SCHOOL OF MECHANICAL ENGINEERING

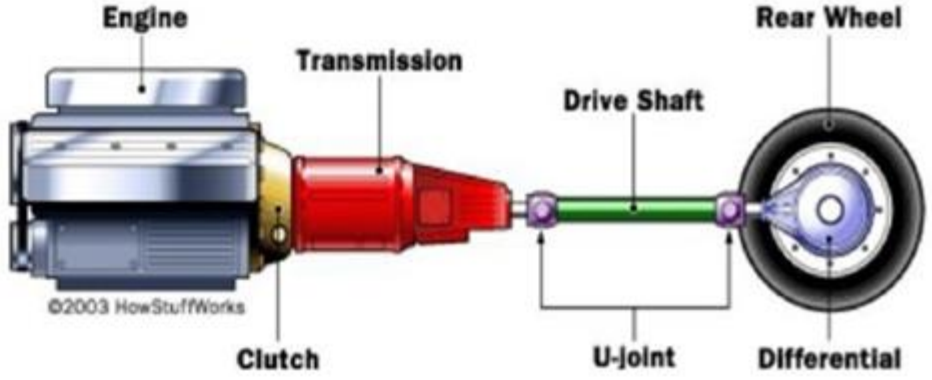
DEPARTMENT OF AUTOMOBILE ENGINEERING

UNIT-I

CLUTCH AND GEAR BOX

Transmission System

Chief function of the device is to receive power at one torque and angular velocity and to deliver it at another torque and the corresponding angular velocity.



Function of Transmission:

- It is used to transmit engine torque to the driving wheels to drive the vehicle on the road.

REQUIREMENTS OF TRANSMISSION SYSTEM

1. To provide for disconnecting the engine from the driving wheels.
2. When the engine is running, to enable the connection to the driving wheels to be made smoothly and without shock.
3. To enable the leverage between the engine and driving wheels to be varied.
4. It must reduce the drive-line speed from that of the engine to that of the driving wheels in a ratio of somewhere between about 3:1 and 10:1 or more, according to the relative size of engine and weight of vehicle.
5. Turn the drive, if necessary, through 90° or perhaps otherwise re-align it.
6. Enable the driving wheels to rotate at different speeds.
7. Provide for relative movement between the engine and driving wheels.

Purpose of Transmission System

- It enables engine to be disconnected from the running driving wheels.
- It enables the running engine to be connected to the driving wheel smoothly.
- It enables the driving wheels to be driven at different speeds.
- It enables turning of the drive round through 90 degree.
- It enables the reduction of engine speed in the ratio of 4:1 in case of passenger car and in a greater ratio in case of heavy-duty vehicles.
- It enables leverage between engine and wheels to be varied

Requirement of Clutch

1) Torque Transmission

The clutch should be able to transfer the maximum torque of engine under all conditions. Usually designed to transmit 125 to 150% of maximum engine torque.

2) Gradual Engagement

Clutch should take the drive gradually without occurrence of sudden jerks

3) Heat Dissipation

During clutch application large amount of heat is generated, the rubbing surfaces should have sufficient area and mass to absorb the heat generated. The design of clutch should ensure proper ventilation or cooling for adequate dissipation of heat.

4) Dynamic Balancing

This is necessary particularly in high speed clutches

5) Vibration Damping

Suitable mechanism should be incorporated within the clutch to eliminate the noise produced in transmission

6) Size

The size of clutch must be smallest possible, so that it occupies minimum amount of space.

7) Inertia

The clutch rotating parts should have minimum inertia. (Otherwise when clutch plate is released for gear changing, clutch plate will keep on spinning)

8) Ease of operation

The operation of disengaging the clutch should be easy for driver.

CLUTCH

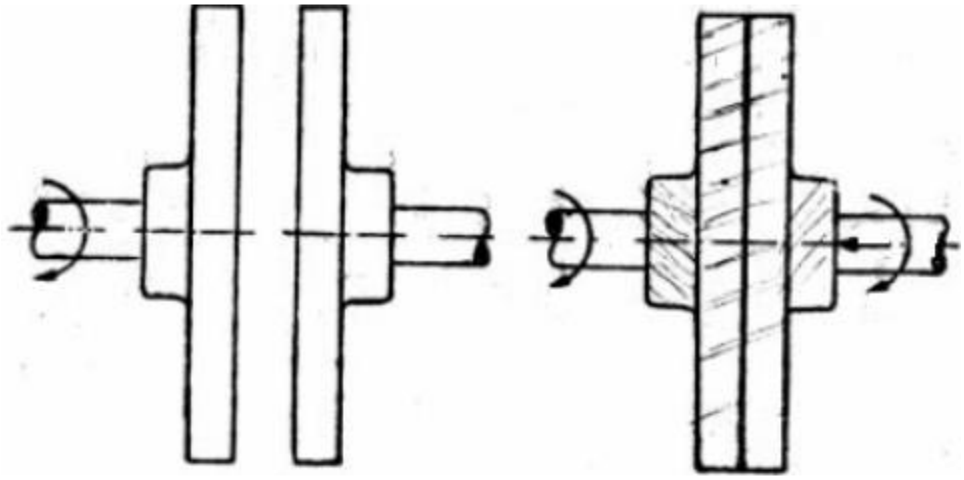
The clutch is housed between the engine and transmission where it provides a mechanical coupling between the engine's flywheel and the transmission input shaft. The clutch is operated by a linkage that extends from the passenger compartment to the clutch housing. The purpose of the clutch is to disconnect the engine from the driven wheels when a vehicle is changing gears or being started from rest.

Disengaging the clutch separates the flywheel, the clutch plate and the pressure plate from each other. The flywheel is bolted to the end of the crankshaft and rotates with it. The clutch plate is splined to the gearbox in order for both to rotate together and the pressure plate clamps the clutch plate to the flywheel. When the pressure is released by depressing the clutch pedal, the crankshaft and gearbox input shaft rotate independently. When the foot is taken off they rotate as one.

REQUIREMENTS OF A CLUTCH

The clutch must

1. Pick up its load smoothly without grab or clatter.
2. Have a driven disc of low moment of inertia to permit easy shifting.
3. Damp out any vibration of the crankshaft to prevent gear clatter.
4. Require little pedal pressure to operate it.
5. Be easy to adjust and service.
6. Be cheap to manufacture.



BASIC PRINCIPLE OF THE FRICTION TYPE CLUTCH

To understand the working principle of clutch, let's take two sanding discs, first one driven by a power drill corresponds to the flywheel of a car, driven by the engine. If a second sanding disc is brought into contact with the first, friction makes it revolve too but more slowly. But when the second disc pressed against the first disc which is connect to the power drill, as the pressure increases the two discs revolve as one. This is how a friction clutch works.

Single Plate Clutch

A Single Plate Clutch is defined as a type of friction clutch, which is made of a single clutch plate. The amount of frictional force that generates within the clutch plate due to the contact that takes place between the friction lining which is mounted on the clutch plate.

Also, the prior component regarding the mechanism of a clutch plate is the flywheel, which is fixed on the crankshaft of an engine. Apart from that, the flywheel rotates with respect to the rotation of the shaft. Every clutch plate's basic working principle depends upon the frictional force that arises within the clutch plate.

The main reason behind the frictional force is the friction lining, which plays a significant role in regards to the same. The friction lining can be mounted by the manufacturer on both sides of the plate.

Apart from that, a single plate clutch can also be termed as a dry clutch due to which any sort of lubricant is not needed for the seamless functioning of the clutch. The coefficient of friction occurs due to the contact between friction lining, which is very high in the case of a single-plate clutch.

Parts of a Single Plate Clutch:

Mainly, a clutch is made of several components like pressure plate, flywheel, disk plate, friction lining, and the spring. Therefore, the major components of a clutch regarding its mechanism are stated below briefly.

Flywheel:

The prior part that can be utilized by a manufacturer in order to develop a clutch is the flywheel. The flywheel is the heaviest part among all the parts that incorporated within a clutch.

In regards to this, the flywheel is attached with the crankshaft and another side of the flywheel made contact with the grasp-plate. Apart from that, the flywheel is the part that decides the amount of time, should be taken by the entire mechanism, regarding engagement and disengagement.

Due to the contact with the grasping plate, a high amount of torque oftentimes arises due to which the engagement takes place within the vehicle.

Pressure Plate:

The main frictional force controlling part is the Pressure plate. The pressure plate is usually attached to the plate of solid metal. It takes the help of weight to maintain contact.

In this regard, the pressure plate uses springs, which are joined with the pressure plate to put the proper amount of weight. Moreover, the pressure plate controls the contact between the frictional surfaces of the grasp- plate and the flywheel to maintain the amount of frictional force.

Friction Lining:

It is the main part of the contact from which the frictional force produces. Friction lining is attached to the grasp-plate, in the both of the sides of it. Along with that, friction lining creates contact with the flywheel and thus creates a frictional force at the time of rotation.

With the help of this force, the torque produces. The frictional lining can also be termed as Frictional Surface. Apart from that, the frictional lining is made of some special type of metal which is the high coefficient in nature and never slips and made by the friction surface.

Clutch Plate:

The clutch plate is the most important part of a clutch. It is the main part also. Apart from that, the clutch plate is made of a thin plate of metals. It consists of frictional lining on both sides of it.

Moreover, the clutch plate fully depends on the working principle of the friction lining. The clutch plate only rotates and the attached friction surface can be used to build the friction with the flywheel to produce friction, as well as torque. A clutch plate is also known as Clutch Disk.

Springs:

Springs are connected with the pressure plate with the help of the bolts. These springs usually help the clutch plate to make contact with the flywheel to produce friction and as well as torque.

Moreover, the pressure plate puts weight on the springs that are attached to the pressure plate. Then the springs maintain the flywheel to move forward or backward from the clutch plate's Frictional Surface to maintain the amount of force that is created by the friction.

So high coefficient friction is also maintained and the proper amount of torque is produced. Apart from that, these springs cannot be slipped.

Thrust Ball Bearing:

The thrust ball bearing is the main part that helps in the rotation of the clutch plate and the flywheel also. It is usually made of some small bearing balls in a circular ring. It can be used in low thrust. Moreover, it helps to produce the rotation between two parts to maintain the low axial loads as low thrust is used.

Working Principle of Single Plate Clutch:

The entire working principle of a Single plate clutch depends upon two distinct areas those are disengagement and engagement. Therefore, the below section briefly discusses the two mechanisms, one is engagement and another one is disengagement.

Engage:

- At first, the clutch plate is placed in its proper position, between the flywheel and the pressure plate.
- The main three parts start to rotate with the help of thrust ball bearings.
- The springs are connected with the pressure plate. In this regard, the pressure plate puts the weight on the springs according to the necessity.
- Springs can control the contact of the friction lining of the clutch plate and the flywheel.
- The friction surface or friction lining turns to rotate with the contact of the flywheel and thus friction can be produced.
- The clutch becomes engaged.

- The clutch plate is attached to the clutch shaft which is in contact with the gear-box of a vehicle.
- Hence, the power transfers to the gearbox from the shaft.

Disengage:

- At first, the pressure plates remove its contact pressure from the springs. As a result, the springs moved backward from the clutch plate.
- The flywheel also comes back from the clutch plate.
- Hence, the clutch plate becomes free from the pressure plate and the flywheel.
- The friction surfaces are not in contact now with the flywheel and pressure plate.
- In this regard, the clutch shaft reduces its speed of rotation as the weight reduced.
- At last, the rotation of the clutch shaft is stopped.
- Therefore, the clutch is disengaged.

Applications of Single Plate Clutch:

Single Plate Clutches are used in various filed like:

- In the automotive industry, a single plate clutch can be used by most of the vehicles around the globe. Due to the large radial shape of the single-plate clutch, it is mostly used in large vehicles as compared to small ones, such as buses, cars, trucks mainly use a single plate clutch.
- This type of clutch does not require any lubricant for cooling. But, behind this, another reason is present. Due to the large size of a single plate clutch amount of heat dissipation takes place significantly. Therefore, oil or lubricant is not needed to cool the plate.
- Due to the high coefficient of friction, most of the vehicles use a single plate clutch. The amount of the coefficient of friction is more than 0.3.
- Apart from that, the amount of torque generation is also very high as compared to a wet clutch due to which this type of clutch can mostly be used in a big vehicle.

- But, in regards to the application of a single plate clutch, the user has to prevent the contamination. Also, the moisture that presents within the plate should be prevented by the user through sealing the ports.

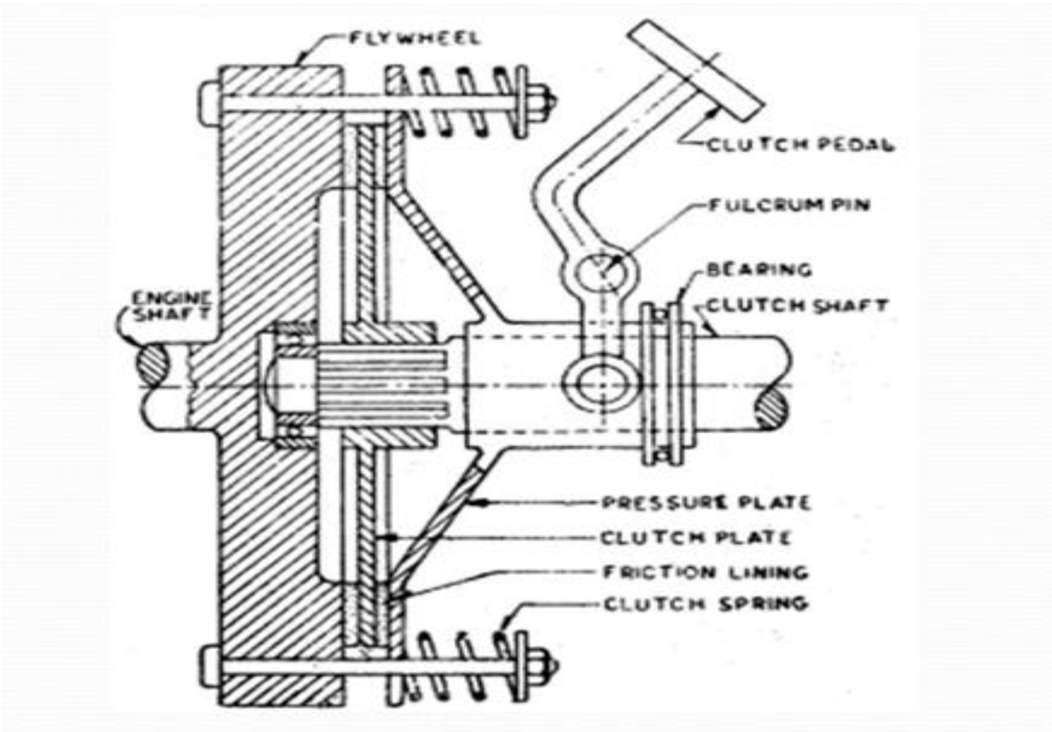
Advantages of Single Plate Clutch:

- In regard to the functions, the single plate clutch is very good. Because of its quick response to the operation of the single-plate clutch, users should use the single-plate clutch.
- The heat can be generated by the clutch due to the frictional force that damages the other parts which help in the process of power transmission.
- As the single plate clutch creates less heat so no coolant medium is needed for cooling the system. So, this clutch can also be termed as the dry clutch. No extra charge for the coolant is required.
- In the case of the single-plate clutch, the torque is less as it can perform at a certain range. In order to this limitation, if the input force exceeds the required torque, then the slippage takes place between the contact surface and plate of the clutch. Due to this incident, the single plate clutch performs like a safety mechanism that works as safeguards and helps the other parts from being damaged.
- The performance of engagement and disengagement of the plate is smooth. So the single plate clutch can perform its work smoothly.
- As the torque is low, so the loss of power is also less. Due to, less power loss, it is safe for the engines to perform the work smoothly.

Disadvantages of Single Plate Clutch:

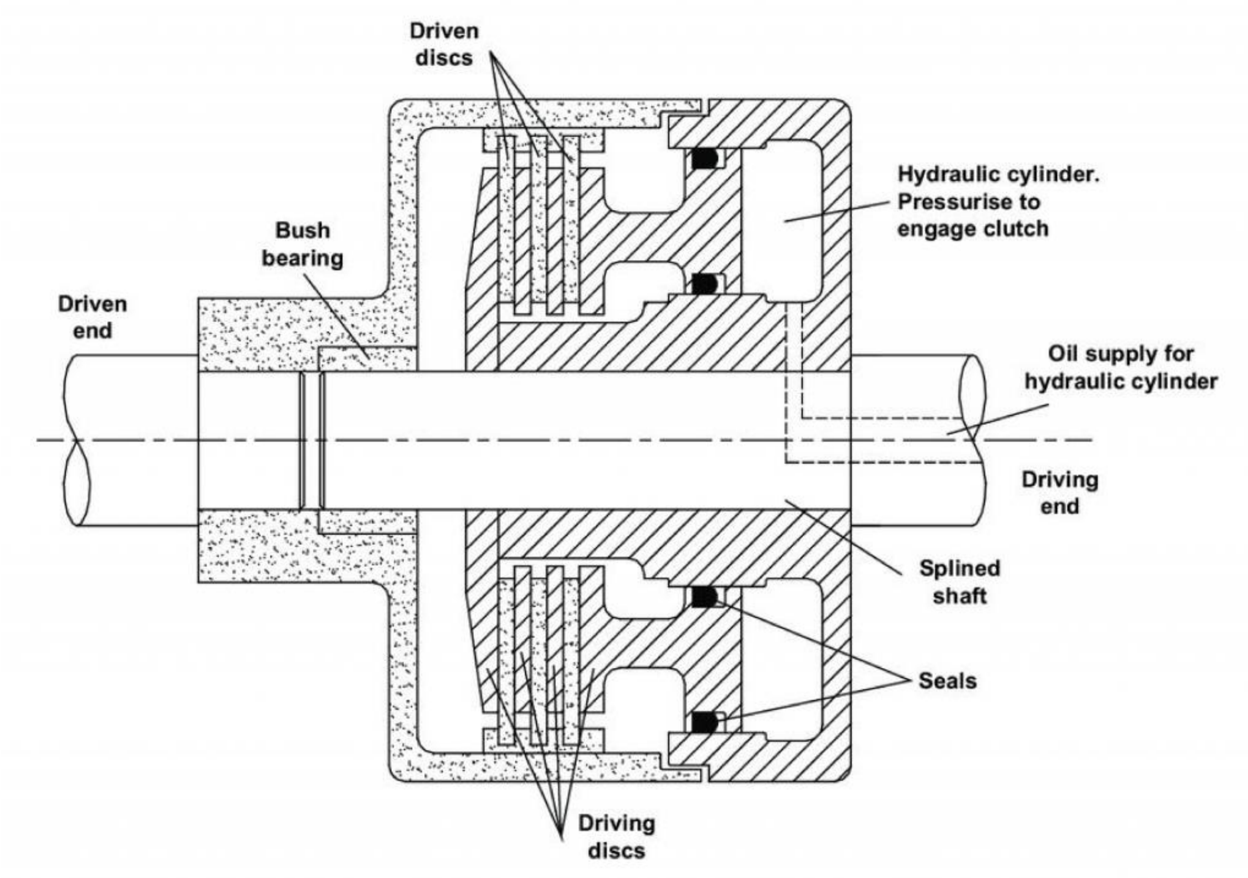
- The single-plate clutch needs no cooling medium. So, this clutch is dry. Due to this dryness, high maintenance is also required. Due to the dryness, the moisture damages the clutch. If any leakage occurs, then the moisture damages the clutch plate. So, the lubricating oil is required to prevent the damage of moisture.

- The diameter of the single-plate clutch is bigger in shape and size. It is also bigger in regard to the transmission of low torque that can be created by the single-plate clutch.
- The single-plate clutch has less capability of transmission of torque. The capacity of low torque is also one of the major disadvantages of the single-plate clutch.



Multi-plate Clutch

One of the most useful clutches is Multi-plate Clutch among all the other clutches. It is usually made by multiple plates hence it is also known as a multi-plate clutch.



Definition of Multi-Plate Clutch:

The multi-plate clutch is a special type of clutch that can produce high torque. It mainly transmits the power from one shaft to another shaft. One of them is the engine shaft and another one is the transmission shaft. Friction takes place in the engine by the clutch plates. This friction makes high torque.

Moreover, it can be said that in the automobiles or in pieces of machinery, where high torque is needed like in the gearbox of motorcycles, this multi-plate clutch can be used to assure the precision level of that machine.

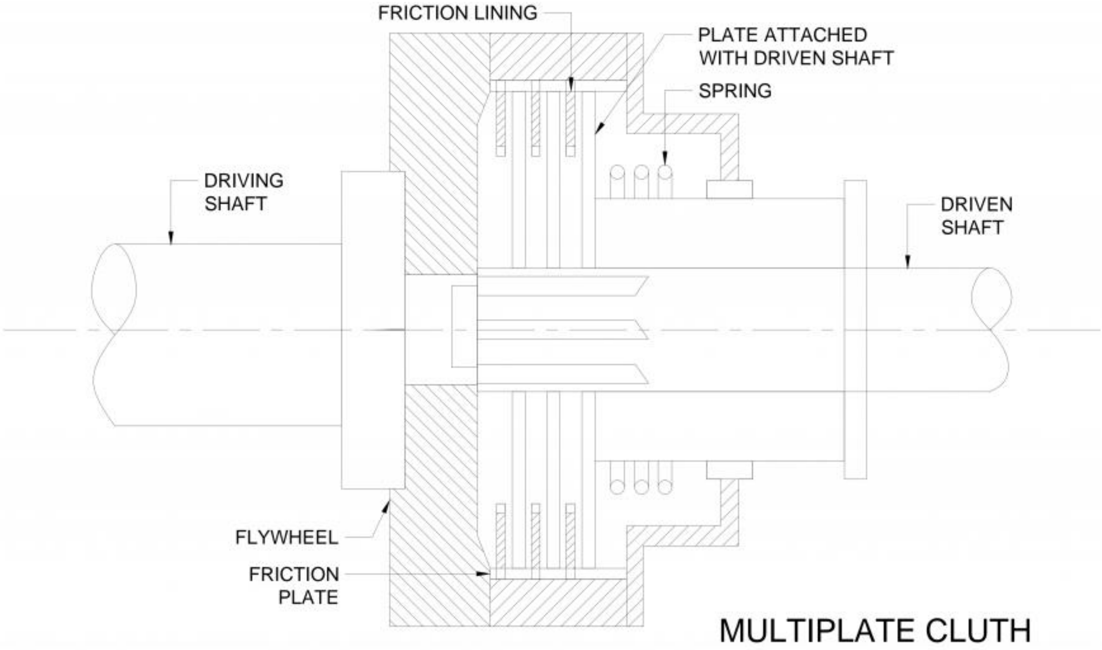
The high amount of torque can be generated by the multi-plate clutch due to the number of plates.

Therefore, it can be asserted that if the numbers of plates are increased by the manufacturer then it can be possible to increase the amount of torque generation.

Multi-Plate Clutch Components or Parts:

The Multi plate clutch is made of different types of components. They are as follows:

- Flywheel
- Pressure Plate
- Friction Disc
- Clutch Paddle
- Friction Lining
- Thrust Spring
- Inner Splined Sleeves
- Diaphragm Spring



Flywheel:

A flywheel is a very useful part of the engine. It is situated beside the clutch. Therefore, when the flywheel and clutch make contact with each other friction is generated through the same.

In regards to the same, this friction produces high power. Hence, the flywheel transmits the generated power from one shaft to another shaft.

Pressure Plate:

It is another prior component of the multi-plate clutch. Although, not only it is used in the multi-plate clutch but also each and every type of clutches are made of the pressure plate.

The overall mechanism of the clutches' pressure plate plays a significant role in its operation. It can be used to make friction in the contact of the clutch plate. The pressure plate is attached with splined sleeves and the pedals respectively.

In this regard, when the pedals are pressed, then the pedals make contact with the pressure plates. Hence, the pressure plate changes its place from backward to forward or vice versa. Moreover, it can be said that the pressure plate is placed to maintain the friction of the clutch.

