po... ..., would meet on the cen... ... therefore shorter than th...

When the vehicle is travel... ..., but, as it moves the steer... ...ated by the dotted lines in ... wheel are turned through ... differenced between these ... front wheels at 90° to any

The Ackermann principle

A motor vehicle is steered by the side swiveling action of the front wheels. In order to provide effective control of the steering of the vehicle, it is important that the wheels rotate on their axles with a true rolling motion.

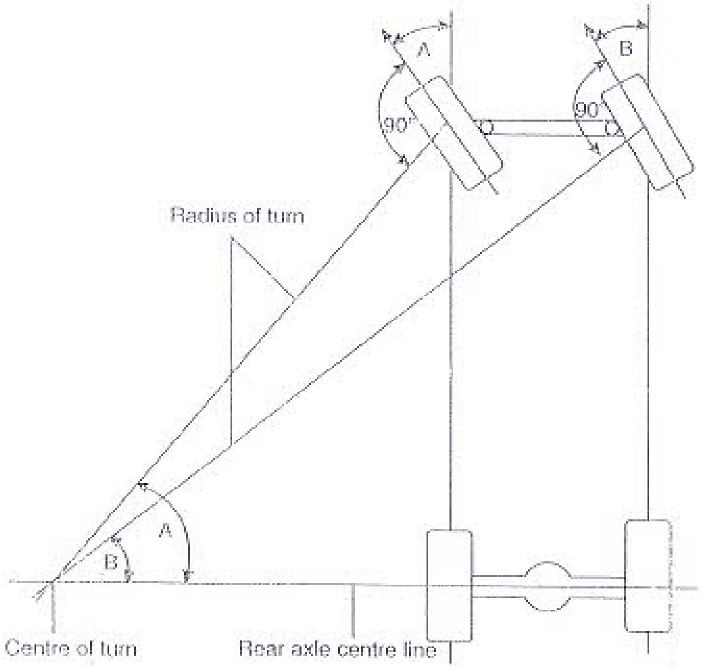


Fig. 12.15 Ackermann principle

When the vehicle is making a turn, true rolling motion must be obtained without sliding. Therefore each road wheel should roll round the centre point of the curve. Each wheel must lie at right angles (90°) to a radius drawn to this centre. As the rear wheels of a conventional vehicle cannot swivel, this centre must be on a line drawn through the axis of the rear axle. Therefore, the rear wheels will always roll true as they are fixed at 90° to the rear axle. If, however, both front wheels must align themselves at 90° to their radius of turn, they must be turned at different angles from the straight-ahead position.

The front wheel on the inside of the corner has therefore to be turned through a greater angle than the outer wheel and this is obtained by the use of the 'Ackermann' steering principle.

Ackermann linkage

The differnce in movement of the inner and outer wheels is obtained by inclining the steering arms. In the straight-ahead position, the steering arms are arranged so that their centre lines, if produced, would meet on the centre line of the vehicle on or near the nose of the rear axle. The track rod is therefore shorter than the distance between the kingpin axes if it lies behind the axle beam.

When the vehicle is travelling in the straight-ahead position, the track rod is parallel to the axle beam but, as it moves the steering arms, the inner end moves nearer to the axle than the outer end (as indicated by the dotted lines in Fig. 12.16). The result of this action is that the inner steering arm and road wheel are turned through a greater angle than the outer arm and wheel. It should be noted that the differenced between these two angles is not constant but is automatically corrected to maintain the front wheels at 90° to any radius of turn.

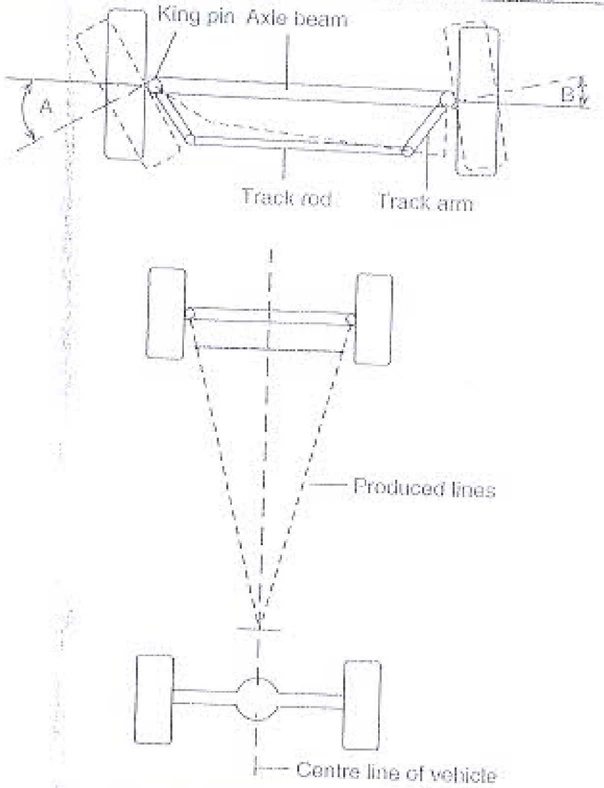


Fig. 12.16 Ackermann linkage

Oversteer and Understeer

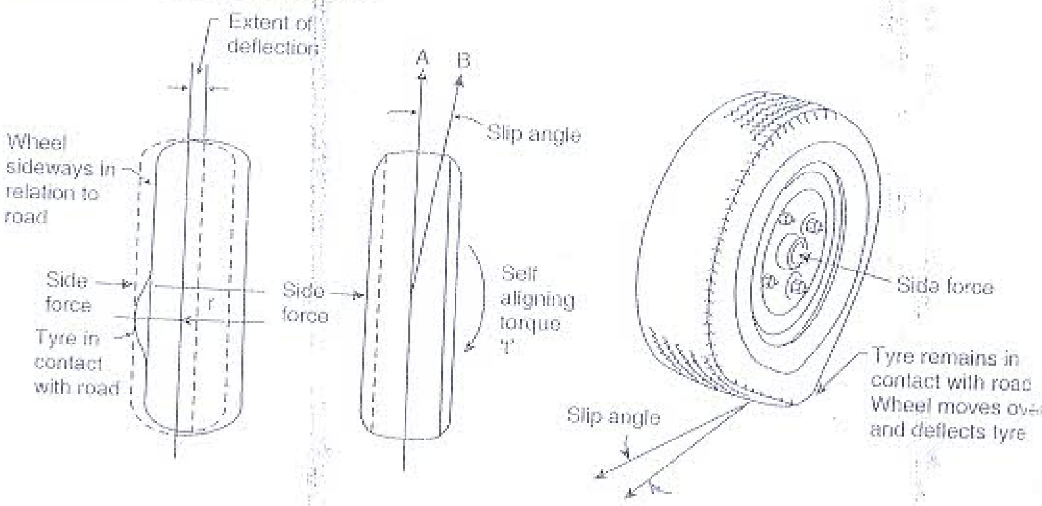


Fig. 12.17 Causes of slip angle

Low-pressure tyres, used on modern vehicles, take a different path when subjected to a side force. A side force caused by wind, road camber or cornering forces produces a slip angle at each tyre. Fig. 12.17 shows a top view of a wheel travelling in the direction of A. If a side force acts on the wheel, tyre deflection will cause the wheel to take the path B, although the wheel is still pointing in the original direction. The angle between the path that the wheel is actually taking and the plane