Friction Disc:

Friction disc is the main cause behind the generation of the frictional force. It can be attached to a pressure plate. According to this, when the pedals are pressed, the pedals make contact with the pressure plates, moreover with the friction discs. Hence, friction discs produce a frictional force.

Clutch Paddle:

The clutch plate is the most important part of this entire mechanism. It creates contact between the different parts like flywheel and pressure plate respectively. Apart from that, it is mainly utilized to control the engagement as well as the disengagement of the clutches.

Thus, the inner portion creates contact with the flywheel and the outer portion creates contact with the pressure plate. Regarding this, clutch plates have friction lines at the end of the outside parts.

Along with that, usually, that part is mainly used to create contact with the pressure plate and thus, produces friction. Apart from that, the clutch plate power is also produced in the engine.

Hence, the power reaches between two shafts, those are engine shaft and transmission shaft. In the case of the multi-plate clutch, due to the presence of more than one clutch plate, more friction can also be produced.

Friction Lines:

The friction line is the main part for producing the frictional force in the engine. It is mainly attached to the end of the outside of the clutch plate. Hence, it can be used to connect to the pressure plate, to produce friction.

Thrust Spring:

Thrust spring is mainly attached to the outer side of the pressure plate. It helps to maintain the contact between two plates, those are the clutch plate and the pressure plate.

Apart from that, these springs can be moved by the clutch pedals. Hence, the clutches become disengaged.

Inner Splined Sleeves:

The inner splined sleeve is attached to the pressure plate. After that, the pedals of the clutch are pressed.

Thus, the pressure plate, as well as the inner splined sleeves, tends to move forward and backward. As a result of this, inner splined sleeves can disengage or engage the clutch.

Diaphragm Spring:

Diaphragm spring is also a very important type of spring in this type of clutch. It takes the place of the thrust spring, in this type of clutch. Apart from that, this spring is circular and has so many fins or fingers.

Thus, it looks like the diaphragm. Hence, its name is Diaphragm Spring. Its uses are almost as same as thrust spring. Moreover, it maintains the friction force.

Types of Multi-Plate Clutch:

There are 3 types of Multi Plate Clutch:

- Spring Type Multi-Plate Clutch,
- Hydraulic or Automatic Multi-plate Clutch and
- Diaphragm Multi-plate Clutch

Spring Type Multi-Plate Clutch:

The main parts of the Spring type Multi-plate clutch are clutch plates, pressure plates, clutch pedals, friction lines, thrust spring, inner splined sleeves, flywheel, and friction discs.

Diaphragm Multi-plate Clutch:

The Diaphragm Multi-Plate Clutch is made of the same parts as of the Spring type Multi-plate Clutch, excluding the thrust spring. In that case, the diaphragm spring can be used in the place of thrust spring.

Hydraulic or Automatic Multi-plate Clutch :

The Hydraulic Multi-plate Clutch is also as same as Diaphragm Clutch but it has some differences in its operational part.

Working principle of Multi-Plate Clutch:

To discuss the working principle of the multi-plate clutch, it can be said at first that it has two types of working procedures. One is the engaging procedure and the other is the disengaging procedure. Regarding this, here the two types are discussed below:

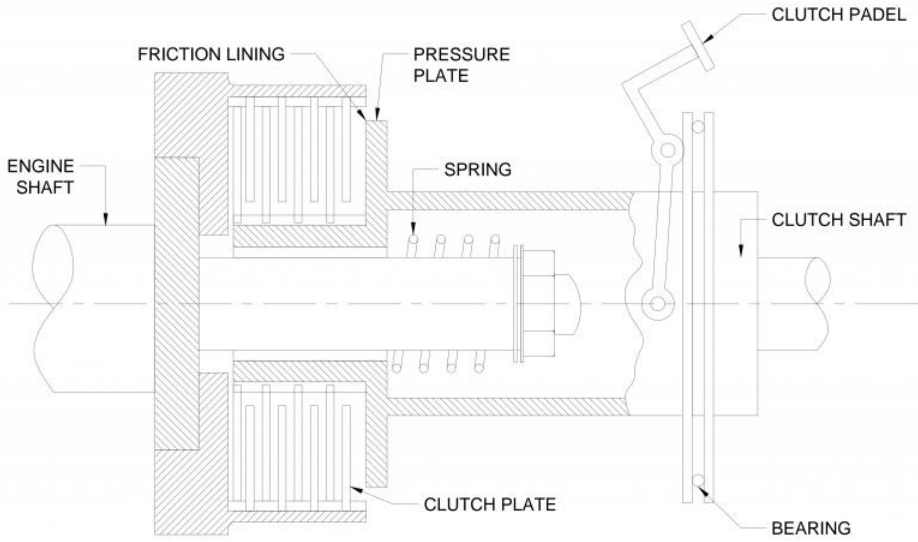
Engage:

- Engagement takes place in the engine when the driver pressed the clutch paddle.
- Apart from that, it enhances the movements of the thrust springs.
- The pressure can be given to give pressure to the pressure plates with the help of thrust springs.
- Hence, the pressure plate tends to move forward.

- Along with that, the friction linings that are attached on the inner side of the pressure plate to make contact with the flywheel, start its action.
- As a result, the clutch engages.

Disengage:

- For disengaging the clutch and the engine of the vehicle, the driver has to press the clutch pedals as well as the fins of inner splined sleeves at first.
- It enhances the thrust spring to move backward.
- This thrust spring releases pressure from the pressure plates.
- Hence, the pressure plate tends to move backward.
- As a result of removing the pressure from the flywheel, pressure plate and springs the clutch becomes disengaged.



MULTIPLATE CLUTH

Advantages of Multi-Plate Clutch:

There are many advantages of the Multi Plate clutch. Some of the advantages are stated below:

- As the multi-plate clutches are made of more clutch plates so the capacity of transmission of torque is quite high.
- This type of clutch is small in size. Due to its compact size, the multi-plate clutch is suitable for any sort of vehicles around the globe. As the motorcycles and scooters have limited space, so the multi-plate clutch can be fitted easily because of its compact size.
- In comparison with the single-plate clutch, the diameter of the multi-plate clutch is smaller than the single-plate. Due to this feature, the multi-plate clutch can be used in many sports such as racing and others.
- The multi-plate clutches have many friction surfaces. As the transmission of torque depends on the number of friction surfaces, so in the case of the multi-plate clutch, torque becomes higher than the single-plate clutch.
- Due to the advantage of higher torque rate, in the case of heavy vehicles which are mainly used for commercial purpose, the multi-plate clutches can easily be used.
- In comparison to a single-plate clutch, the multi-plate clutch helps the engine to perform with better acceleration.
- There is a force required to press the clutch pedal to make the clutch operational. To operate a multi-plate clutch, less pedal effort is required.

Disadvantages of Multi-Plate Clutch:

There are some disadvantages too. Some of the disadvantages are stated below:

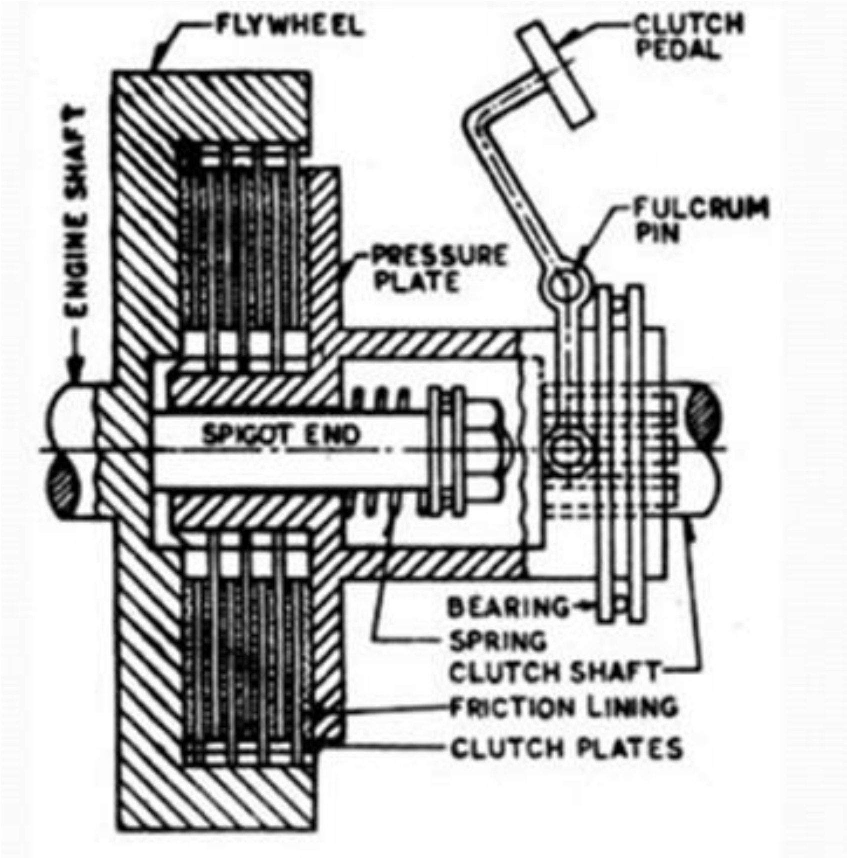
- The weight of the multi-plate clutch is heavy so it is not suitable for all-time use.
- The cost of the multi-plate clutch along with its maintenances is very expensive. So, it is not good for the users of the multi-plate clutch, with a low budget.
- As the number of frictional surfaces is more than the single-plate clutch, so more heat can also be generated. Due to more heat, the engine gets heated

quickly. In this case, a cooling medium is required for the multi-plate clutch. So, for the cooling medium, users have to spend extra money. Due to this drawback, the maintenance cost becomes high automatically.

Application of Multi-Plate Clutch:

The application of Multi-Plate clutch are stated below:

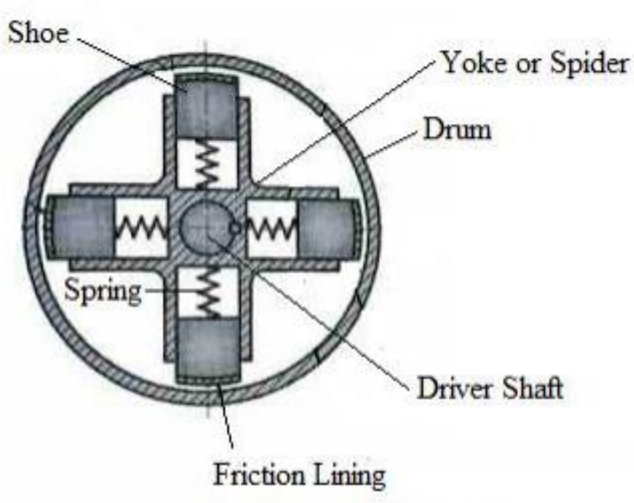
- It can be used in the pieces of machinery and automobiles where high power is required.
- It can be used in the motorcycle or high-speed racing cars due to the compact gearbox and high torque production.
- It can be used in ships, trucks, locomotive engines due to compact gearbox design.
- It is appropriate for heavyweight types of machinery like bulldozers, excavators, tanks and crawlers and others as the multi-plate clutch is heavy and produces high power. Due to that, the heavy pieces of machinery easily lift heavyweights.



Centrifugal Clutch

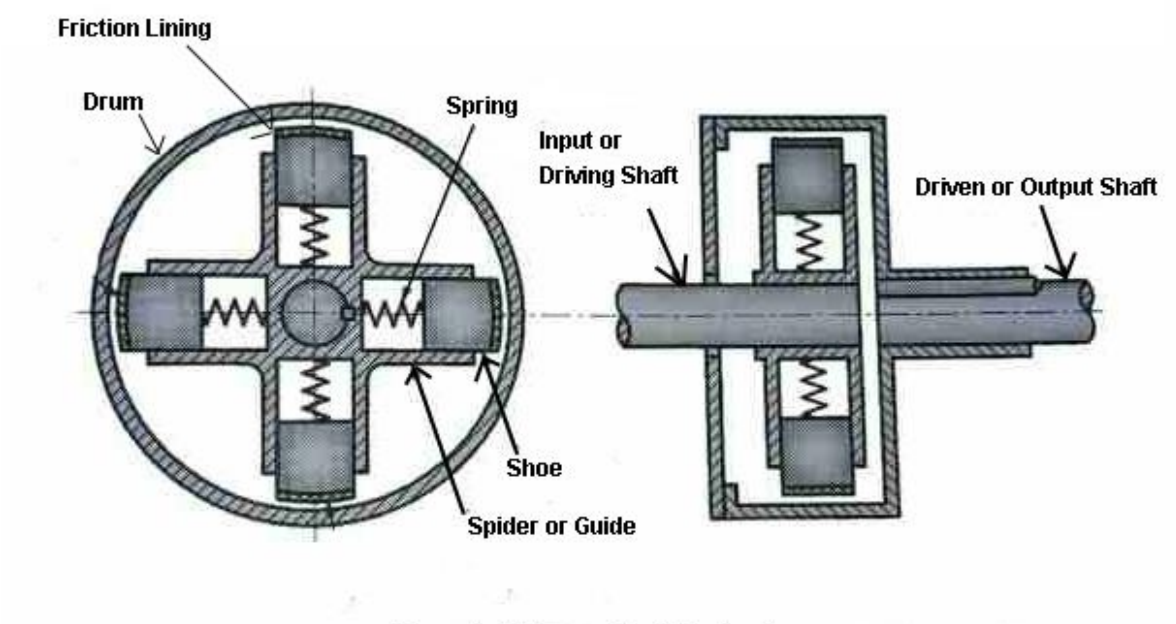
Construction and Working Principle of Centrifugal Clutch: Centrifugal clutches are being increasingly used in automobiles and machines. The main parts of the centrifugal clutch are shown in figure 4, which are as below,

1. **Drum:** The drum is mounted on the driven shaft or output, it acts as the housing and encloses other parts of the clutch such as spider or guide, shoes, springs etc.
2. **Spider or yoke or guide:** The spider or yoke or guide is mounted on the driver shaft of the prime mover, four housings are provided in the yoke or guide in which shoes are inserted, the housings are equally spaced.
3. **Spring:** Tension springs are used in the centrifugal clutch. One end of the each spring is attached with the yoke or guide and other end of the each spring is attached with each shoe.
4. **Friction Lining:** The friction lining is bonded with the outer surface of the each shoe in order to make strong grip between the shoe and the inner surface of the drum.
5. **Shoes:** Shoes having friction lining are fitted in housings or guide ways provided in the yoke or spider and each shoe slides in its housing or guide way.



When the driver shaft rotates, the centrifugal force acts on the shoes but drum does not rotate. As the speed of the driver shaft increases, the centrifugal force on the shoes increases. When the centrifugal force exceeds the resisting force of the springs, the shoes move forward away from the centre against the spring force and press against the inner surface of the drum. The outer

surfaces of the shoes are lined with some friction material and shoes make strong grip with the drum. The drum starts moving with the spider, thus torque is transmitted to the driven shaft. In this way, the clutch is engaged only when the prime mover gains sufficient speed to take up the load in an effective manner. When the speed decreases to a such value that the centrifugal force is less than the spring force, the shoes move towards the centre, the grip between shoes and the drum get terminated, thus clutch becomes disengaged and power is not transferred from the driver shaft to driven shaft.



Centrifugal Clutch

When the engine starts to rotate then the Centrifugal force produces. This centrifugal force turns the driveshaft. This force also activates the transmission depending on the enhancement of the engine rpm.

The size of the clutch is developed according to the load but in that case, the motors' horse power cannot be considered anytime. Alongside, a small-sized motor can also be utilized in order to develop or bring the maximum output regarding the torque. Also, the size of the gear reducer is small.

The Centrifugal force can also be used to push the sliding shoes outward. Then the friction lining of the shoes makes a connection with the drum's inner surface. So, the drum starts to move. The drum is then attached to the driven shaft. At first, it helps to transmit the power to the transmission shaft from the engine shaft and then to the load.

Centrifugal clutch makes the current draw to be the minimum and the torque is the maximum. Due to less amount of heat emissions the clutch plate does not slip through which the load can be accelerated. Alongside this, the motor is also safe due to the low amount of heat dissipation. Oftentimes it is found that due to high heat, motor JA burnt and that is not good for any machinery around the manufacturing industry.

Advantages of Centrifugal Clutch:

- Centrifugal clutch does the work of engaging and disengaging automatically. So there is no necessity or requirement of any other kind of mechanical part to control the peak speed of the engine. The working principle of the centrifugal clutch is mainly based on the law of physics.
- In comparison with other clutches, the cost of the Centrifugal clutch is much lower. Relatively the Centrifugal clutch is less expensive. In the case of the Centrifugal clutch, fewer parts are involved. No battery or extra component is needed to assist the Centrifugal clutch to perform the function properly.
- The servicing and maintenance cost of the centrifugal clutch is low. As the construction and primary design is good so there is a little chance of breaking down or wearing away of the system. As the construction and design of this clutch are sound at the initial stage so there are minimal chances present to be damaged. So, users of this clutch have to expend a little money for

maintenance and servicing. Therefore, it is more cost-effective and too good to use the centrifugal clutch and it is economically good for users.

- Overloading and abrupt starting can create a burden on the engine which causes damage to the engine. In the case of a centrifugal clutch, it is better and safer than the others with load and progressive engagement. Centrifugal clutch is mainly specialized to perform shock less and smooth acceleration.
- The centrifugal clutch can control the speed of the engine. This clutch has a greater progressive engagement and this feature helps in increasing the torque, a twisting force moving toward the load from the engine.
- The centrifugal clutch having the feature of greater engagement and speed control that enhances the longer lifespan and excess energy accumulation on the startup.

Disadvantages of Centrifugal Clutch:

- Though the centrifugal clutch has many benefits yet this clutch is not suitable for all applications on all occasions. The user must be aware about the fact of a lack of experience on applications of a centrifugal clutch.
- The transmission power of the centrifugal clutch has limitations because of slippage. In the case of an engine with a low RPM, centrifugal clutch is not suitable for that one because of the overheating problem. More heat can be produced due to friction between shoes and clutch drum. This problem of overheating can damage the clutch due to slippage and loss of power.
- Various sizes of clutch create a different amount of peak speed. The clutch is smaller in size and produces a faster speed. This happens due to the centrifugal force that is needed to be engaged.
- The clutch is activated when an engine reaches a particular speed. If the engine wants to attain a certain speed the clutch does not work properly. If loading capacity goes beyond the capability of the clutch loses its performance which leads to slippage. Due to this problem engine cannot perform properly causing damage to the engine. So, the centrifugal clutch is suitable for an engine having high speed but not for a lower speed engine. So,

the centrifugal clutch protects driven equipment and saves the engine with a vast range of speed.

- Centrifugal clutch cannot create high torque.
- So much power loss is present, during the slipping and friction.
- In the case of vehicles, so many heat gets produced during bad driving habits. This overheating may damage the clutch completely.

Applications of Centrifugal Clutch:

- Centrifugal clutch is generally used in vehicles.
- Centrifugal clutch is widely used in industrial applications like machinery, mining, military, manufacturing purposes.
- In chemical industries, the Centrifugal clutch is used in mixers.
- Used in lawn movers, chain saw.
- Used in scooters, go-karts, and mopeds.
- During stalling, in paramotors and boats, Centrifugal clutch is used to keep this stalling and during idling and start of the disengagement of the loads are done by Centrifugal clutch.

Problems of Clutch

Clutch Grab

Grab is the sudden jerky motion of the vehicle when clutch pedal is released.

Clutch Clatter

Clatter is the alternative movement of the clutch disc between flywheel and pressure plate. (Or) A shaking or shuddering of the vehicle as the clutch is operated.

Clutch Drag

A problem in which the clutch disc does not come to a complete stop after the clutch pedal is depressed.

Cushion Springs

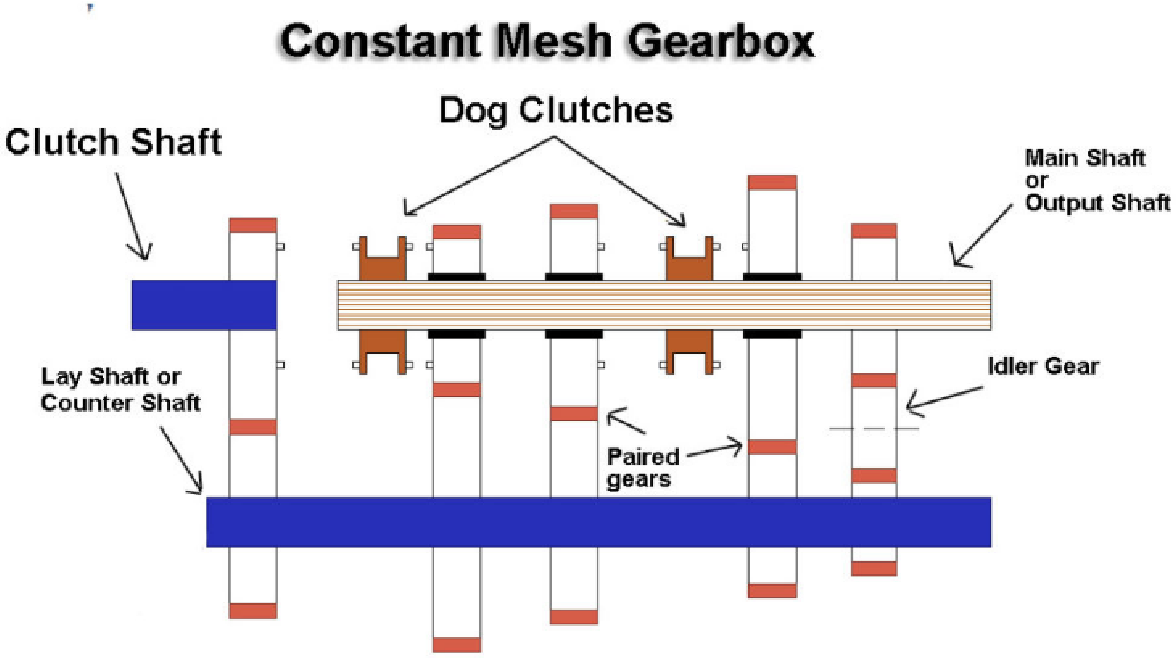
The clutch clatter is avoided by providing cushion spring between friction facings. Cushioning device consists of waved cushion springs to which the facings are riveted. These springs compress slightly as the clutch engages producing a cushioning effect.

GEAR BOX

Constant Mesh Gearbox

In this gearbox, all the gears are always in mesh. The gear remains fixed and not slide like the sliding mesh gearbox.
In this gearbox, the sliding mesh was replaced with constantly meshed pairs of gears and the new shifting devices named dog clutches were introduced.
A constant mesh gearbox usually comes with 4-speed 1-reverse manual transmission configuration. This gearbox has different parts like counter shaft, main shaft, clutch shaft, gears and dog clutch.
Gears on the counter shaft are fixed to it and the gears on the main shaft are free to rotate. Helical and herringbone gears are usually used in this gearbox, so it is quiter than sliding mesh gearbox which uses spur gears.

- In this gearbox all the gears in the main shaft and the counter shaft are always engaged with each other . Different transmission ratio or speed ratio are obtained by using the dog cluth . Dog clutches engage with gears on the main shaft to obtain desired speed or torque.



Main Parts of Constant Mesh Gearbox:

The main parts of Constant Mesh Gearbox are :

There are 3 shafts present in this gearbox which are :

i)Main Shaft:

It is also known as output shaft. It is the splined shaft over which the dog clutches along with gears are mounted. Gears on this shaft are free to rotate.

ii) Lay Shaft or Counter Shaft

It is an intermediate shaft between the Main Shaft and Clutch Shaft. The gears of counter shaft are in constant mesh with gears of main shaft. Also the gears of counter are shaft are not free to rotate as they are directly connected to the Counter Shaft.

iii) Clutch Shaft:

The clutch shaft carries the engine output to the gearbox but act as input for the gearbox. It is also known as input shaft.

2). Dog Clutch:
The dog clutch couples the lay shaft and main shaft by interference and not by friction. Dog clutches are used to transmit appropriate gear ratio to the main shaft or output shaft by coming in interference with pair of gears with suitable gear ratio.
There are usually two dog clutches in a Constant Mesh Gear Box.

3) Gears:
Gears of constant mesh gearbox come in pairs. All gears of lay shaft or counter shaft are always paired with gears of main shaft or output shaft.
This paired gears of counter shaft and main shaft provide different gear ratio which can be transmitted to main shaft by engaging dog clutch with appropriate gear ratio required.

Two type of gears are used in constant mesh gearbox:-
i) Helical Gears:
These gears have angular cut teeth over cylindrical cross-section metal body.
ii) Bevel Gears:
These gears have angular cut teeth over conical cross-section metal body.
Construction of Constant Mesh Gearbox:

- The output of the engine is carried by clutch shaft. The gear in clutch shaft is in constant mesh with the gear of lay shaft.
- There are 5 gears in lay shaft, one of which is connected to gear of clutch shaft and the other 4 are connected with gears of main shaft.
- All four gears are of different sizes to obtain different gear ratios.
- An idler gear is present between the gear of lay shaft and gear of main shaft to form reverse gear.

Working of Constant Mesh Gearbox:

- When the dog clutch is engaged with different gears of main shaft different gear ratios are obtained as gears of main shaft are always paired with gears of counter shaft to form different gear ratios.
- If the dog clutch is not in contact with any gear of main shaft the gears of main shaft rotates freely and does not rotates the main shaft as they are connected with main shaft using bearings.
- The main shaft rotates only when one of the dog clutch is engaged with any of the gear of the main shaft.
- Reverse gear is obtained in this gearbox using the same technique that was in sliding gearbox i.e using the idle gear between main shaft gear and counter shaft gear.

Different gear ratios in Constant Mesh Gearbox:

First Gear:

First gear is obtained in constant mesh gearbox when dog clutch gets engage by interference with the largest gear of main shaft which is in constant mesh with smallest gear of main shaft. This gear provides maximum torque and minimum speed to the main shaft.

Second Gear:

Second Gear is obtained when dog clutch gets engage with second largest gear of main shaft which is in a constant mesh with second smallest gear of lay shaft. This gear provides higher speed and lower torque than first gear.

Third Gear:

Third gear is obtained when dog clutch engages with second smallest gear of main shaft which is in constant mesh with second largest gear of lay shaft. This gear more speed and less torque than second gear.

Fourth Gear:

This gear provides the highest or maximum speed in a vechile using constant mesh gearbox. This gear is obtained when dog clutch engages with smallest gear of main shaft which is in constant mesh with largest gear of lay shaft.

Reverse Gear:

In this gear the vehicle goes in reverse direction. Like sliding mesh gearbox, an idler gear is also used in constant mesh gearbox between the main shaft gear and lay shaft gear to form reverse gear. Reverse gear is obtained when dog clutch engages with gear in main shaft which is paired with idler gear.

Advantages of Constant Mesh Gearbox:

- Constant Mesh Gearbox are quiter because helical or herringbone gears can be used in this gearbox instead of spur gears.
- Since the gears are engaged by dog clutches, if any damage occurs while engaging the gears, the dog unit members get damaged and not the gear wheels.

Application:

- Constant mesh gearbox was mainly used in farm trucks, motor bikes and heavy machinery.
- It is also used in cars like Ford Model T.
- Constant Mesh Box was used in motor bikes before the introduction of synchromesh gearbox in 1928 by General Motors.

problems of Sliding Mesh Gearbox were solved by Constant Mesh Gearbox

Sliding Mesh Gearbox

The Sliding Mesh Gearbox was a great success for the automobile industry as now there was a system which can provide different speed and torque needs by the vehicle to face different road conditions.
But there were some limitations and problems of Sliding Mesh Gearbox which were solved by Constant Mesh Gearbox. These problems are:-
1) The shifting of gears was very noisy process as spur gears were used but in constant mesh gearbox the gear shifting process becomes very less noisy as helical gears and bevel gears are used.

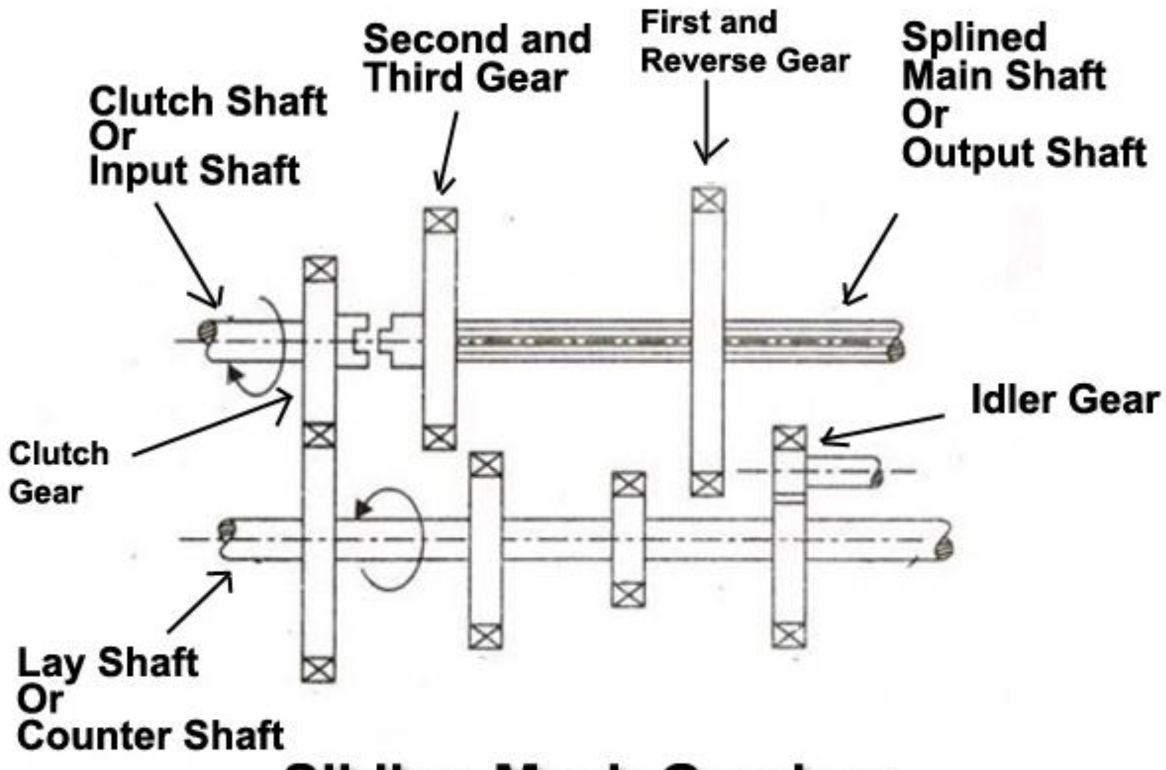
2) In sliding mesh gearbox, gears to be messed were in continuous rotation, so the meshing of gears can cause breakage of gear teeth's or wear and tear of gears. This problems was solved by constant mesh gearbox by introducing dog clutches.

3) Shifting was not an easy task for drivers and requires special skill to change

gears using double-de-clutching technique. But changing gears become easy for drivers after introduction of constant mesh gearbox.

This type of transmission offered multiple gear ratios. The gears were engaged by sliding them on their shafts. Shifting of gears was not an easy task, it can only be done by a skilled person. While shifting gears, the gears which are needed to be meshed with each other should be almost at same speed while meshing with each other.

Now the sliding mesh gearbox is superseded by constant mesh gearbox in which all gears mesh at all times with its pair and synchronous mesh gearbox is a further refinement of constant mesh gearbox.



Sliding Mesh Gearbox

Parts of Sliding Mesh Gearbox:
The main parts of sliding mesh gearbox are:

i) Shafts :- There are 3 shafts present in Sliding Mesh Gearbox:

a) Clutch Shaft –
It is input shaft in the sliding mesh gear box. The clutch shaft carries the engine output to the gearbox with the help of engaging and disengaging clutch which is mounted at the engine end. A gear is mounted over this shaft known as clutch gear which is used to transmit rotational motion to lay shaft.

b) Lay Shaft or Counter Shaft –
After the input shaft comes the Lay Shaft. Lay shaft is an intermediate shaft between the Clutch Shaft and Main Shaft. In the lay shaft, the gears are rigidly fixed and rotates with the lay shaft. One of the gear of this shaft is always in contact with the gear of the clutch shaft. So when the clutch shaft rotates, the lay shaft also rotates.
Lay shaft rotates in a direction counter to the engine rotation. So, it is also known as Counter Shaft. Other gears of lay shaft meshes with different gears of main shaft to obtain different gear ratios. Also, lay shaft has reverse gear which has idler gear attached to it.

c) Main Shaft:
This shaft is used as an output shaft in sliding mesh gearbox. In this shaft the gears are not rigidly fixed. The gears of this shaft have internally splined grooves and the outer surface of this shaft is made splined so that the gears can easily slide over the shaft.
The gears of main shaft slides over the shaft to mesh with appropriate gears of lay shaft so that required gear ratio is obtained.

ii) Gears:
Usually two types of gears were used in sliding mesh gearbox. They are:-
a) Spur gear

Spur gears have straight teeth that are produced parallel to the axis of gear. These gears are most economical types of gear but tend to vibrate and become noisy at high speed.

b) Helical gear

The teeth of helical gears are not parallel to gear axis. The teeth of this gear type are at angle to the gear axis. These gears are less noisy and have a smoother operation than spur gear. Also these gears have higher tooth strength and a higher load carrying capacity.

iii) Gear Lever :-

It is used slide the gears in the main shaft to obtain appropriate gear ratio. It is operated by the driver.

Construction of Sliding Mesh Gearbox:

- The clutch shaft is connected to the engine output and rotates when the engine rotates. A gear is mounted on the clutch shaft which is connected with a gear of lay shaft.
- The lay shaft has several gears, one of which is connected to gear of clutch shaft and others gears connect with different gear of main shaft to obtain different gear ratio. Also, one gear in lay shaft is reverse gear and has and idler gear which is placed between the lay shaft gear and main shaft gear when operated.
- The main shaft has several gears and these gears can slide over the main shaft to mesh with different gears of main shaft.

Working of Sliding Mesh Gearbox:

- At first, the clutch shaft is driven by engine. It carries the engine output and rotates in the same direction as that of engine. The gear connected to the clutch shaft also rotates.
- As gear of clutch shaft rotates, the lay shaft gear which is connected to the clutch shaft gear also rotates but in opposite direction.
- So the lay shaft rotates due to rotation of lay shaft gear that is rigidly fixed in the lay shaft. Due to rotation of lay shaft other gears of lay shaft also rotates as all the gears in lay shaft are rigidly fixed including the reverse gear.

- The gears of main shaft are internally splined and the main shaft is also splined, so the gears of main shaft can slide over it. The gear of main shaft are shifted and meshed with different gears of lay shaft to obtain different gear ratios required to face different road problems.

Different gears of Sliding Mesh Gearbox:

Different gears of Sliding Mesh Gearbox is obtained in the following ways:-

1. First Gear :

First Gear is used at the time when vehicle starts its movement in forward direction. First Gear provide maximum torque and minimum speed and this gear is obtained when the smallest gear on the lay shaft meshes with the biggest gear in the main shaft.

2. Second Gear:

Second Gear is obtained when second largest gear of second smallest gear of lay shaft meshes with middle size gear of main shaft. Second Gear provides lower torque and higher speed than First Gear.

3. Third Gear:

Third gear is last gear or top gear of Sliding Mesh Gearbox. This gear is obtained when biggest gear of lay shaft meshes with smallest gear of main shaft. This gear provides maximum speed and minimum power.

4. Reverse Gear:

Reverse Gear is used when the vehicle needs to move in the opposite direction. In this gear the rotation of the output shaft or main shaft is reversed by placing an idler gear between the lay shaft gear and the main shaft gear which changes the direction of rotation of output shaft.

Advantages of Sliding Mesh Gearbox:

1 Since only one gear is in mess in sliding mesh gearbox so less fluctuating loads on shafts causing less vibration and noise unlike the constant mesh gearbox in which all gears are in constant mesh.
2. Its efficiency is more than constant gearbox as only one gear is in mess unlike

the constant mesh gearbox in which all gears are in constant mesh.
2. Its manufacturing is easy as compared to constant mesh gearbox.
3. Its mechanism is simple.

Disadvantages of Sliding Mesh Gearbox:

1 Only spur gears can be used as gears are not in constant mesh like constant mesh gearbox in which helical or herringbone gears can be used.
2. More effort is required to engage the gear as the gear has to be sliced in sliding mesh gearbox unlike constant mesh gearbox where only dog clutch has to be slides for engagements of different gears.
3. Less life of gear as more wear and tear of gear is caused in sliding mesh gearbox due to friction.
4. It takes more time and money to replace the gears if the gearbox fails but in constant mesh gearbox only dog clutches are to be replaced at failure which takes less time and money.

Applications:

1. Sliding Mesh Gearbox is used in Alfa 12HP with 4-speed manual transmission.
2. It is also used in Fiat 6HP with 3-speed manual transmission.
3. It is also used in Mercedes 35 HP and Renault Voilturette.

Synchromesh Gearbox:

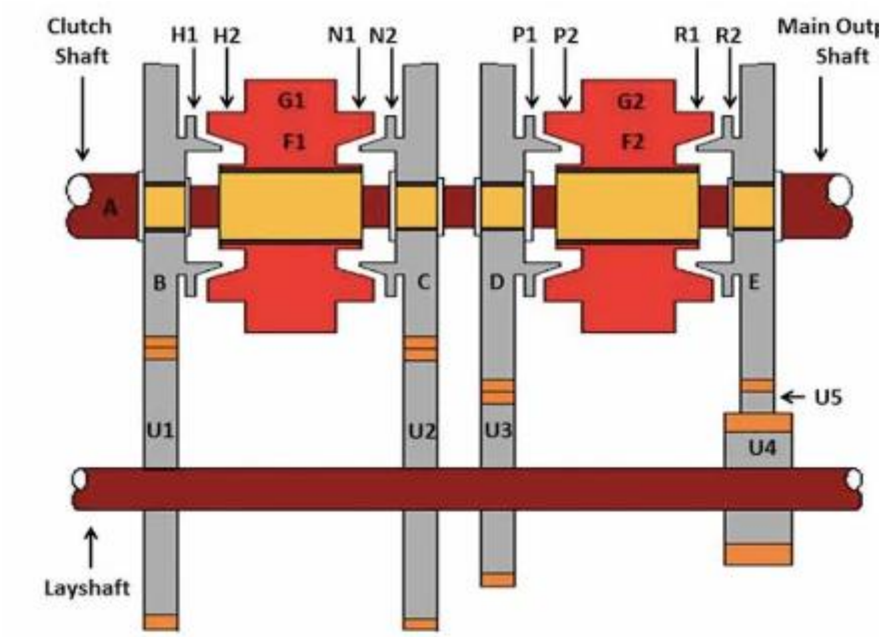
Synchromesh gearbox is the latest version of Constant mesh type. It is a manually operated transmission in which,
Change of gears takes place between gears that are already revolving at the same speed. In this type of gearbox, gears can rotate freely or it is locked on layout shaft. Synchromesh is an improvement on dog clutch. The synchronizer is the main part of this gearbox that stabilizes the speed. A synchronizer is a kind of clutch which lets
Components turning at different speeds. To synchronize the speeds cone friction is used.

Principle:

In a gearbox, there is always a difficulty in engaging the Stationary gear with the gears already rotating at a high speed. The principle states that
"Before engaging the gears they are brought in frictional contact with Each other and after equalizing the speed the engagement is done."

Construction:

The synchronizer is placed between two gears. So, we can use one unit for two gears. G1 and G2 are the ring-shaped members who are having the Internal tooth that fits onto the external teeth. F1 and F2 are the sliding members of the main shaft. H1, H2, N1, N2, P1, P2, R1, R2 are the friction surface.



Synchromesh Gearbox

1. Main shaft Gears:

A spline shaft is used as the output shaft over which the synchronizers and Gears are mounted. According to Fig. B, C, D, E are the gears that can freely rotate on the main shaft in mesh with corresponding gears in the lay shaft. As long as shaft A is rotating all the gears in the main shaft and Lay shaft rotates continuously.

2. Lay Shaft Gears:

It is the intermediate shaft over which gears with Suitable size are mounted and is used to transmit the rotational motion From clutch shaft to the final output shaft. According to Fig. U1, U2, U3, U4 are the fixed gears on the countershaft (lay shaft).

3. Clutch Shaft:

It is the shaft used as an input shaft in the gearbox as it Carries the engine output to the gearbox.

4. Cone Synchromesh:

The side of the gear to be engaged has two features. One is hollow-cone, and the other is cone surrounded by the ring of dog teeth. The gear is made the cone and teeth that the synchromesh mechanism contacts.

5. Synchronizers:

They are the special shifting devices used in the Synchromesh gearbox which has conical grooves cutover It's surface that provide frictional contact with the gears which is to Mesh to equalize the speed of the main shaft, Layshaft and clutch shaft which in turn provides smoother shifting of gears.

6. Gear lever:

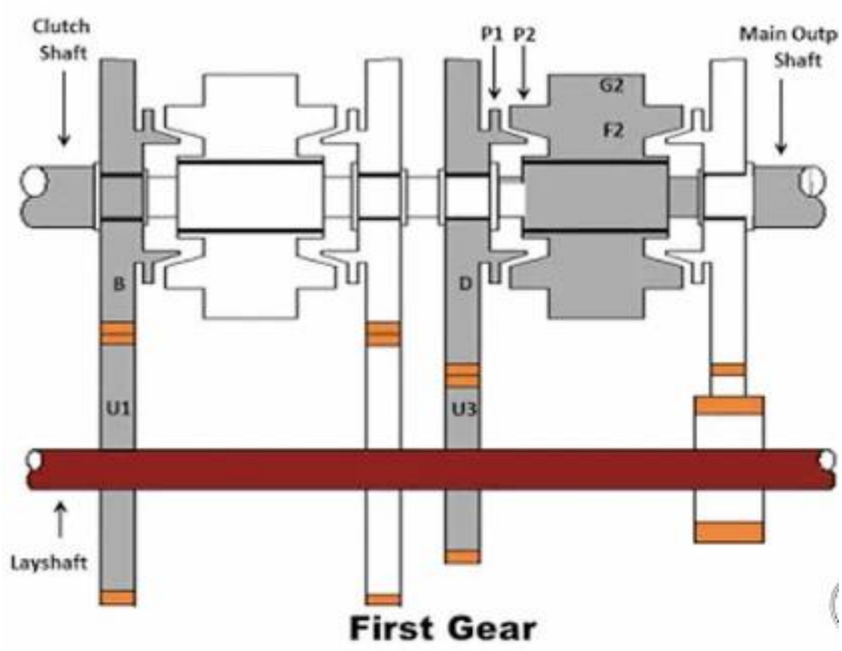
It is the shifting lever operated by the driver and is used to Select the appropriate gear i.e. 1, 2, 3, 4, 5 or reverse gear.

Working:

In synchromesh gearbox Layshaft is connected to the engine directly, But it rotates freely when the clutch is disengaged. Because the gears have meshed all the time, The synchro brings the layshaft to the right speed for the dog teeth to Mesh to achieve the desired speed of output shaft.

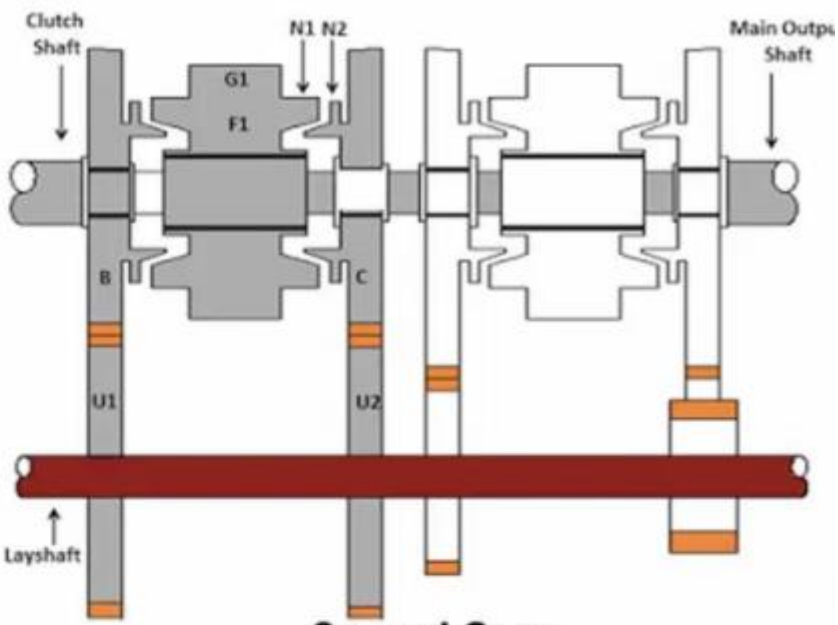
1. Working of First Gear:

For first gear, the ring shaft member and the sliding members i.e., G2 and F2 moves towards left till the cones P1 and P2 rub each other. Then friction makes their speed equal. Once their speeds are equal G2 is further pushed towards Left and it engages with the teeth L2. A motion is carried from clutch gear B to the layshaft gear U1. Then it goes to layshaft U3, and the motion is moved to the main shaft gear D. From there the motion is transferred to F2 which is the sliding, Member and then to the main shaft for the final drive.



2. Working of Second Gear:

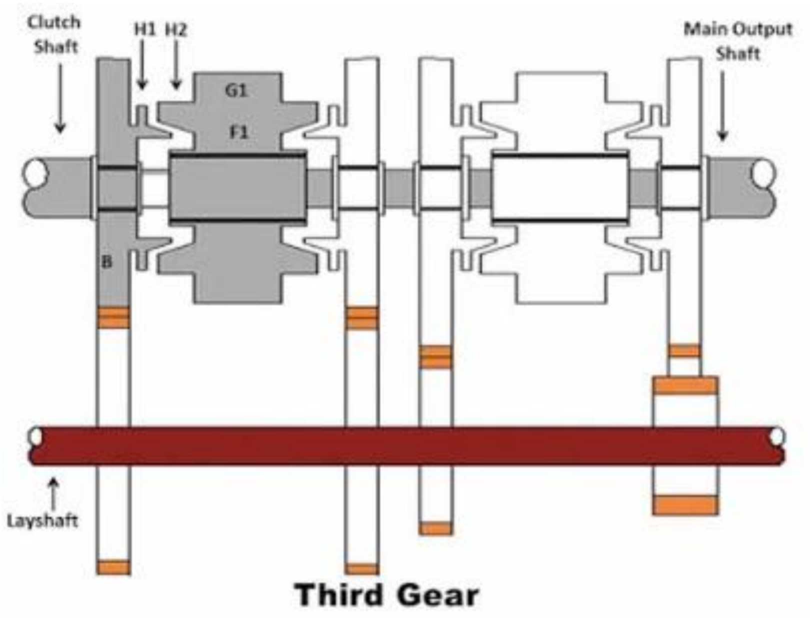
For second gear the ring shaft and the sliding members i.e., G1 and F1 moves towards the right till the cones N1 and N2 rub each other. Then the friction makes their speed equal. G1 is further pushed towards the right so that it meshes with the gear. The motion is transferred from clutch gear B to the layshaft gear U1. From U1 the motion is transferred to U2. From U2 it is shifted to the main shaft gear C. Then the motion is transferred to the sliding member F1. Then it goes to the main shaft for the final drive.



Second Gear

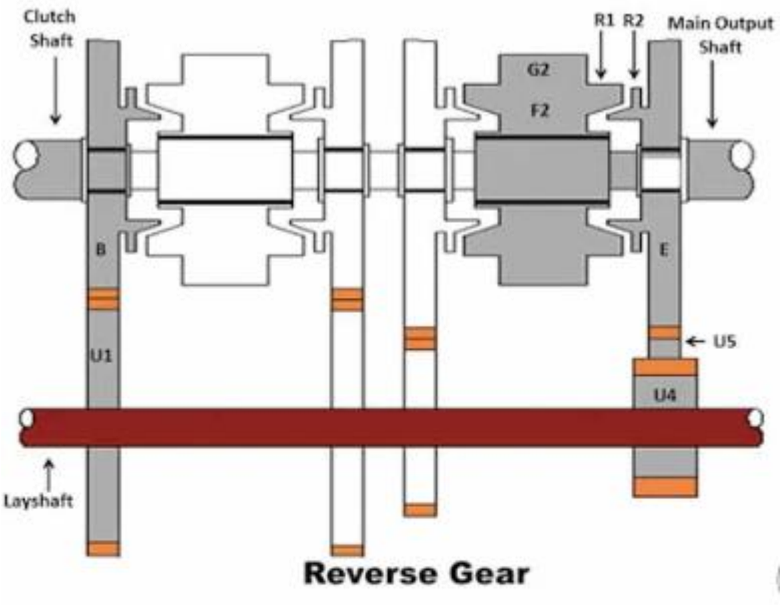
3. Working of Top Gear:

For top gear or direct gear, The motion is shifted directly from clutch gear B to the sliding member F1. Then from F1 to the main shaft. This is done by moving G1 and F1 to the left.



4. Working of Reverse Gear:

For reverse gear, the motion is transferred from clutch gear A to the layshaft gear U1. From there it is transferred to layshaft gear U4 and then to the intermediate gear U5. From there to the main shaft gear E and then to the sliding member, F2 and then to the main shaft for the final drive. This is done by moving G2 towards the right. Intermediate gear helps to achieve the reverse gear.



Advantages:

- Smooth and Noise-free shifting of gears which is most suitable for cars.
- No loss of torque transmission from the engine to the driving wheels during gear shifts.
- Double clutching is not required.
- Less vibration.
- Quick shifting of gears without the risk of damaging the gears.

Disadvantages:

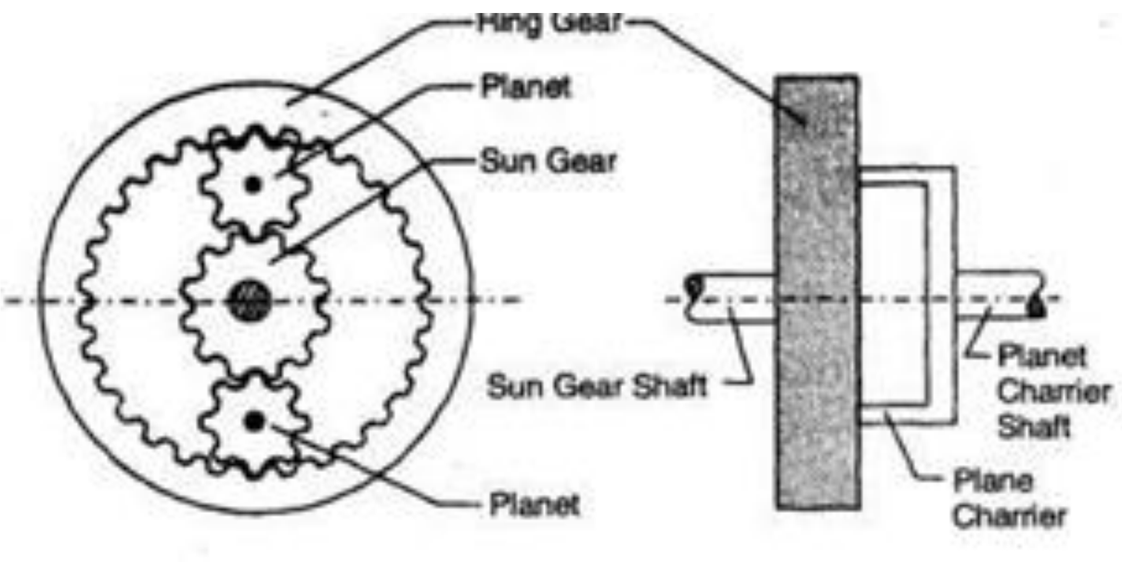
- It is extortionate due to its high manufacturing cost and the number of moving parts.
- When teeth make contact with the gear, the teeth will fail to engage as they are spinning at different speeds which causes a loud grinding sound as they clatter together.
- Improper handling of gear may easily prone to damage.
- It cannot handle higher loads.

Epicyclic Gear Box

Automatic transmission :-

Automatic transmission system is the most advanced system in which drives mechanical efforts are reduced very much and different speeds are obtained automatically. This system is generally also called Hydromatic transmission. It contain Epicyclic gear arrangement, fluid coupling and torque converter. In this planetary gears sets are placed in series to provide transmission. This type of transmission are used by Skoda ,Toyota , Lexus , etc

Epicyclic gearing (planetary gearing) :- it is a gear system consisting of one or more outer gears, or planet gears, revolving about a central gear .By using Epicyclic gear , different torque speed ratio can be obtained . It also compact the size of gear box.



Stages of automatic transmission :-

- Park(P) :- selecting the park mode will lock the transmission, thus restricting thevehicle
  from moving.
- Reverse(R) :- selecting the reverse mode puts the car into

reverse gear, allowing the vehicle to move backward.

- Neutral (N) :- selecting neutral mode disconnects the transmission from thewheel.
- Low (L) :- selecting the low mode will allow you to lower the speed to move on hilly and middy areas.
- Drive (D) :- selecting drive mode allows the vehicle to move and accelerate through a range of gears.

Comparison between manual transmission and automatic transmission

Manual transmission	Automatic transmission
Vehicles with manual transmission are usually cheaper.	Vehicles with automatic transmission are costlier than those of manual transmission.
Manual transmission has better fuel economy. This is because manual transmission has better mechanical and gear train efficiency.	Automatic transmission has not better fuel economy. This is because automatic transmission has not better mechanical and gear train efficiency as compare to those of automatic transmission.
Manual transmission offers the driver more control of the vehicle.	Automatic transmission does not offer the driver more control of the vehicle as compare to that of automatic transmission system.

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DEPARTMENT OF AUTOMOBILE ENGINEERING

UNIT-II

FLUID COUPLING AND TORQUE CONVERTORS

Introduction

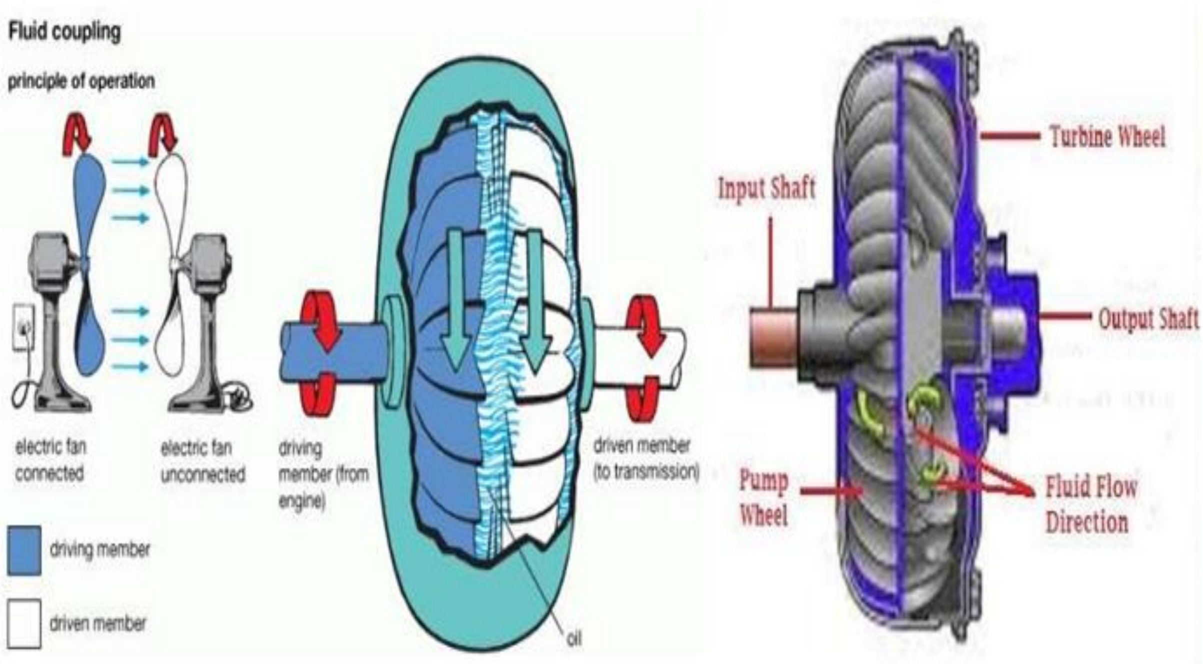
A fluid coupling or hydraulic coupling is a hydrodynamic device used to transmit rotating mechanical power.

Function

It is used for transmitting power or torque from one shaft to other shaft with help of an oil (fluid) without Mechanical connection between the two shafts

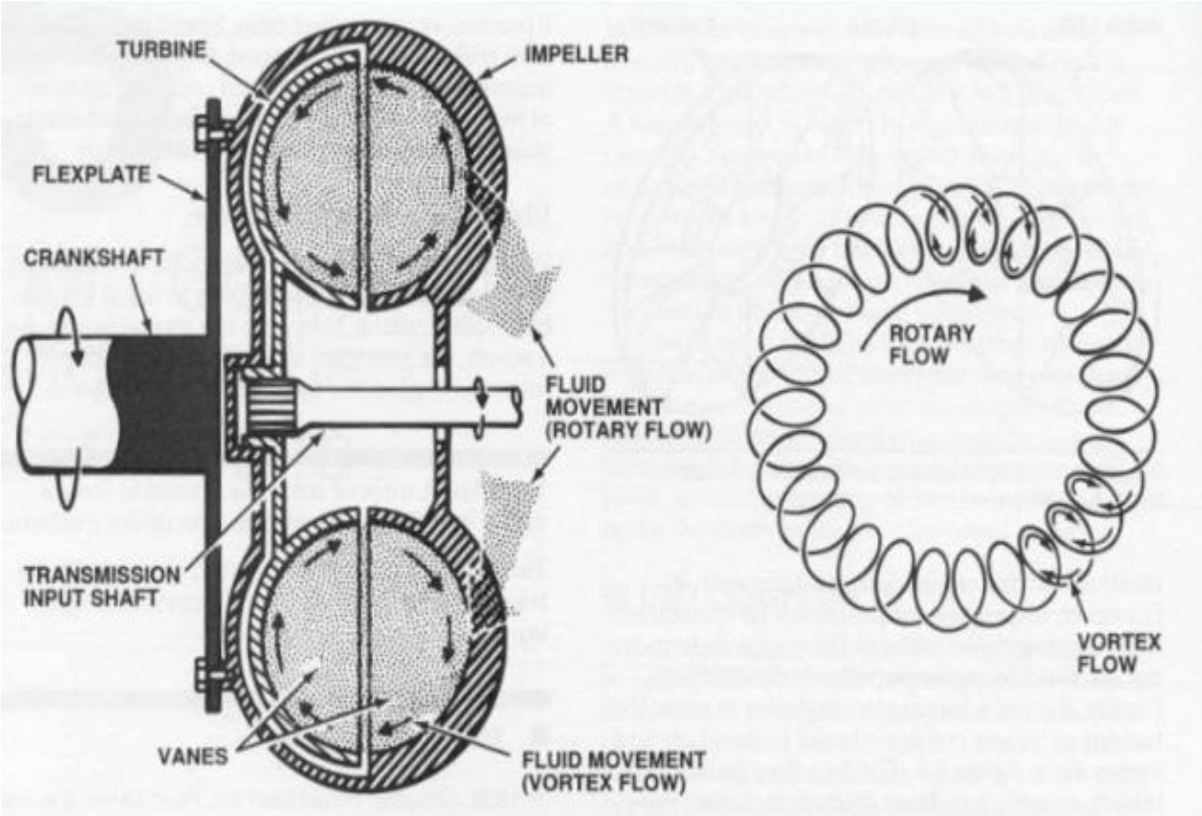
FLUID COUPLING

Fluid coupling is a device which is used to transmit torque from engine to gear box with fluid as working medium. The purpose of fluid coupling is to act as flexible power transmitting coupling.



CONSTRUCTION DETAILS AND PRINCIPLE OF OPERATION

The function of the Fluid Coupling is to act as an automatic clutch between engine and gearbox. It allows the engine to idle when the car is stationary but takes up the drive smoothly and progressively when the driver speeds up the engine by depressing the accelerator pedal.



There are two main rotating parts; an impeller driven by the engine and a turbine which drives gearbox. Each is bowl shaped and contains a number of partitions called vanes. The two bowls are placed face to face in a casing filled with oil, and they are separated by a small clearance so that no rubbing contact between them.

The basic form of the fluid drive known as fluid flywheel or fluid coupling is used in place of friction clutch in cars with pre-selector gearboxes. It generally consists of an impeller and a turbine with oil continuously circulated between the two when engine is running. When the engine is idling, the oil is flung from the impeller by centrifugal force. Directed forward by the vanes, it enters turbine which remains stationary because the force of oil is not yet sufficient to turn it.

When the driver depresses the accelerator pedal, impeller speed increases and turning ef fect derived from fast moving oil becomes great enough to overcome the resistance of the turbine, which begins to rotate so setting the car in motion. After giving up the energy to turbine, oil reenters the impeller and is circulated back to the impeller again. If the speed of engine continues to increase, the difference between the rotational speeds of impeller and turbine gradually diminishes until the slip between then is reduced to as little as 2%. The limitations of FC is that torque applied to turbine can never be greater that that delivered by impeller.

IDLING

The driving part of FC is attached to the engine and faces the driven part from which it is separated by small clearances. At idling speed, there is insufficient centrifugal force for the oil to turn turbine and to move the car.

LOW TO MEDIUM REVOLUTIONS

As the engine speeds up, centrifugal force pushes oil into turbine and some turning effort is transmitted. But there is still a large degree of slip in the unit. The output shaft is thus rotating more slowly than input shaft.

MEDIUM TO HIGH REVOLUTIONS

Once the engine reaches a preset speed, the oil forces is sufficient to transmit full power. This gives in effect a direct drive with output shaft rotating at about 98%of speed of input shaft.

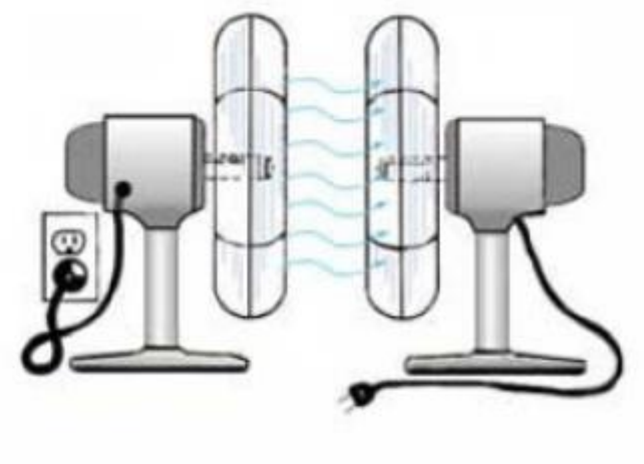
ADVANTAGES OF FLUID COUPLING

1. It provides acceleration pedal control to effect automatic disengagement of drive to gearbox at a predetermined speed.
2. Vibrations from engine side are not transmitted to wheels and similarly shock loads from transmission side will not be transmitted to engine.
3. The engine will not stall if it is overloaded.
4. No wear on moving parts and no adjustments to be made.
5. No jerk on transmission when gear engages. It damps all shocks and strains incident with connecting a revolving engine to transmission.
6. Vehicle can be stopped in gear and move off by pre ssing acceleration only.
7. There is no direct firm connection between engines and wheels. So when engine is overloaded, it will not stop. But it results in slip within coupling.
8. Unlike friction clutch, slip within coupling does not cause damage within working components.
9. In case of FC, engine is not f orced to operate at very low speeds when it is overloaded.
10. No wear is experienced on impeller or turbine blades.

TORQUE CONVERTER

BASIC PRINCIPLE OF TORQUE CONVERTER

On automatic transmissions, the torque converter takes the place of the clutch found on standard shift vehicles. It is there to allow the engine to continue running when the vehicle comes to a stop. The principle behind a torque converter is like taking a fan that is plugged into the wall and blowing air into another fan which is unplugged. If you grab the blade on the unplugged fan, you are able to hold it from turning but as soon as you let go, it will begin to speed up until it comes close to the speed of the powered fan. The difference with a torque converter is that instead of using air, it uses oil or transmission fluid, to be more precise.

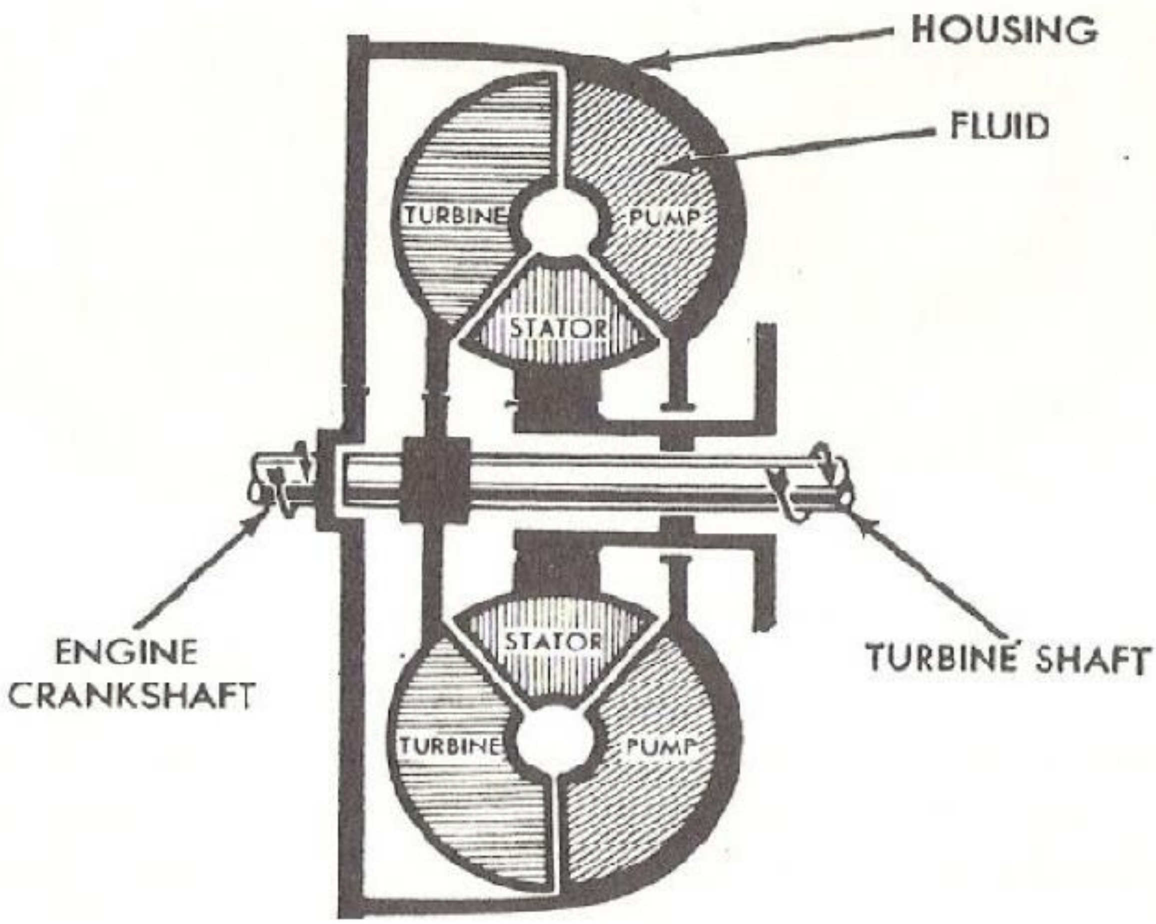


TORQUE CONVERTER

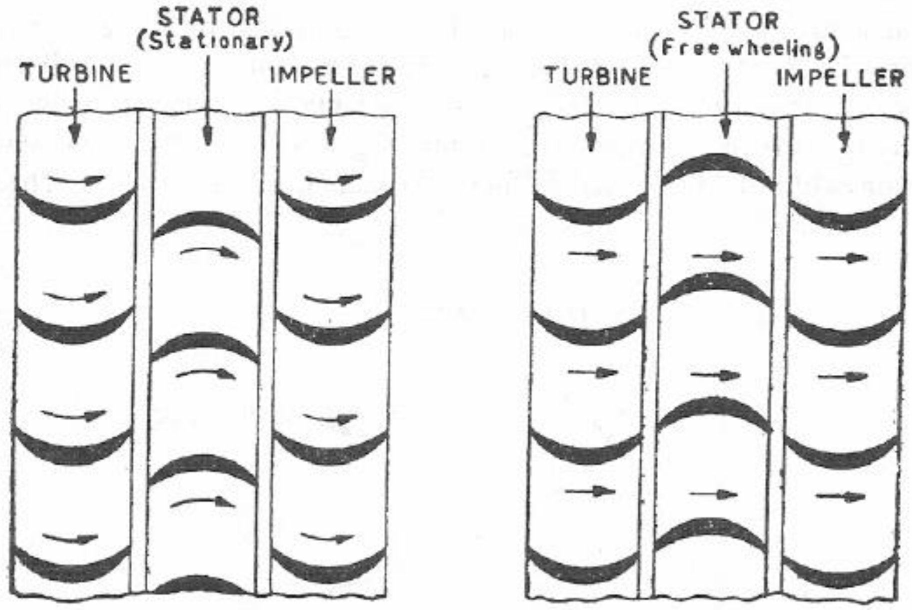
Most cars with automatic transmission use a form of fluid drive known as toque converter as the name implies, it converts the torque or tuning effort of engine into higher torque needed by cars at low road speed. An increase in torque has same effect as changing to a lower gear; so a TC is also a gear reducer, acting like an extra set of gears before engine drive reaches gear box.

Like fluid flywheel, TC has an engine driven impeller and a turbine connected to GB input shaft. It is also able to deliver a higher torque than that engine produces, because it is also able to deliver a higher torque and a small vane wheel known as reactor (stator). A one way clutch (ORC) lock reactor to gear box casing at lower engine speed.

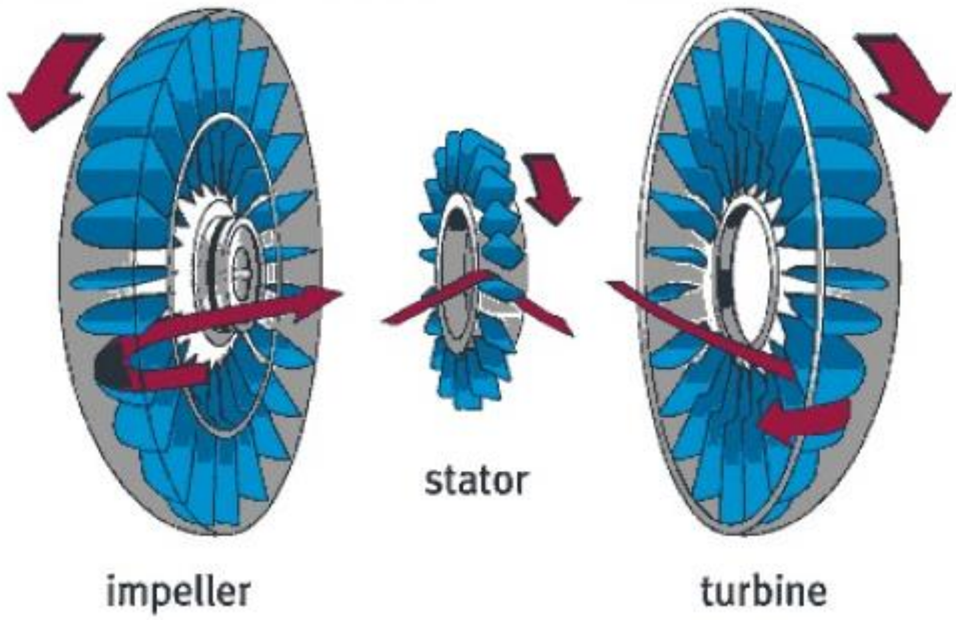
In a fluid flywheel, oil returning from turbine tends to curb the speed of impeller. But in TC, the vanes of locked reactor direct oil along a torque favorable path back to the centre of impeller enabling it to give extra thrust to turbine blades.



At pull away speeds, Torque Converter double the effort produced by engine. As engine picks up speed, this 2:1 increase in torque is reduced until at cruising speed, there is no torque increase at all. The reactor is spun round by oil at some rate as turbine. TC now acts like a fluid flywheel with reactor 'free wheeling' and having no torque increasing effort. Neither FC nor TC can be epicycle transmission which aloe gear changing without disconnecting.



An alternative used on few models, is to provide a friction clutch in addition to TC. This enables a synchromesh gear box to be used, as friction clutch disconnects engine when gears are being changed.

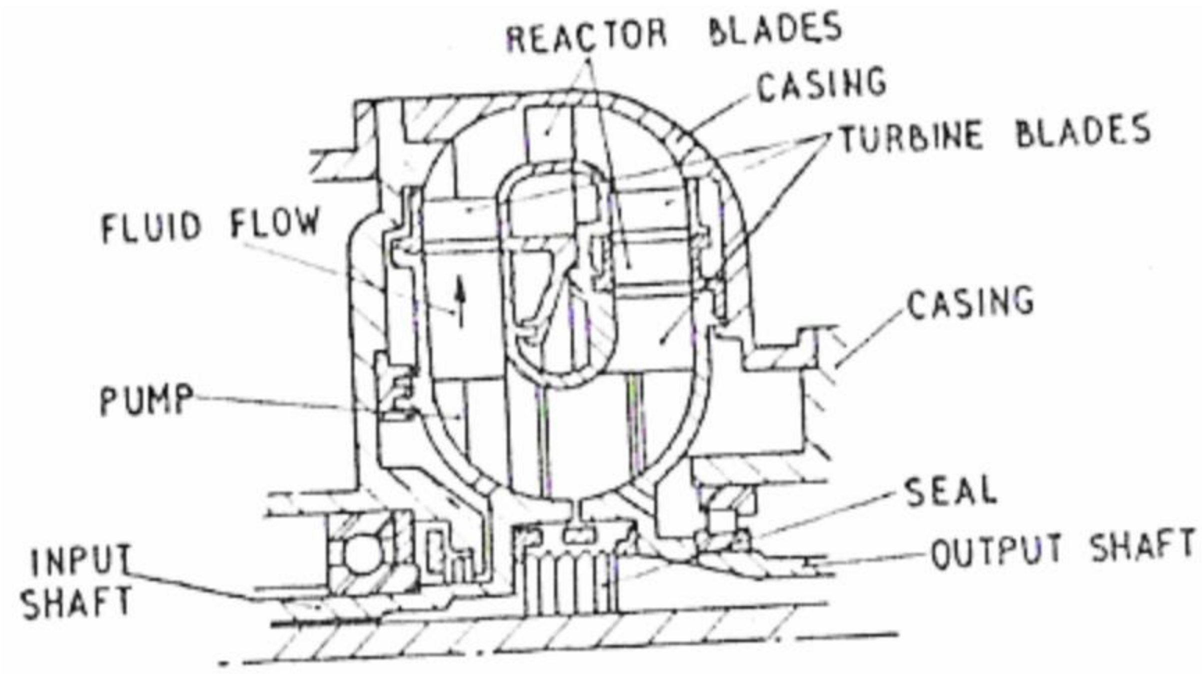


MULTISTAGE TORQUE CONVERTERS

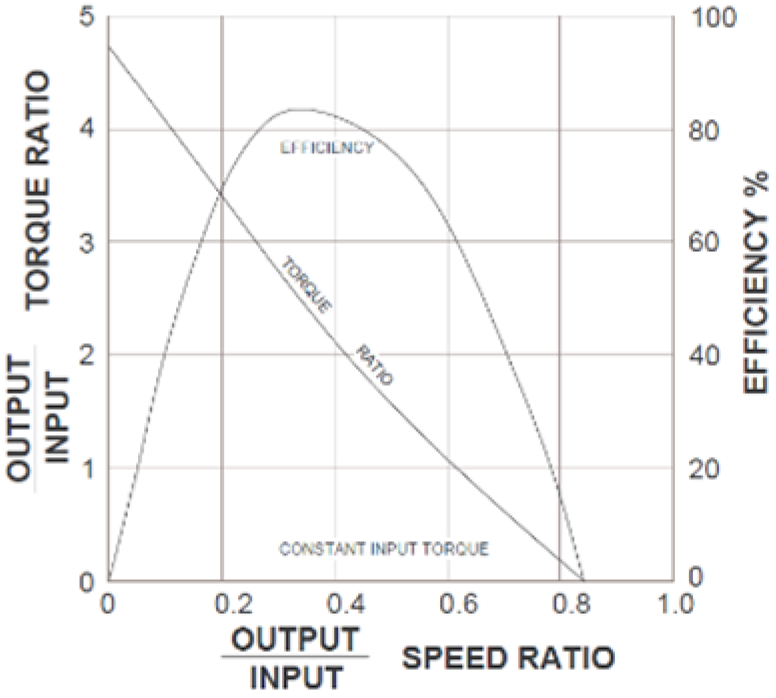
For the highest torque ratios, it is necessary to employ multi-stage converter. The M.S converter is one in which, the circulating fluid impinges two or more turbine members separated by reactors. First stage of conversion is reached when the fuel has traveled through the impeller, turbine and reactors and extra stages are sometimes added to obtain a particular type of performance.

The provision of an additional turbine is referred to as an extra stage and thus conforms to steam turbine practice. It is necessary to emphasize that additional turbine member must be separated by a reactor from a previous turbine to create an extra stage, and should not be confuse with practice of dividing the reactor member for instance into several parts, so as

to carry out operation of reactor in a number of phases.



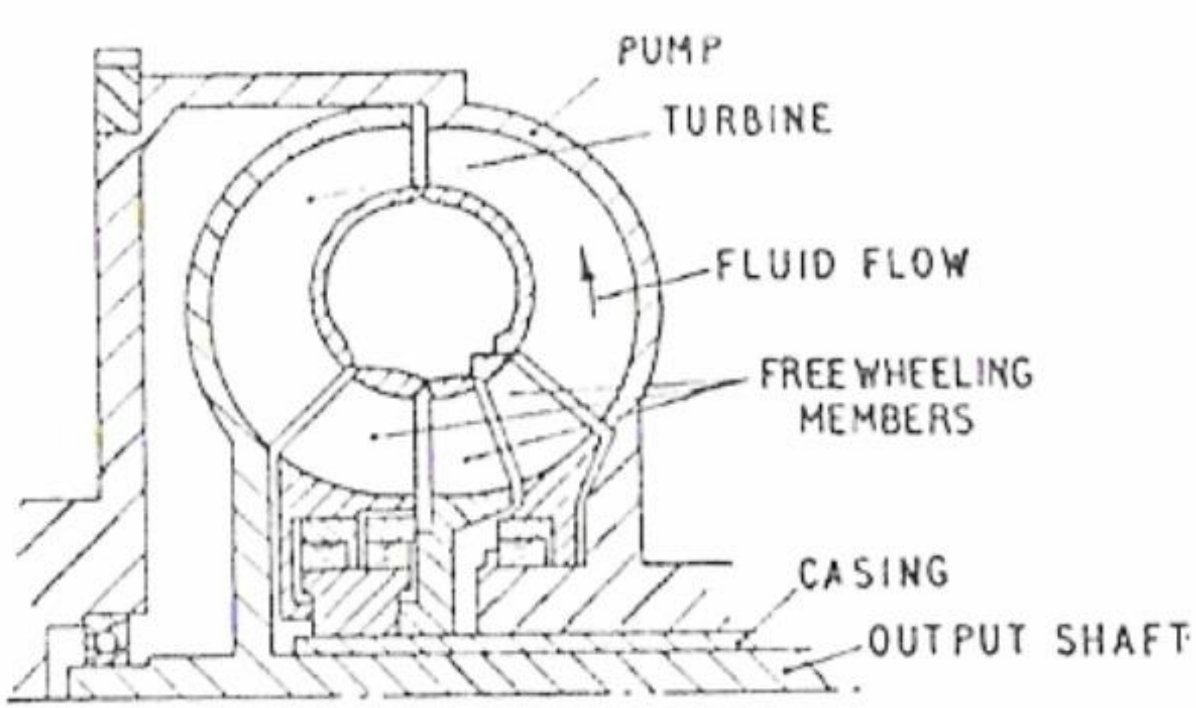
The reason for using an increased number of stages is usually to increase torque conversion ratio but certain other advantages are obtainable. A multistage converter having a turbine immediately preceding impeller has advantage that as the vehicle accelerates, fluid can be delivered at greater velocity head to turbine which is enabled to rotate at faster speed. This fact extends useful range of converter and increases it power rating. The increased number of stages may increase f luid friction on account of longer circulation path, and efficiency of multistage converter tends to fall of rather sharply and racing usually occurs at lower speed ratios than for a single-stage converter.



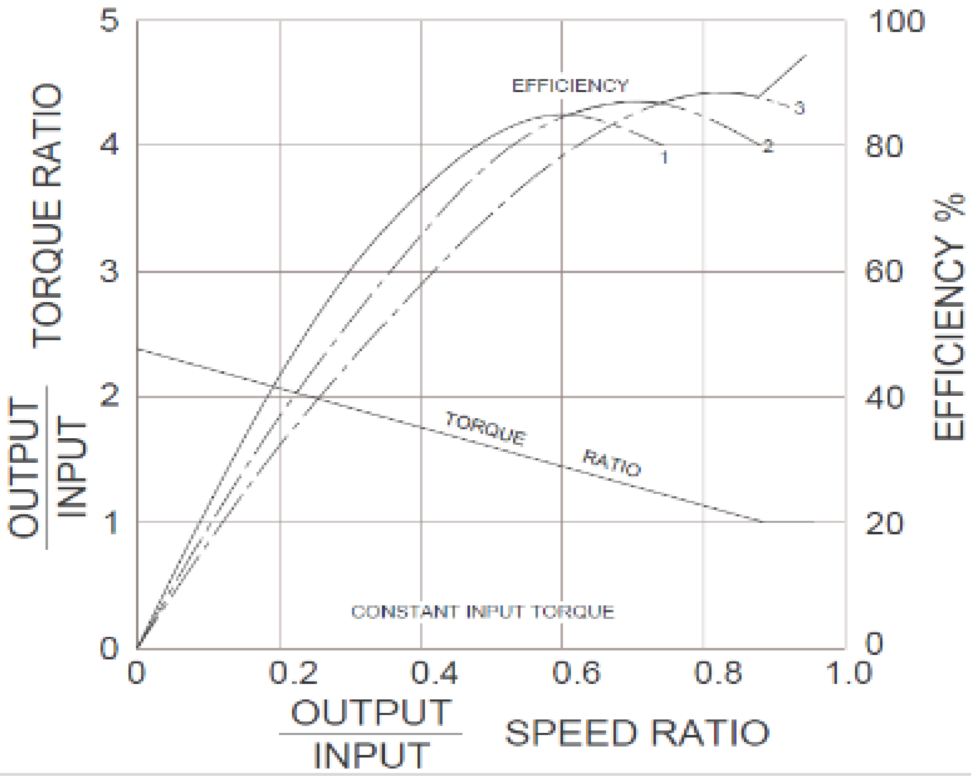
Thus, although increased torque ratios are obtained with multistage converter, it is noticed that all the forms of converter discussed so for exhibit a similar o/p characteristic which is roughly parabolic in shape. Variations in blade design or number of stages has the effect of moving the peak of curve towards low ratio (stall) end of o/p speed range or towards the higher ratios (racing).consequently a typical Multi Stage converter will develop an o/p torque equal to about 2 ½ times the value of i/p torque at its maximum efficiency point. But as the turbine accelerates, the falls rapidly and o/p torque soon falls to zero. This type of converters thus would give a good initial acceleration of vehicle from rest but would be inefficient for a normal cruising which is mainly carried out at unity torque ratio (direct drive). For this reason, most MS or high torque ratio converters are used in conjunction with a friction clutch are some other way of obtaining an efficient direct drive.

POLY PHASE CONVERTER-COUPLING

This type of fluid drive represents an attempt to combine the best operating characteristics of two or more different designs of converters into a single converter. These ideas are usually incorporated into converter couplings, but it is converter operation it takes place in several phases.



A poly phase converter coupling is a variation of a normal 3-element machine in which at least one of the 3 basic members is divided into further elements. The reactor has to deal with fluid flow from widely changing entrance direction and this member can be divided into a number of elements which adjusts them selves to the changing flow. The practice of dividing a rotating member into several elements is widely used at the present time and it is usual to have 2&3 phases, each of which is represented by a bladed ring element which is also rotate freely when the fluid flow has changed the direction by a given amount. In this way, the elements of reactor enables the operation of redirecting the flow to be carried out in a number of distinct phases, giving rise to the use of the term poly phase converter, or poly phase converter coupling.



This method is not confined to reaction member, and impeller or turbine member may also be divided into a number of these elements which may rotate at different speed by the introduction of free-wheel units. Such free-wheeling blade elements detach themselves from parent member and rotate at speeds that least resistance to fluid flow occurs. At this point, the detached members can be considered as turbines at raising speed. From figure, it is seen that efficiency curve combines the most useful parts of curves of three different converter designs as the fluid drive effects a three phase transition from converter to coupling. Each peak is related to a particular design point which is referred to as one of the three separate phases of particular design. The poly phase converter coupling represents modern practice in which entrance losses are almost completely removed for a useful range of speed ratios. There still remains a need to extend this useful range of ratio and most transmission use and auxiliary gear box to give increased o/p torque for improved acceleration and for climbing steeped gradient.

SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF AUTOMOBILE ENGINEERING

UNIT-III

AUTOMATIC TRANSMISSION

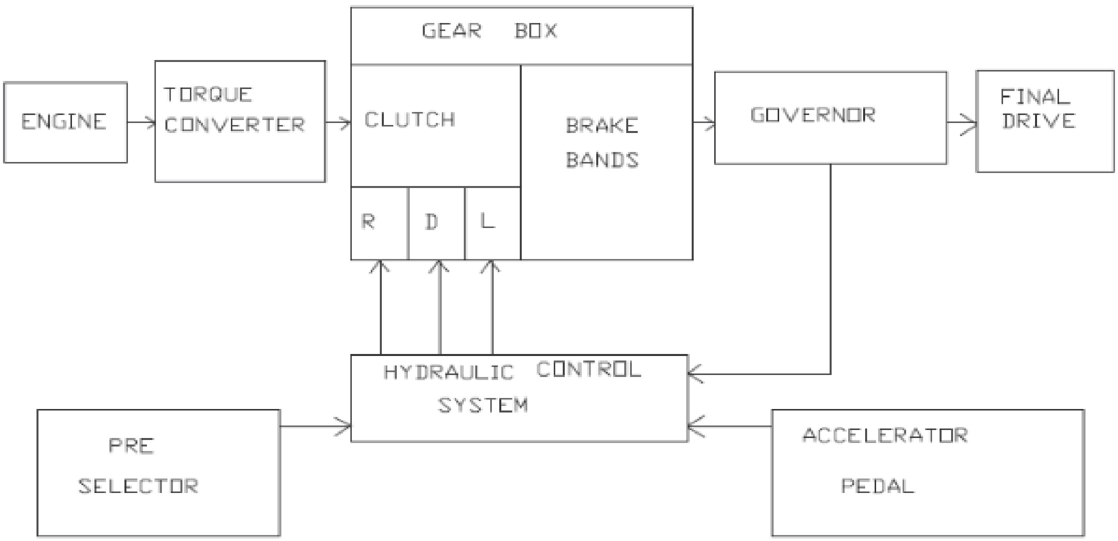
AUTOMATIC TRANSMISSION

It is the transmission which automatically provides varying gear ratios to suit operating conditions. In this case gear changes are effected automatically without manual assistant.

MAIN COMPONENTS OF AUTOMATIC TRANSMISSIO N SYSTEM

1. Torque converter.
2. Gearbox of planetary type with friction brake bands and multiple disc clutch operated by hydraulic system.
3. Hydraulic Control System. This system has a source of hydraulic pressure servo units and control valves.

BLOCK DIAGRAM OF AUTOMATIC TRANSMISSION



ADVANTAGES OF AUTOMATIC TRANSMISSION SYSTEM

1. Smooth operation.
2. Ease of control, i.e. it relieves the driver from fatigue due to the elimination of clutch and gear controls.
3. Numerous numbers of gear ratios are available.
4. Quick change of gear ratios effected automatically.

5. Minimum interruption of power during gear shifts.

DISADVANTAGES OF AUTOMATIC TRANSMISSION SYSTEM

1. High cost.
2. Complicated design.
3. Possibility for oil leakage.

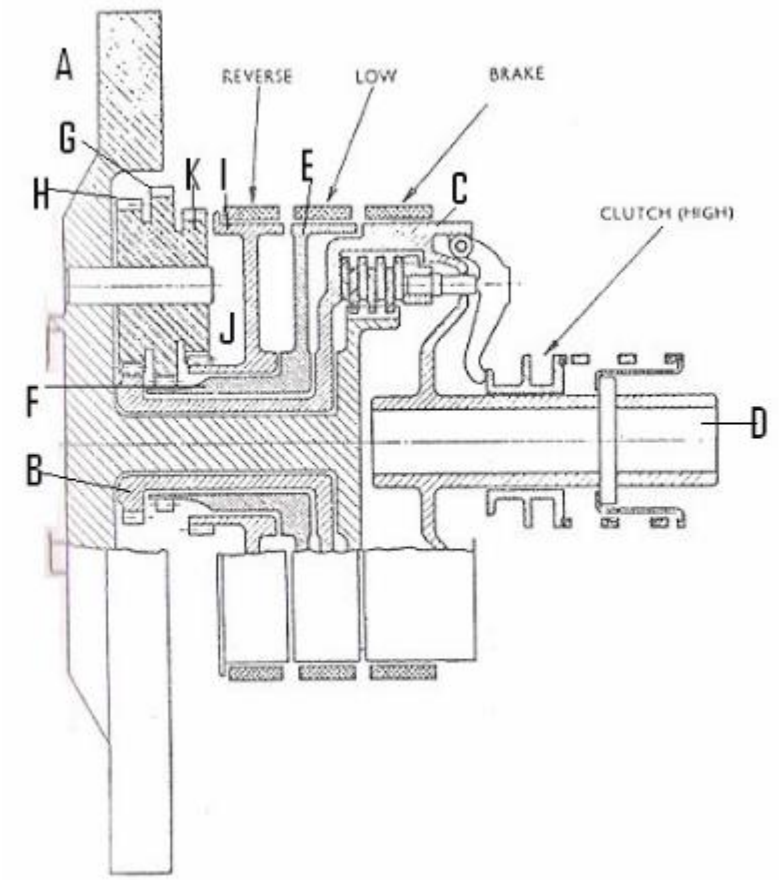
Comparison between Manual and Automatic Transmission

Manual Transmission	Automatic Transmission

Vehicles with manual transmission are usually cheaper	Vehicles with automatic transmission are costlier than those of manual transmission.
Manual transmission has better fuel economy. This is because manual transmission has better mechanical and gear train efficiency	Automatic transmission has not better fuel economy. This is because automatic transmission has not better mechanical and gear train efficiency as compare to those of automatic transmission.
Manual transmission offers the driver more control of the vehicle.	Automatic transmission does not offer the driver more control of the vehicle as compare to that of automatic transmission system.

FORD T-MODEL GEAR BOX

An example of the "all-spur" type of planetary transmission is the ford model T, with which millions of cars have been equipped.



The flywheel rim A serves as planet carrier and driving member, having lateral studs secured into it which carry triple planetary pinions. Gear B is the driven member, being keyed to the hub of clutch drum C, which in turn is secured to driven shaft D. By applying a brake band to drum E, gear F is held stationary, pinion G rolls on it, and the smaller pinion H causes gear B to turn slowly in the same direction as pinion carrier A. By applying a brake band to drum I, gear J is held stationary; pinion H turns gear B slowly in the reverse direction. For the high gear or direct drive, the friction clutch locks clutch drum C to the engine crankshaft, and the gear rotates as a unit.

The three pedals control the transmission and brakes. When the left pedal is push down all the way, the car is low gear. To remain in low gear, you must continue pushing on the left pedal. (It's been said that you push a Model T up a hill in low gear with your left foot!). If the left pedal is pushed to the halfway position, the car is in neutral. When the left pedal is completely released (not depressed at all) , the car is in high gear. If the car is in neutral (either by depressing the left pedal halfway or by moving the leaver to the left of the pedals to an upright position) the middle pedal can be pushed to engage reverse gear. The right pedal is a brake that acts on the transmission when pushed. Operating the brake and transmission sounds more difficult than it really is. After some practice, most drivers don't give it a second thought.

Interestingly, the Model T has a planetary transmission that's the forerunner of the transmission. It's very similar to an automatic transmission expect you use foot pedal pressure to operate the bands rather then hydraulic pressure and it doesn't have a torque converter. The leaver at the right and under the steering wheel is the hand throttle. It controls the speed, much like the control found on the tractor or riding mower.

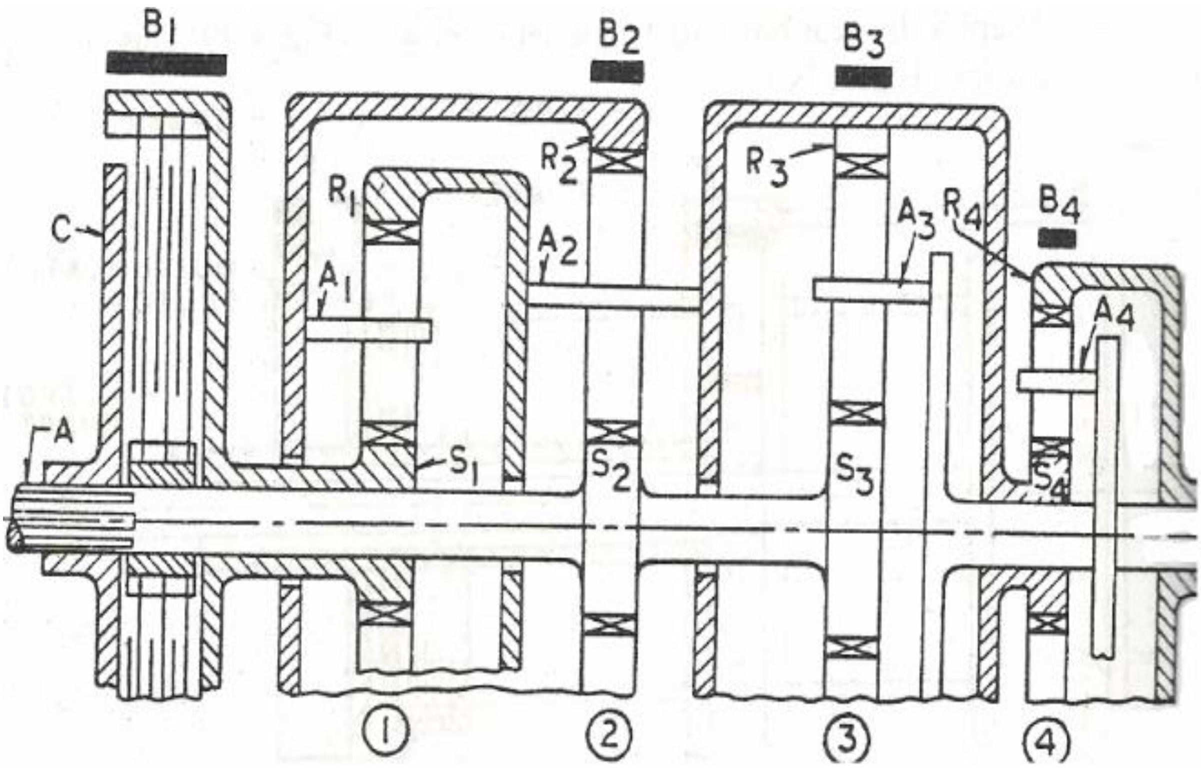
(Model T's were made from 1908 until 1927. Over 15 million Model T's were produced. Far more were produced than any other car until the Volkswagen Beetle overtook its production in the 1970's, at a time when two-car families become the norm. The impact of the Model T's in its day is hard far us to imagine, but in the early 1920s, half of all cars on the road worldwide were Model T's.A Model T in good mechanical condition will cruise all day at 30 to 35 mph. Most can go 45 to 50 mph but the engine is working pretty hard at these speeds, so most drivers go this fast only briefly. These figures also depend upon the body style and weight of the car, with roadsters and sedans and depot hacks the heaviest).

WILSON GEAR BOX

CONSTRUCTION

The gearbox comprises of three sub assemblies, the running gear, the brake harness and the control mechanism housed in an oil tight container. This consists of a four epicyclic trains of gear inter connected, so that different ratios and a reverse can be obtained. The direct drive is achieved by engaging the clutch.

One train of epicyclic gearing is used for all the various ratios, its sun S1 being secured to a shaft D coupled permanently to the engine and its arm R1 to the shaft E which is coupled permanently to the driving road wheels and the various ratios are obtained by driving the annulus A1 at different speeds in relation to the engine speed.



OPERATION

FIRST GEAR

First gear is obtained by applying a brake to the first gear train annulus A1. So that it is held stationary. The engine will then, be turning the sun gear S1. So that the planet gears will be rolling round inside the annulus A1 carrying their arm R1 round with them. As this arm R1 fixed to the output shaft its motion is imported to it.

First Gear ratio:

Engine speed = 1000 rpm = sun S1 speed

Arm R1 speed = wheel speed = 1000 x s/ (a +s)

= 1000 x 25 / (100 + 25)

= 200

Where

s = 25 = sun wheel teeth

a = 100 = annulus teeth

Gear ratio:

1000: 200

5: 1

SECOND GEAR

Second gear is obtained by holding the second gear train annulus A2 stationary by its brake. The main sun gear S2 still turned by the engine cause the planet gear to revolve and their arm R2. But this arm R2 is connected to the first gear train annulus A1 which therefore turns, speeding up the rotation of the planet gear and arm R1 and it turning the output shaft faster than was the case in first gear, i.e. less reduction.

Second Gear ratio:

Engine speed = 1000 rpm = sun gear S1
Annulus speed = 100 rpm

Gear ratio:

1000 : 280
3.57 : 1

THIRD GEAR

Third gear is obtained by holding the third gear sun wheel S3 by brake drum holding. Which is interconnected further the annulus A3 is an integral part of the second gear planet arm R2 which is in turn connected to the first gear annulus A1. The third gear arm R3 is connected to the second gear annulus A2 so driving it in same direction as the engine. i.e. increasing its speed so the drive is taken back through the second gear planets and arm R2 and the first gear train annulus A1 both of which are speeded up. The result is to speed up the first gear train arm R1 which are connected to output shaft. In other words by interconnecting the second and third arms, an increase of speed is obtained at the first gear train annulus, which increases the speed of the arm R1.

Third Gear ratio:

Sun wheel S1 speed = 1000 rpm
Arm R1 speed = 360 rpm
Gear ratio: 1000 : 360
2.78 : 1

TOP GEAR

In the top gear all the gear trains are locked together and revolve as a solid block driving the output shaft at engine speed. This is brought about by the engagement of this driving member to the clutch which is the drum and sun gear S3 gear train. So that locking the third gear sun to the driving shaft.
Those are all the sun gear will be revolving at the same speed. Since the first and second gear train sun wheel are fixed to the shaft (output) and their will not be any individual action of the various gear train. All the brake bands being loose their annulus.

Gear ratio:

1000 : 1000
1 : 1

REVERSE GEAR

The first gear annulus A1 is connected to the sun gear S4 of the reverse gear train and hence drive output shaft opposite to engine rotation. When the brake is applied to reverse gear annulus A4 the reverse gear planet wheels turned by the reverse sun gear connected to the first gear annulus and therefore turning opposite to the engine speed output shaft. As the arm A4 connected to the output shaft the direction of rotation of the propeller shaft reversed.

Reverse Gear ratio:

Sun wheel S1 = 25
Annulus A1 = 100
Sun wheel S4 = 40
Annulus A4 = 80

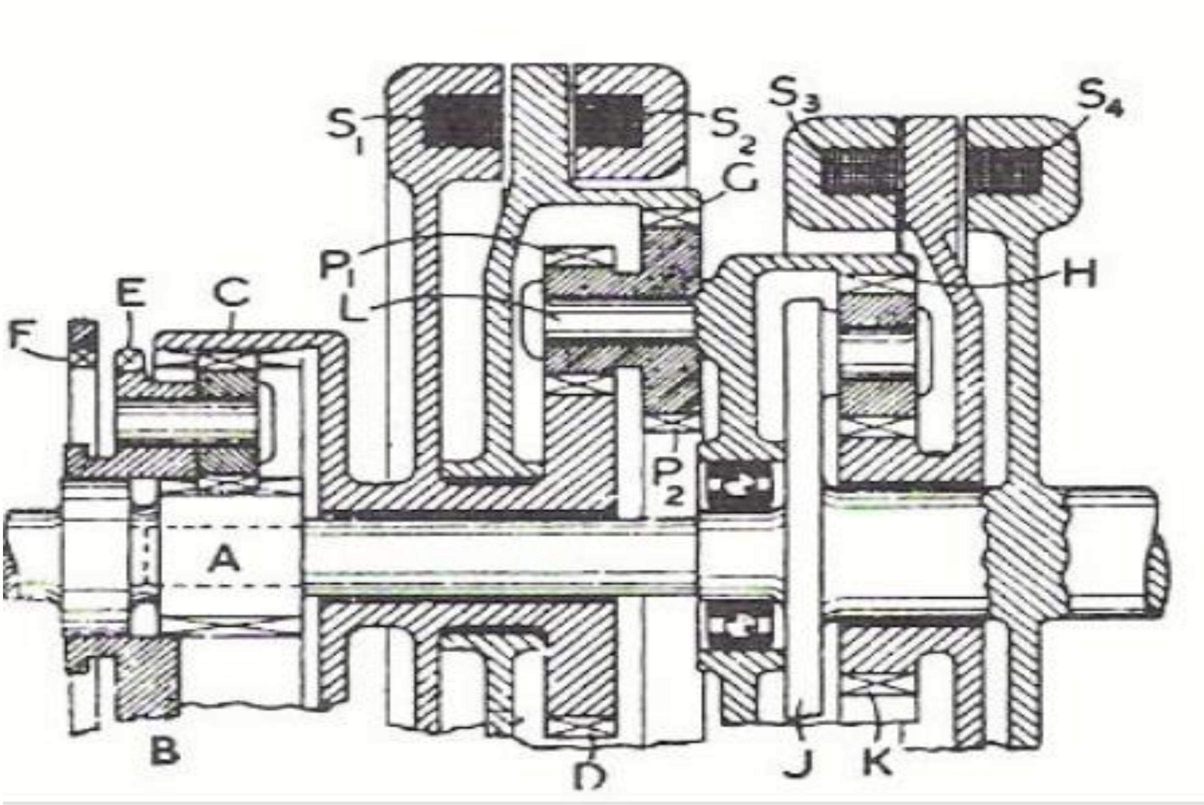
Gear ratio: 7 :1

COTAL ELECTROMAGNETIC TRANSMISSION SYSTEM

CONSTRUCTION

The wheel A is integral with the engine shaft and meshes with pinions carried by a spider A which is free to slide along the outside of the engine shaft. When the spider B is slid to the left, its teeth E mesh with teeth F of an annulus which is fixed to the gearbox casing. The pins of the spider then form fixed bearings for the pinions, and so the annulus C with which the latter mesh is driven in the opposite direction to the wheel A. This gives the reverse drives. When the spider B is slid to the right its teeth E engage the teeth of the annulus C and then the wheel A, pinions, spider B and annulus C revolve

'solid'. This gives the forward drives.



When this is done the annulus H is driven in the same direction as the sun D but at a lower speed. The second train consists of the annulus H, the sun K and the arm J which is fixed on the output shaft. The sun K can be held at rest so that the train gives a reduction between the annulus H and the arm J and it can also be locked to the output shaft so that the train must revolve solid. The annulus G can also be locked to the sun D so that the first train must revolve solid.

WORKING

The fixing and locking of the members is done by electromagnets whose windings S1 S2 S3 S4 are energized as may be required. **For first gear** S2 and S3 are energized and both epicyclic trains provide a reduction since both annulus G and sun K are fixed. **For second gear**, S2 and S4 are energized and the second train revolves solid, the only reduction being in the first train. **For third gear**, S1 and S3 are energized, the first train is locked solid and the only reduction occurs in the second train. **For fourth gear** S1 and S4 are energized and both trains revolves solid so that a direct drive is obtained.

The windings S1and S4 are carried by parts that sometimes rotate and so these windings are connected to slip rings on which brushes bear. The current for energizing the windings is supplied by the battery or generator of the car and is between two and three amperes.

The control is extremely simple consisting merely of a switch which connects the appropriate winding to the battery. This switch is usually mounted at the center of the steering wheel.

HYDRAULIC CONTROL SYSTEM

Hydraulic fluid is drawn from input and ensures that pressure is available as soon as the engine starts. The rear pump is driven from the output shaft so that pressure is generated in this pump as soon as the vehicle moves, and this feature provides a means of preventing the reverse and park mechanisms being engaged whilst the vehicle is in motion.

Non-return valves ensure that hydraulic pressure can be available from either pump and the joint delivery is regulated to a suitable pressure by a pressure relief valve.

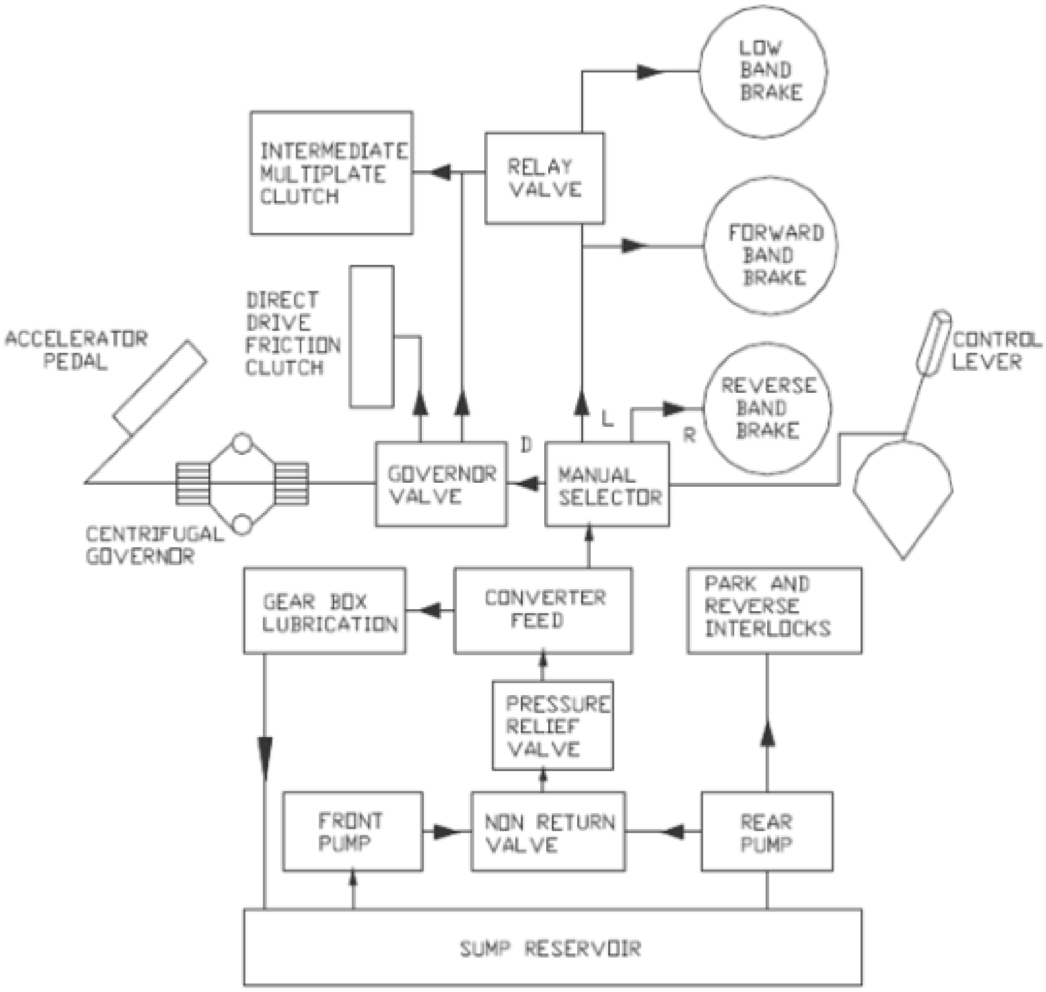
The fluid at regulated pressure is fed to the converter which is kept full of fluid and a small flow from the converter is used for lubrication of the gearbox.

The main fluid supply is fed to the manual selector valve which is controlled by a steering-column selector lever, and this may be moved to any of five positions.

This valve may direct fluid under pressure to the reverse brake when a reverse ratio is obtained. In the low selection, fluid is applied to both the forward and low brakes and maintains the transmission in low gear.

Neutral selection is obtained by removal of pressure from all friction elements, and the park position engages a mechanical lock preventing rotation of the output shaft.

When the Drive selection is made the manual selector applies fluid under pressure to the Forward and Low brakes and also to the governor valve.



The governor valve is moved by the combination of an accelerator pedal movement together with the position of a centrifugal governor. At low road speeds the governor valve is blocked and the transmission is retained in low gear.

At a higher road speed the governor valve moves to apply fluid at pressure to the multi-plate clutch so as to engage Intermediate gear.

As the multi-plate clutch begins to take up the drive the pressure in the clutch rises and becomes sufficient to operate the relay valve and cut off the fluid supply to the low friction brake band.

This relay valve carries out the transition from Low to Intermediate clutch.

This relay valve corresponds to the more usual shift although in this case the valve is moved by spring force in opposition to hydraulic pressure.

The change into direct drive is effected by the application of fluid pressure to the single-plate clutch by the governor valve. The other friction elements remain in the same condition as for the Intermediate gear so that no transition from one element to another is needed.

No smoothing device is incorporated for the take-up of this clutch, which relies on the capacity of the clutch piston to give a steady build-up of pressure. Gear changes to lower ratios operate in the reverse sequence.

The complete hydraulic circuit diagram is only slightly different from the simplified block diagram and a typical system. It will be noted that a hydraulic accumulator is included to give a rapid initial flow of fluid when the selector or governor valves operate, and a converter shuffle valve adjusts the converter pressure to a higher valve in low gear.

A small hydraulic detent applies a slight bias to the governor valve so that hunting, or repeated gear changes between two ratios, is avoided. Interlocks are provided to prevent engagement of the mechanical Park interlock mechanism when the rear pump is generating pressure, indicating movement of the output shaft.

A similar interlock piston prevents Reverse gear being engaged when rear pump pressure is available. This piston operates so as to block the control line which supplies pressure to the Reverse servo pistons. The relay valve is restored by hydraulic pressure to ensure a rapid operation of the piston return spring when a manual selection of low is made

HYDRAULIC COMPONENTS USED IN HYDRAULIC CONTROL SYSTEM

Front Pump: Driven from input shaft and provides the main hydraulic supply.

Rear Pump: Driven by output shaft and acts as an auxiliary supply in case of front pump failure, and also to detect forward movement of the vehicle.

Pressure Relief Valve: Regulates hydraulic supply pressure from both pumps to predetermined values. Initially, the relief valve springs ensure that 20 lb. /sq. in. pressure is admitted to the back of the relief valve raising the system to 80 lb. /sq. in. which is the normal pressure. When Reverse is selected, hydraulic pressure is applied to another piston so as to raise the pressure to 200 lb. /sq. in

Ball valves: Two balls inserted in the main supply line prevent a failure of either pump causing a complete loss of pressure. The system is arranged so that either pump will supply the control system as soon as the vehicle is moving.

Hydraulic Accumulator: Spring deflects when pressure is applied and the accumulator piston retracts in the cylinder to store a small volume of fluid at pressure. At a given deflection of the piston, fluid is admitted to the back of the pressure relief valve to increase the regulated pressure.

"Park" Interlock: A small spring loaded piston deflects due to pressure from the rear pump to prevent engagement of the Park lock.

Reserve Interlock Valve: A spring loaded piston deflects due to pressurem from the rear pump to prevent pressure being applied to the Reverse band brake.

Manual Selector Valve: operated by the selector lever for the five positions: park, netural, drive, low and reverse.

"Park," "Neutral" positions: All pressure is cut off from the friction clutches and bands. The park mechanism is operated from the selector lever but will not engage if the vehicle is moving forwards.

"Drive" position: Pressure is applied to the forward and low band brakes and also to the governor valve.

"Low" position: Pressure is maintained on the forward and low bands but is removed from the governor valve and applied to the back of the relay valve.

Governor valve: Operated by a combination of road speed (as measured from the output shaft), together with the accelerator pedal position. The valve initiates the gear changes between low and intermediate ratios and between intermediate ratio and direct drive at predetermined speeds when the manual selector valve has been moved to drive.

Converter shuttle valve: Regulates the flow of fluid into the hydraulic converter-coupling. Fluid is supplied from the main supply line to the valve and flows through a conical shaped valve seat. When reverse is selected, or when intermediate or direct gear is operative the pressure applied to the converter by inserting a conical plug into the valve seat so that an orifice of reduced size is presented to the flow. An increased pressure, and hence, flow is permitted for the low selection.

"Reverse" Position: Pressure is applied to the Reverse band brake, via the interlock valve. Pressure is also applied to the converter shuttle valve and the main relief valve.

Lubrication valve: The fluid drive is maintained at pressure by a spring loaded ball valve. When the pressure exceeds the set value the balls lifts and permits a flow of fluid through the converter. The escaping fluid is used for lubrication of the gearing.

Clutch Pistons: The single plate friction clutch and the multi-plate Intermediate clutch are both operated by annular pistons which fit in appropriate housings and apply the necessary load to the friction plates when fluid pressure is available.

Brake Pistons: The friction band brakes are applied by servo pistons which develop the necessary loads to hold the brake drums stationary. The servo cylinders each contain two pistons which act in tandem. A small restriction is placed between the two pistons as a means of smoothing the application and release of the bands.

SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF AUTOMOBILE ENGINEERING

UNIT-IV

AUTOMOTIVE TRANSMISSION APPLICATIONS

CHEVROLET TURBOGLIDE TRANSMISSION

This is a combination of a converter and an epicyclic gear and is shown in figure. The converter has five elements, the pump P, three turbines or driven elements T1, T2 and T3, and a reaction member R. The latter is free to rotate in the forward direction on the freewheel F1 and is provided with a set of blades B, whose angles are adjustable; the mechanism for making the adjustment is not indicated.

The first turbine element T1 is coupled by the shaft D to the sun S2 of the second epicyclic train; the second turbine T2 is coupled through the sleeve E to the annulus A1 of the first epicyclic train and the third turbine T3 is coupled to the output shaft H by the sleeve G1, the clutch C1 (which is always engaged except when neutral and reverse are selected), the sleeve G2 and the planet carrier R2.

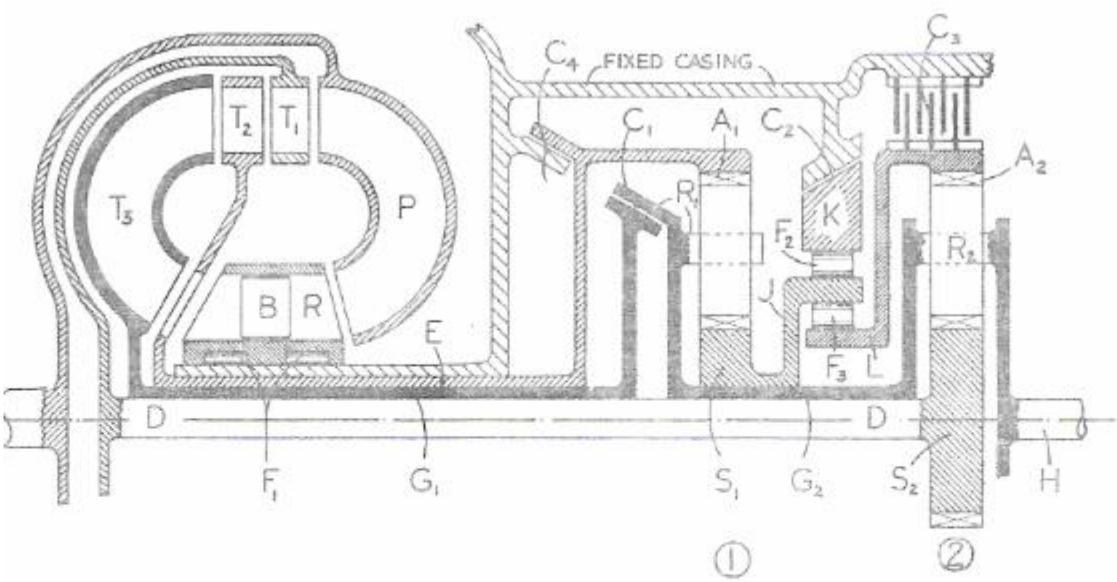
The sun S1 is normally prevented from rotating backwards by the free wheel F2, since usually the clutch C2 is engaged and the member K is fixed so that the sleeve J cannot rotate backwards. The annulus A2 is also prevented from rotating backwards by the freewheel F3 which locks it for such rotation to the sleeve J. Engagement of the clutch C3 fixes the annulus A2 against forwards or backwards rotation, and this is done when 'low' is selected so as to reduce the load on the freewheel F3, when the engine is pulling hard under adverse road conditions, and to allow the engine to be used effectively as a brake on down gradients.

At low forward speeds of the output shaft H relative to the engine speed, the sun S1, and annulus A2 will be stationary because the torques on them will tend to make them rotate backwards and this motion is prevented by the freewheels F2 and F3. Both epicyclic trains then provide speed reductions and torque increases, and all three turbines will be driving.

As the output speed rises, the torque passing through the sun S2 will fall and at some point will tend to become negative, and then the annulus A2 will start to rotate forwards and the turbine T1 will be effectively out of action. At a higher output shaft speed, the sun S1 will start to rotate forwards and the turbine T2 will go out of action. The drive will then be through T3 direct to the output shaft, the only torque magnification then being that due to the torque converter itself.

Finally, the reaction member R will start to rotate forwards and the torque converter will run as a fluid coupling. The speeds and torques at which these events occur will depend on the angle at which the blades B are set.

Reverse is obtained by engaging the clutch C4 and disengaging C1, C2 and C3. The trains 1 and 2 are then compounded and give a reverse ratio, the whole of the driving torque being transmitted by the turbine T1 and sun S2. Forward motion of S2 tends to drive R2 forwards and A2 backwards; backward motion of A2, however, results in backward motion of S1 (through the free wheel F3 and the sleeve J) and so in train 1, whose annulus is fixed, the sun tends to rotate the planet carrier R1 backwards. The backward torque on R1 is greater than the forward torque on R2 (from S2), and so R1 and R2 will move backwards.



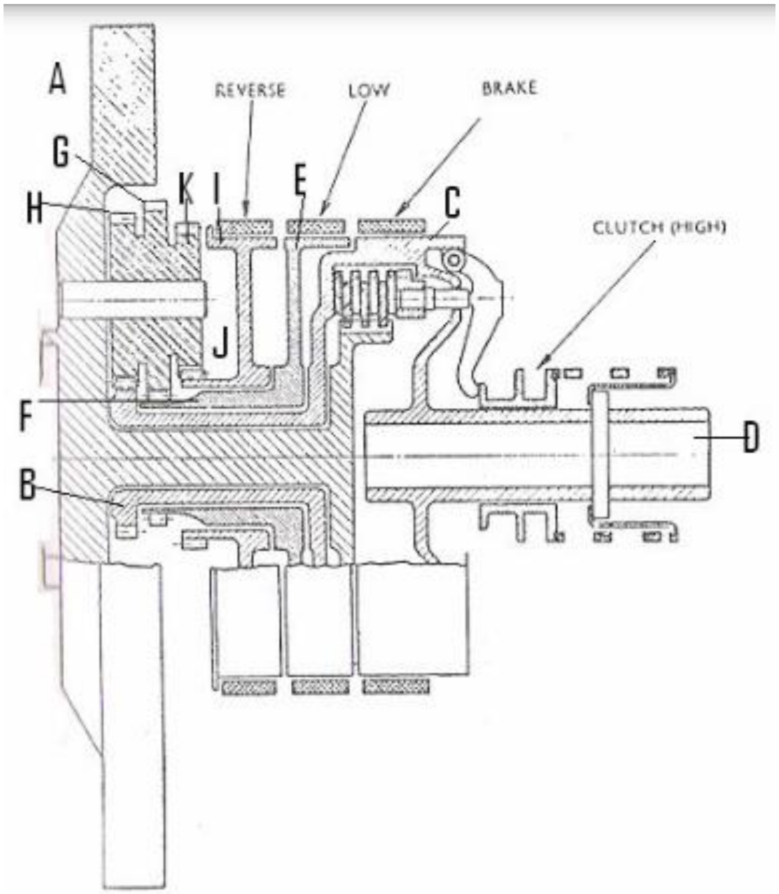
FORD T-MODEL GEARBOX

An example of the "all-spur" type of planetary transmission is the ford model T, with which millions of cars have been equipped.

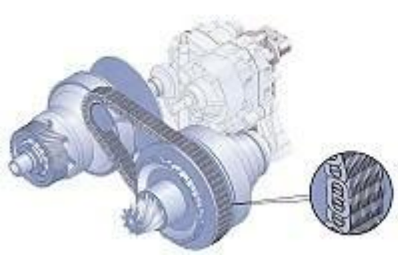
The flywheel rim A serves as planet carrier and driving member, having lateral studs secured into it which carry triple planetary pinions. Gear B is the driven member, being keyed to the hub of clutch drum C, which in turn is secured to drive shaft D. By applying a brake band to drum E, gear F is held stationary, pinion G rolls on it, and the smaller pinion H causes gear B to turn slowly in the same direction as pinion carrier A.

By applying a brake band to drum I, gear J is held stationary; pinion H turns gear B slowly in the reverse direction. For the high gear or direct drive, the friction clutch locks clutch drum C to the engine crankshaft, and the gear rotates as a unit. The three pedals control the transmission and brakes. When the left pedal is push down all the way, the car is low gear. To remain in low gear, you must continue pushing on the left pedal. (It's been said that you push a Model T up a hill in low gear with your left foot!). If the left pedal is pushed to the halfway position, the car is in neutral. When the left pedal is completely released (not depressed at all), the car is in high gear.

If the car is in neutral (either by depressing the left pedal halfway or by moving the lever to the left of the pedals to an upright position) the middle pedal can be pushed to engage reverse gear. The right pedal is a brake that acts on the transmission when pushed. Operating the brake and transmission sounds more difficult than it really is. After some practice, most drivers don't give it a second thought. Interestingly, the Model T has a planetary transmission that's the forerunner of the transmission. It's very similar to an automatic transmission expect you use foot pedal pressure to operate the bands rather than hydraulic pressure and it doesn't have a torque converter. The lever at the right and under the steering wheel is the hand throttle. It controls the speed, much like the control found on the tractor or riding mover.



Continuously Variable Transmission



The continuously variable transmission (CVT) is a transmission in which the ratio of the rotational speeds of two shafts, as the input shaft and output shaft of a vehicle or other machine, can be varied continuously within a given range, providing an infinite number of possible ratios.

A CVT need not be automatic, nor include zero or reverse output. Such features may be adapted to CVTs in certain specific applications.

Other mechanical transmissions only allow a few different discrete gear ratios to be selected, but the continuously variable transmission essentially has an infinite number of ratios available within a finite range, so it enables the relationship between the speed of a vehicle, engine, and the driven speed of the wheels to be selected within a continuous range. This can provide better fuel economy than other transmissions by enabling the engine to run at its most efficient speeds within a narrow range

About CVT

How CVTs work and how they improve performance, etc….

- The purpose of CVTs-To vary the transmission ratio continuously.

- Working of CVT depends on the type of CVT:
    - Friction CVTs vary the radius of the contact point between two rotating objects, thus the tangential velocity;

    - Hydrostatic CVTs vary the fluid flow with variable displacement pumps into hydrostatic motors

    - Ratcheting CVTs vary the stroke of a reciprocating motion, which is connected to a free-wheel, resulting unidirectional rotation.

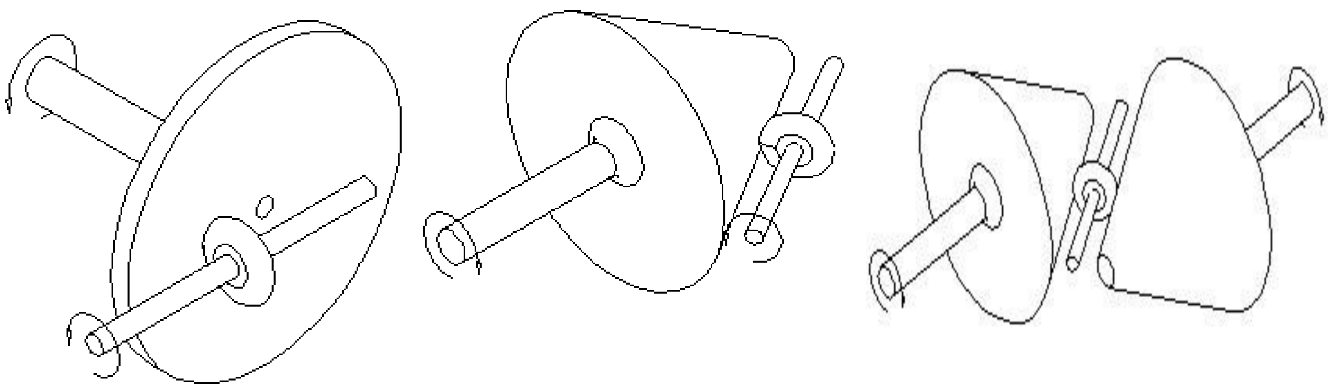
- CVT improves efficiency by allowing the engine to operate always in it's optimum R.P.M., whatever the vehicle's speed.

- What are the benefits of operating in the optimum R.P.M.?
  - Lower consumption;
  - Less greenhouse gas emissions;
  - Better performance;
- CVT is the ideal transmission, so why are there so few CVT cars?

  The existing inventions are based on
  - Friction,
  - hydrostatic,
  - Ratcheting which are all mechanical systems with inherent limitations, (compared to traditional transmissions).
- How to extract the full CVT potential?
- A conceptual innovation is the only way out. Although, research continues improving the friction CVTs and ratcheting CVTs, these efforts are accomplished by expensive high-tech materials and precision manufacturing. This is to overcome the inherent limitations of these concepts (friction and ratcheting).

TYPES OF CVTs

1. Frictional Type CVTS



The most common type of CVT is the frictional type, in which two bodies are brought into contact at points of varying distance from their axes of rotation, and allowing friction to transfer motion from one body to the other. Sometimes there is a third intermediary body, usually a wheel or belt.

The simplest CVT seems to be the **"disk and wheel" design**, in which a wheel rides upon the surface of a rotating disk; the wheel may be slid along it's splined axle to contact the disk at different distances from its center. The speed ratio of such a design is simply the radius of the wheel divided by the distance from the contact point to the center of the disk.

Friction plays an important part in frictional CVT designs - the maximum torque transmissible by such a design is:

$$\mathbf{T_{max} = C_f \times F_N \times R_o}$$

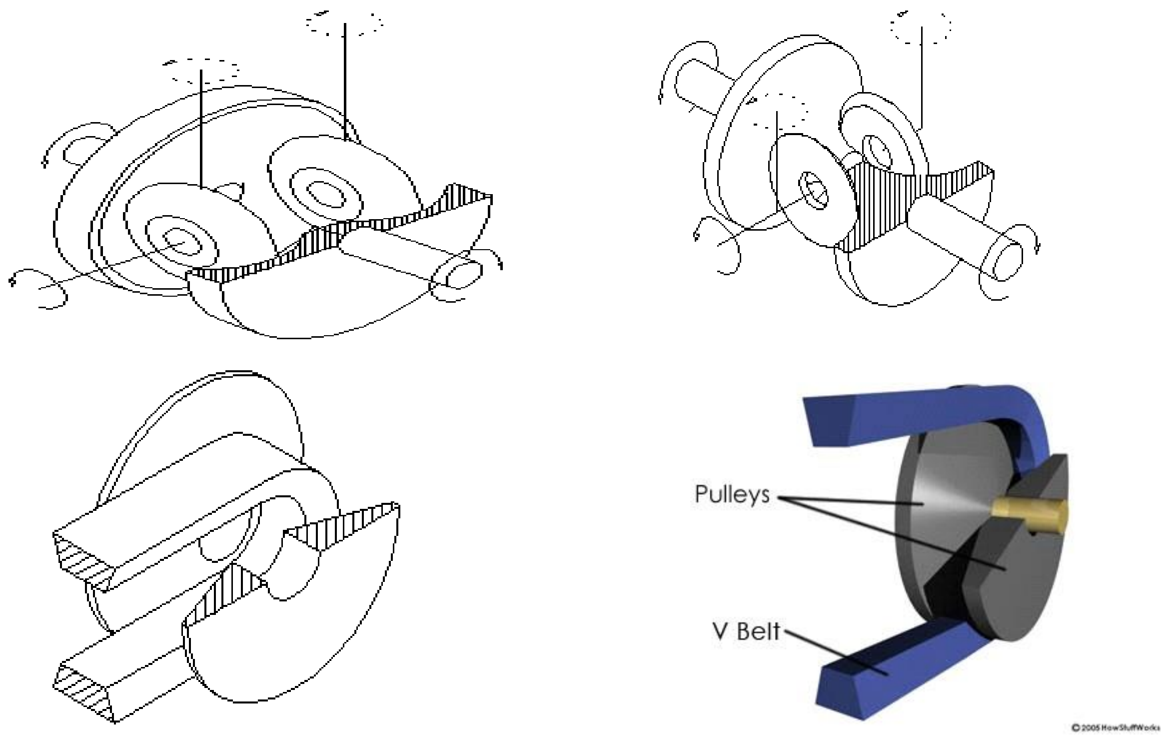
where $\mathbf{T_o}$ is the torque output, $\mathbf{C_f}$ is the coefficient of friction between the wheel and the disk, $\mathbf{F_N}$ is the force pushing the wheel into the disk (normal force), and $\mathbf{R_o}$ is the radius of the output wheel or disk. The coefficient of friction depends on the materials used; rubber on steel is typically around 0.8 to 0.9.

Power is lost in two ways:

- Deformation of the components;
- Differential slip.

Deformation of the components, the larger factor of the two, is caused by high normal forces, and can be minimized by using very hard materials that do not deform much, and materials with a very high coefficient of friction. Differential slip is caused by a large contact area between the rotating components; in this example, the "footprint" of the wheel riding on the disk. The edge of the footprint closest to the axis of rotation of the disk will roll along a smaller radius than the edge furthest from the axis of rotation, causing further distortion of the wheel and the edges of the footprint to slip. Differential slip is minimized by using a hard wheel that produces a small contact area.

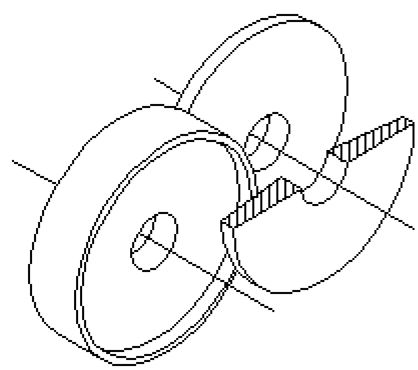
Very similar to the "disk and wheel" is the **"cone and wheel" design**, in which the disk is replaced by a cone. There is little advantage to using a cone instead of a flat disk, except to decrease the differential slip of the contact surface by minimizing the difference in the radius traveled by the inner and outer edges of the contact area. Other designs have used different shapes, but the principle remains the same.



More advanced designs used three bodies instead of two. There are two advantages to using three bodies: an increase in speed ratio range; and a simpler design. However, the range of speed ratios usually crosses unity - for example, it might range from 1:5 to 5:1 - making necessary a secondary gear sets, often a planetary set. Almost all such designs are based on toroidal contact surfaces, an exception being the "dual cone" design, which only affords the former advantage.

Toroidal CVT

The simplest toroidal CVT involves two coaxial disks bearing annular groves of a semi-circular cross section on their facing surfaces. The spacing of the disks is such that the centers of the cross sections coincide. Two or more (in patent-speak, "a plurality of") idler wheels, of a radius equal to the radius of the cross sections of the grooves, are placed between the disks such that their axes are perpendicular to, and cross, the axes of the disks.



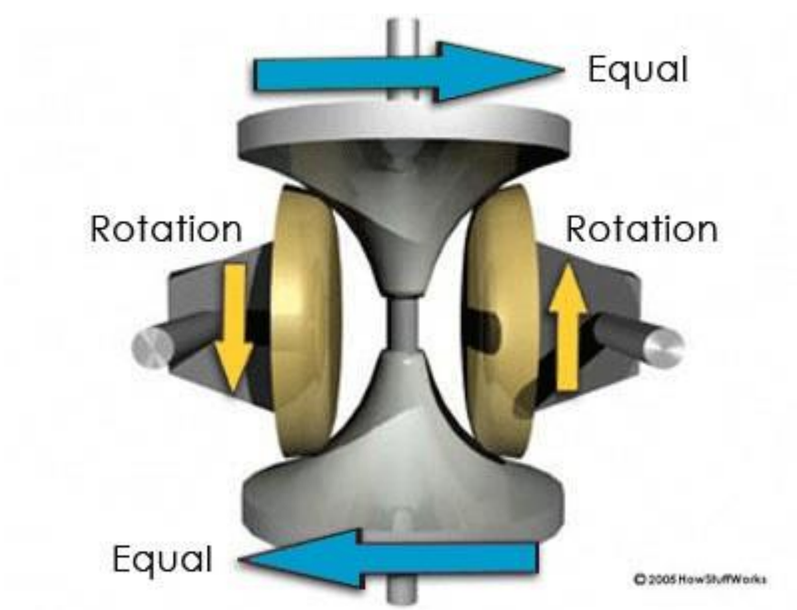
In the image, the speed ratio is varied by rotating the wheels in opposite directions about the vertical axis (dashed arrows). When the wheels are in contact with the drive disk near the center, they must perforce contact the driven disk near the rim, resulting in a reduction in speed and an increase in torque. When they touch the drive disk near the rim, the opposite occurs.

This type of transmission has the advantage that the wheels are not required to slide on a splined shaft, resulting in a simpler, stronger design.

Just as the disk CVT evolved into the cone CVT, the toroidal CVT has evolved toward a cone-shape as well. The result is a much more compact transmission. This type is peculiar in that the speed ratio may be controlled by directly rotating the wheels, or by moving them slightly up or down, causing them to rotate and change the speed ratio on their own.

Some more detail about Toroidal CVT

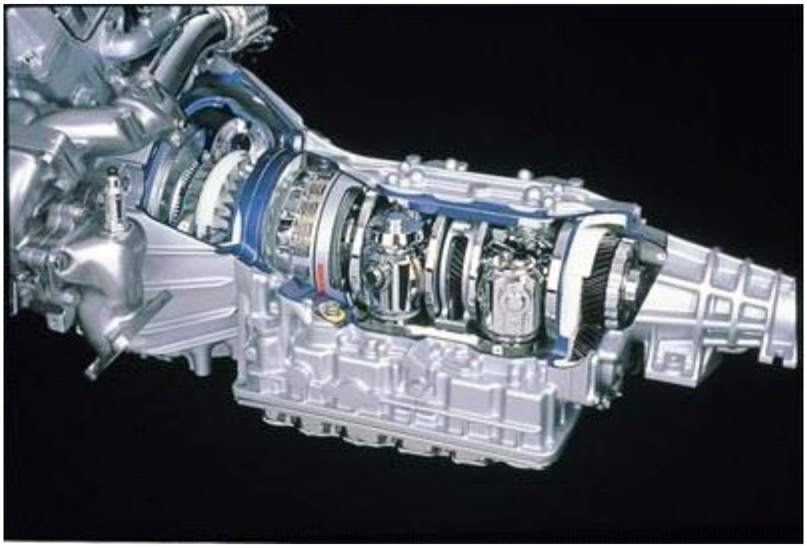
Another version of the CVT - the toroidal CVT system -- replaces the belts and pulleys with **discs** and **power rollers**.



Although such a system seems drastically different, all of the components are analogous to a belt-and-pulley system and lead to the same results -- a continuously variable transmission. Here's how it works:

- One disc connects to the engine. This is equivalent to the driving pulley.
- Another disc connects to the drive shaft. This is equivalent to the driven pulley.
- Rollers, or wheels, located between the discs act like the belt, transmitting power from one disc to the other.

The wheels can rotate along two axes. They spin around the horizontal axis and tilt in or out around the vertical axis, which allows the wheels to touch the discs in different areas. When the wheels are in contact with the driving disc near the center, they must contact the driven disc near the rim, resulting in a reduction in speed and an increase in torque (i.e., low gear). When the wheels touch the driving disc near the rim, they must contact the driven disc near the center, resulting in an increase in speed and a decrease in torque (i.e., overdrive gear). A simple tilt of the wheels, then, incrementally changes the gear ratio, providing for smooth, nearly instantaneous ratio changes.



Nissan Exterior toroidal CVT

Variable diameter pulleys type CVT

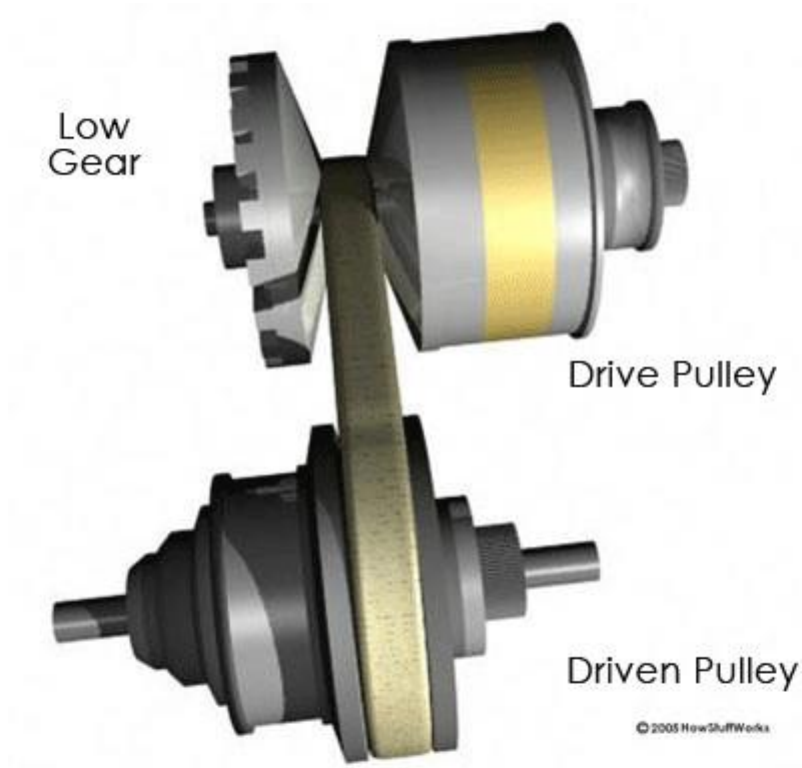
Variable diameter pulleys are a variation in the theme. Two 20° cones face each other, with a v-belt riding between them. The distance from the center that the v- belt contacts the cones is determined by the distance between them; the further apart they are, the lower the belt rides and the smaller the pitch radius. The wider the belt is, the larger the range of available radii, so the usual 4L/A series belt is not often used in this way. Often special belts, or even chains with special contact pads on the links, are used. Variable diameter pulleys must always come in pairs, with one increasing in radius as the other decreases, to keep the belt tight. Usually one is driven with a cam or lever, while the other is simply kept tight by a spring. Variable diameter pulleys have been used in a myriad of applications, like

- power tools
- Snowmobiles,
- Automobiles.

The variable-diameter pulleys are the heart of a CVT. Each pulley is made of two 20-degree cones facing each other. A belt rides in the groove between the two cones. **V-belts** are preferred if the belt is made of rubber. V-belts get their name from the fact that the belts bear a V-shaped cross section, which increases the frictional grip of the belt.

When the two cones of the pulley are far apart (when the diameter increases), the belt rides lower in the groove, and the radius of the belt loop going around the pulley gets smaller. When the cones are close together (when the diameter decreases), the belt rides higher in the groove, and the radius of the belt loop going around the pulley gets larger. CVTs may use hydraulic pressure, centrifugal force or spring tension to create the force necessary to adjust the pulley halves.

Variable-diameter pulleys must always come in pairs. One of the pulleys, known as the **drive pulley** (or **driving pulley**), is connected to the crankshaft of the engine. The driving pulley is also called the **input pulley** because it's where the energy from the engine enters the transmission. The



second pulley is called the **driven pulley** because the first pulley is turning it. As an **output pulley**, the driven pulley transfers energy to the driveshaft.

The distance between the centers of the pulleys to where the belt makes contact in the groove is known as the pitch radius. When the pulleys are far apart, the belt rides lower and the pitch radius decreases. When the pulleys are close together, the belt rides higher and the pitch radius increases. The ratio of the pitch radius on the driving pulley to the pitch radius on the driven pulley determines the gear

Variable diameter friction gears are very similar, only with the belt replaced by a wheel with friction surfaces along the sides of its circumference. The two wheels are moved together or apart to control the speed ratio, with the proper distance between the cones being maintained by a spring.

2. Electrical Type

It could easily be argued that a generator powering a motor through some kind of electronic speed control would constitute a continuously variable transmission. Electrical transmissions have the advantage of great flexibility in layout, as the generator can be located at any distance or orientation with the motor. Furthermore, any excess power generated can be stored in batteries, and drawn upon when high loads are experienced. However, they are heavy and inefficient. A typical generator or motor is only 75% to 80% efficient, so compounding two results in an efficiency of only 56% to 64%. This limits their use to situations where other types of transmissions cannot be used.

Diesel locomotives and some ships use such drive trains, and more recently, "hybrid" gas-electric cars.

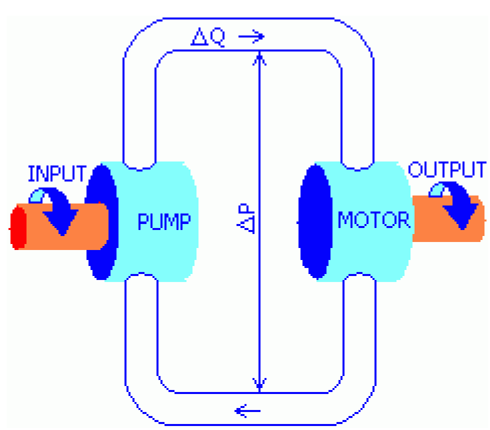
3. Hydraulic Type

A hydraulic CVT is a hydraulic pump driving a hydraulic motor, at least one of which has a variable displacement. If, for example, the pump has a variable displacement, the increasing the displacement will obviously increase the speed of the motor. If the motor has a variable displacement, then the situation is reversed; increasing the displacement will decrease the speed at which it turns, as the volume produced by the pump remains constant. Decreasing the displacement of the motor will likewise increase its speed.

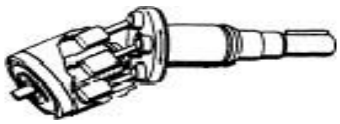
This kind of transmission is used in the Honda Rubicon ATV. It consists of a hydraulic swash plate pump driving a swash plate hydraulic motor. The motor is variable displacement, achieved by controlling the angle of the swash plate.

"Hydrostatic" CVTs

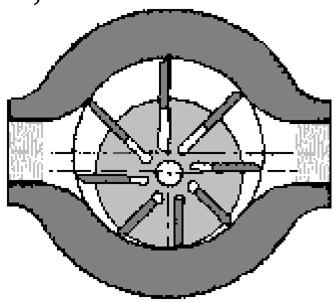
Principle: Hydrostatic CVTs convert rotational motion into fluid flow (hydrostatic pump), and then back to rotational motion (hydrostatic motor).



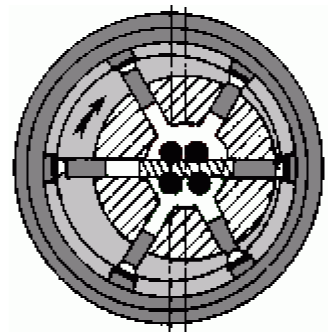
In some cases, the fluid flow is continuously varied by variable displacement pump. There are other cases where the variable displacement unit is the hydrostatic motor, or both.



Bent Axis Pump (variable angle)

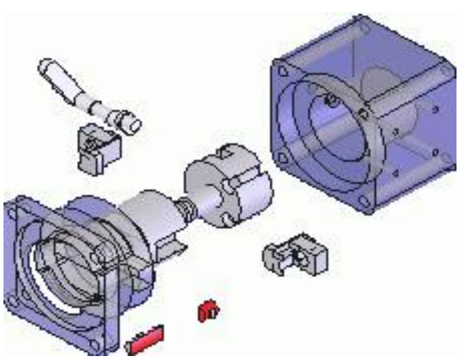


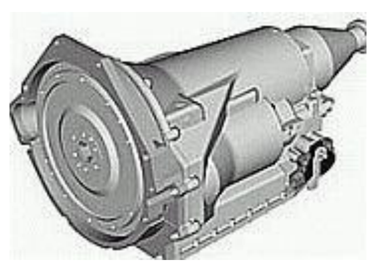
Radial Piston Pump (variable axis offset)



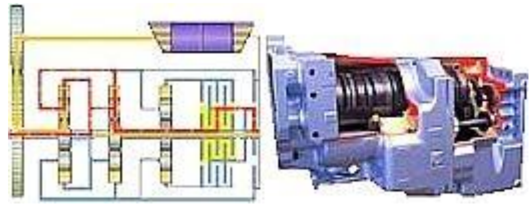
Vane Pump (variable axis)

Some examples of "Hydrostatic" CVTs:





Hydrostatic CVTs for Tractors:



Hydrostatic CVTs for Motorcycles:

Hydrostatic CVTs for Bikes:

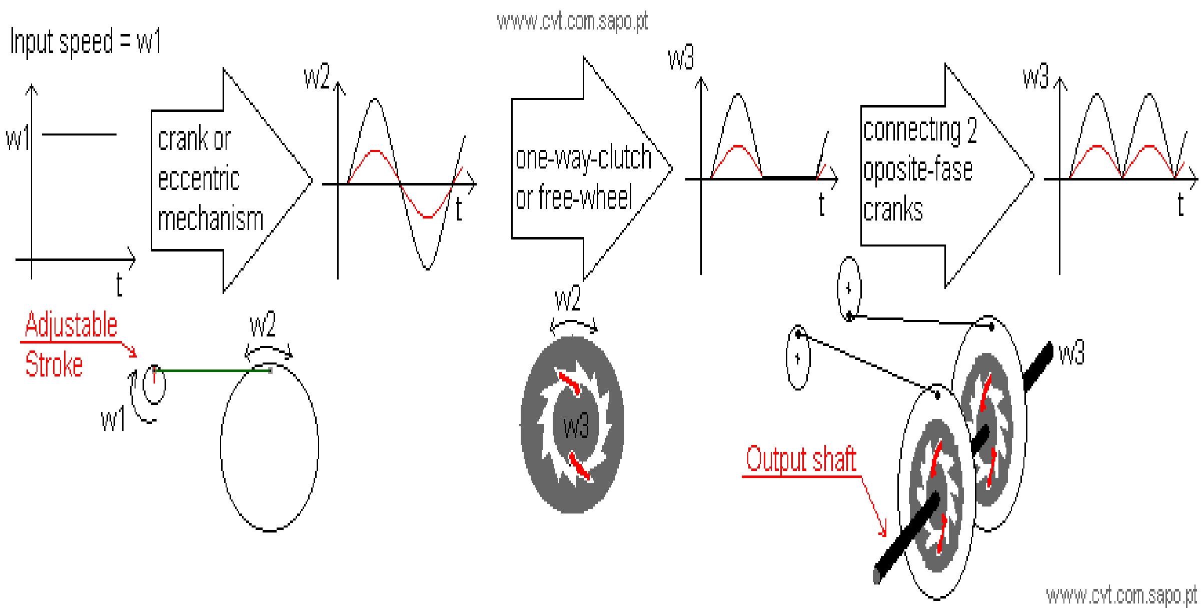
4. "Ratcheting" CVTs or "Crank-CVT" or "Variable-Stroke CVT"

Principle:

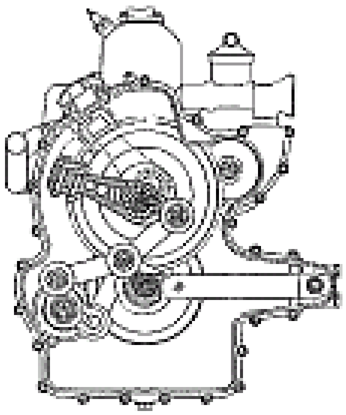
These CVTs convert uniform motion to reciprocating motion, and then rectify it back to an "almost" uniform motion.

Firstly, there is a mechanism that produces reciprocating motion from

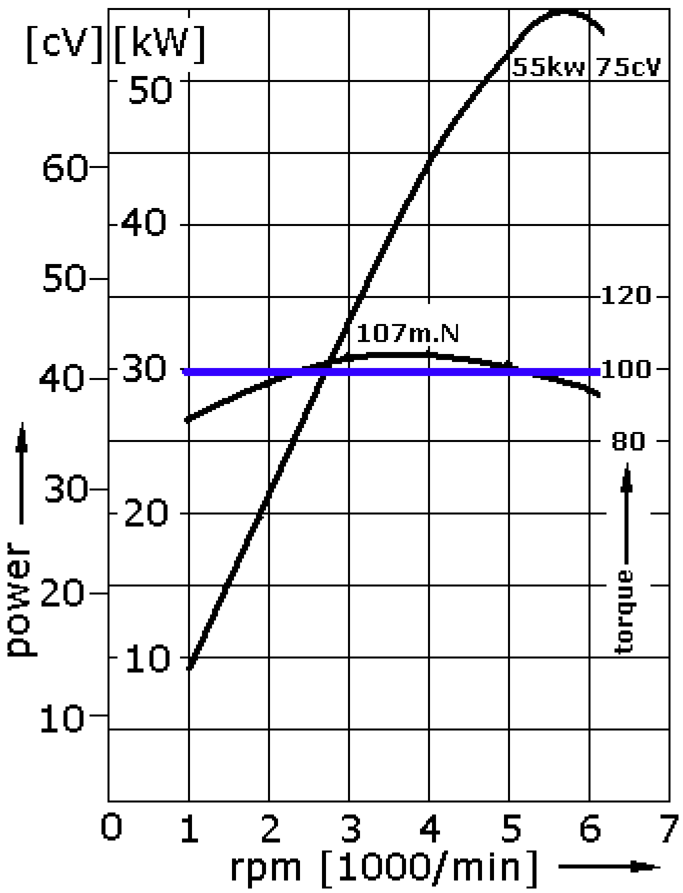
rotational input. This mechanism allows adjustable reciprocating stroke.
Secondly, the reciprocating motion is rectified by a mechanism such as a one-way-clutch (or free-wheel).Thus, the reciprocating motion is rectified to a unidirectional rotational output.
It is possible to adjust the speed of this rotational output simply by adjusting the reciprocating stroke.
To obtain a smoother output motion, several out-of-phase cranks are used:



Some examples of "Ratcheting" CVTs:



Bike-CVTs (reciprocating input -> rotational output)



According to the technical specifications, this car takes 12.1s to accelerate from rest to 100 km/h. If we include luggage and passengers, the value should rise to about 15.5s.

Anyway, we will have to calculate this MT case <u>theoretically</u> in order to compare with the corresponding <u>theoretical</u> calculations for the CVT case.

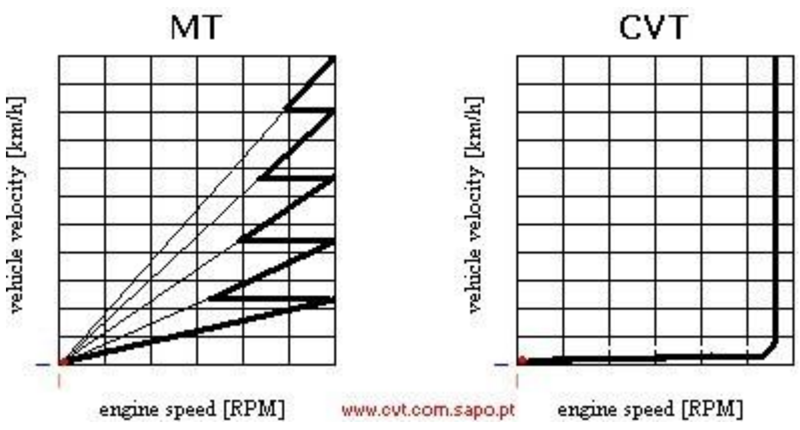
During each gear, the torque will be almost constant, and so will be the car's acceleration. Force=Power/Velocity. Also, Acceleration=Force/Mass. Thus,

Acceleration = Power / (Velocity * Mass).

2nd case: Continuously Variable Transmission (CVT):

Now we will calculate the required time to accelerate from rest to 100km/h, using a Continuously Variable Transmission (CVT). To simplify calculations, we will consider the IVT case, because it allows continuous ratio variation from rest.

To maximize acceleration, power must be kept on it's greatest value



Advantages of CVTs

1. Constant, stepless acceleration from a complete stop to cruising speed which Eliminates "shift shock" -- makes for a smoother ride

2. Works to keep the car in its optimum power range regardless of how fast the car is traveling which Improves fuel efficiency

3. Responds better to changing conditions, such as changes in throttle and speed which Eliminates gear hunting as a car decelerates, especially going up a hill

4. Less power loss in a CVT than a typical automatic transmission gives Better acceleration

5. Better control of a gasoline engine's speed range which gives Better control over emissions

6. Can incorporate automated versions of mechanical clutches which Replaces inefficient fluid torque converters

A CVT Test Drive

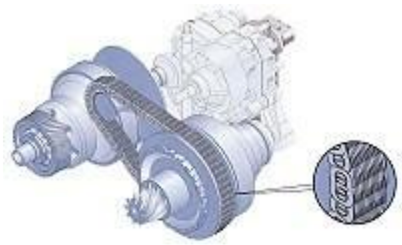
Cars with CVTs have been common in Europe for years. But it's taken a while for the technology to gain a foothold in the United States. The first production automobile to offer a CVT in the United States was the Subaru Justy.

Sold between 1989 and 1993, the Justy never attracted the attention of American drivers. So, what's different about newer CVT-based cars -- cars like the Saturn Vue, the Audi A4 and A6, the Nissan Murano and the Honda Insight? The best way to answer that question is to take one of these cars for a "test drive." The animation below, which compares the acceleration of a car with a CVT to one without, gives you a good feel for the experience. When you step on the gas pedal of a car with a continuously variable transmission, you notice the difference immediately. The engine revs up toward the rpms at which it produces the most power, and then it stays there. But the car doesn't react immediately. Then, a moment later, the transmission kicks in, accelerating the car slowly, steadily and without any shifts. In theory, a car with a CVT should reach 60 mph (100 km/hr) 25-percent faster than the same car with the same engine and a manual transmission. That's because the CVT converts every point on the engine's operating curve to a corresponding point on its own operating curve.

CVTs are equally efficient on hills. There is no "gear hunting," because the CVT cycles stepless down to a gear ratio appropriate for the driving conditions. A conventional automatic transmission shifts back and forth trying to find the right gear, which is far less efficient.

With all of their advantages, CVTs do have some shortcomings. Traditionally, belt-drive CVTs were limited in the amount of torque they could handle and were larger and heavier than their automatic and manual counterparts. Technological advances have put CVTs in the realm of their competition -- the Nissan Murano's CVT can handle its 3.5-liter, 245-horsepower V6 engine
-- but first impressions are hard to overcome.

A Case study of Audi cars having CVTs



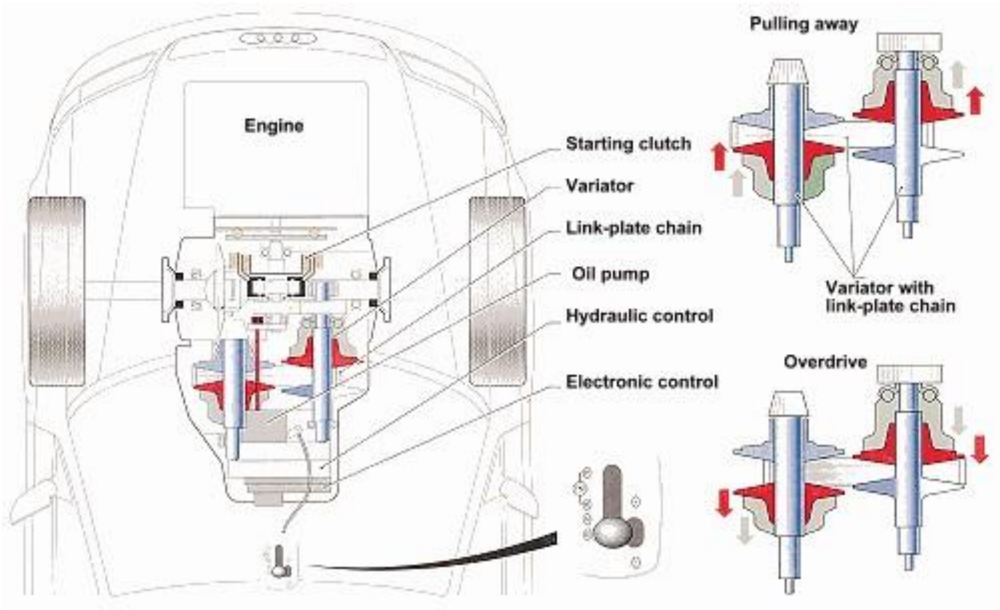
1st is the Audi multitronic CVT showing the variator with link-plate chain & 2nd is the General view of Audi multitronic CVT.

In 1490, Leonardo da Vinci made a sketch that indicated the potential of the stepless continuously variable transmission (CVT). Leonardo, it seems, took the invention of the automobile itself as mundane and obvious: He just wanted to get down to details. He reckoned two pedals would be better than three and that conventional gears were already passe. However, he has had a long wait. CVTs may be great in theory but the fact is they have a questionable image and have made, until recently, relatively little impact on the automotive scene.

Now, Audi has revealed that it has developed a new CVT it believes overcomes the drawbacks of earlier systems and will, at last, make the principle generally acceptable. It adds that its CVT, which it calls multitronic, when installed in an A6 sedan or wagon (Avant) not only offers markedly better fuel consumption than a regular automatic but gives marginally improved acceleration to 100 km/h (62 mph) compared to a five-speed manual. And Audi feels it can offer the system at only slightly higher cost than its current conventional automatic. AEI went to Germany to find out more.

In Europe, DAF in The Netherlands produced a CVT for a car in 1958. This was developed and improved over the years. Basically, it was a simple (some would say crude) rubber band and cone system. The attractions of CVT are (in theory) many and varied, including seamless power delivery, the ability to allow the engine to rev almost immediately to deliver maximum torque, and a wide spread of ratios. However, the DAF CVT had something of an image problem. Because it was simple to use with just a stick shift for selecting forward or reverse and fitted to a low-powered car (the original production DAF had a 0.6-L engine) it was popular with older people. Later, the system was taken up by various manufacturers but at a time when cars were becoming quieter and more refined. The CVT's trait of going to high revs on wide throttle openings with subsequently increased interior noise levels met with customer resistance. It was also decided that the system should have low speed "creep" similar to that of a regular automatic for low-speed maneuvering or when driving in very slow city traffic. But this created a jerky response. Its performance was improved as more advanced electronics were developed, but the electronics actually became a limiting factor. There was also a problem with regard to the maximum torque that could be handled by a CVT even when the rubber belt was replaced by a steel thrust belt.

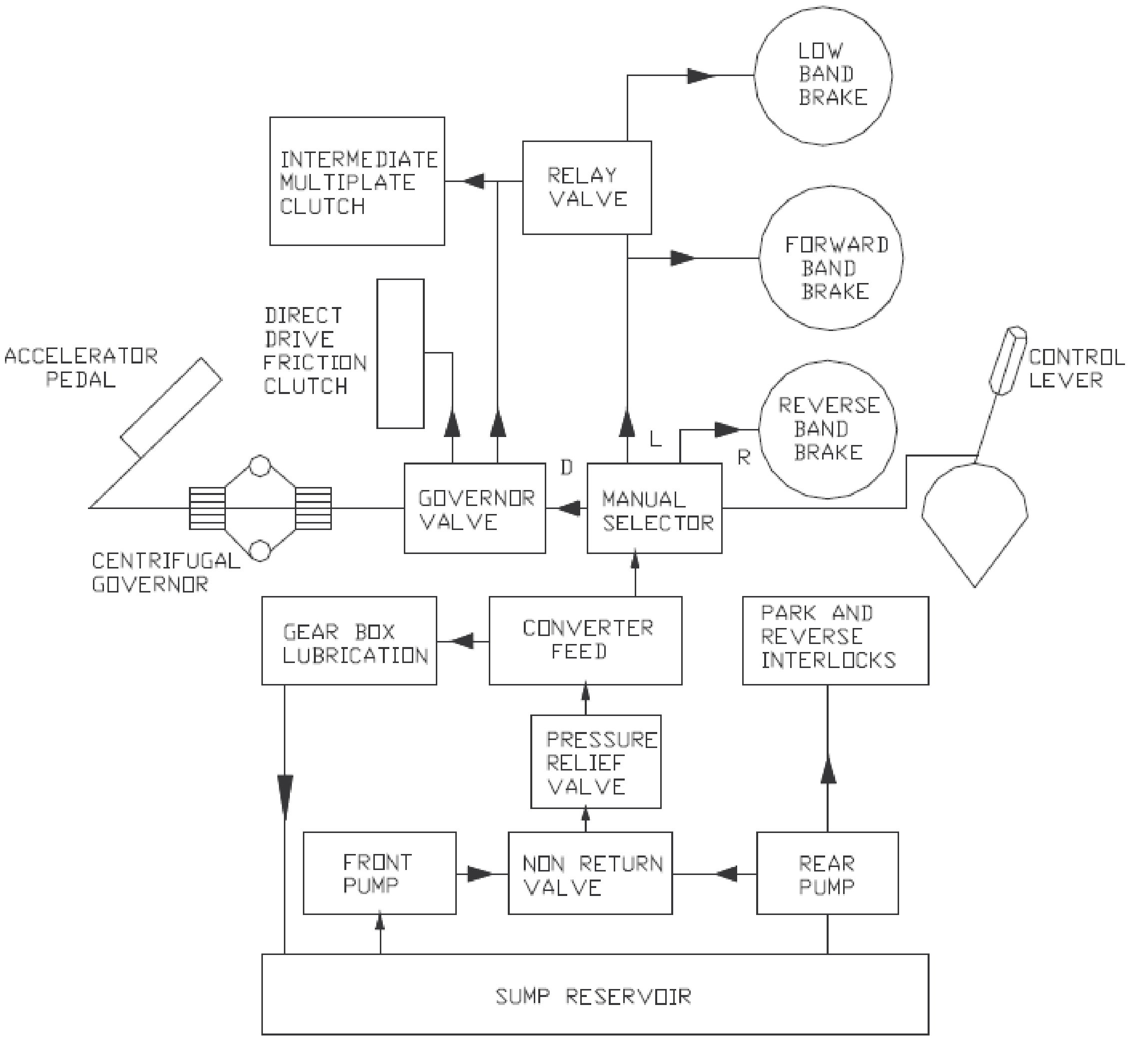
Audi's research and development engineers watched all this with caution and it has been almost 20 years since its first tentative CVT work started, and only now it feels that it has overcome the system's minus points and enhanced its pluses. To demonstrate it, Audi invited AEI to sample its multitronic system fitted to a 2.8-L A6, over a mixed route of regular roads and autobahn. It is unlike other CVTs experienced by this journalist. Audi states that multitronic finally overcomes all the drawbacks of the stepless principle, and that the multitronic is the first transmission of its kind not to pay the high price of poorer dynamism and economy for the added convenience it brings A key element of the Audi design is a variator that Audi explains adopts a new transmission element called a link-plate chain made entirely from steel, said to be almost as flexible as a V-belt (it has been tested "over a number of years"), to handle the high forces and torque levels of the A6's engine, which has a peak torque of 280 N•m (207 lb•ft). The variator allows a spread of ratios equating to a six- speed system: due to its high maximum torque ratio, the variator facilitates acceleration from rest and renders a hydraulic torque converter unnecessary. Audi has opted instead to use an oil-cooled multi-plate clutch which it said implements a variety of starting strategies which respond to driver preference via sensors linked to the accelerator pedal. The system allows sport or economy mode driving. The multi-plate clutch also provides constant creep behavior. By optimizing the hydraulics, the transmission engineers have ensured that the adjustment processes take place dynamically and without any trailing effects. The "rubber band effect" or "slipping clutch syndrome," which have been a common source of criticism on conventional CVTs, are essentially banished.



The variator uses a novel dual-piston system and oil flow is separated into high pressure and cooling circuits. Pump output of the hydraulic system is said to be lower than that of a conventional transmission, which aids in efficiency and road performance. The rubber band effect is avoided by electronically controlled speed tracking, producing, says Audi, dynamic driving properties in conjunction with a reassuringly familiar pattern of sound — in other words, the engine does not rev with manic insistence as the car's speed "catches up." Multitronic also has a "manual" mode with six fixed transmission stages, working in a similar way to the manual one-touch sequential element of a conventional automatic transmission. Audi claims that the multitronic A6 accelerates from 0-100 km/h (0-62 mph) 1.3 s quicker than a geared automatic transmission and is 0.1 s quicker over the same speed than an equivalent model with "optimum" use of a five-speed manual gearbox. Gasoline consumption measured to EU standards shows a 0.9-L (0.25-gal) savings over 100 km (62 mi) less than an automatic and 0.2 L (0.04 gal) less than a manual. Audi claims it to be the first automatic transmission to achieve lower fuel consumption and better performance than an otherwise identical model with a manual five-speed gearbox. Audi opted to use magnesium for the gearbox housing and claims the multitronic as the first automatic transmission to use the material. "This factor alone brought about a weight reduction of approximately 7 kg (15.4 lb.)," says Reinhard Gesenhaus, Audi's Manager of Transmission Engineering, who discussed some of the other key elements of the multitronic system. "We used an oil cooled drive-off clutch to replace the torque converter usually found in automatic transmissions. An input side step-down gear matches the torque to the variator and provides a suitable overall ratio. The variator with link-type chain provides a continuously variable ratio according to torque and engine speed. Output to the front wheels is via an integral front axle differential. The hydraulic control unit with integrated pump and local electronic system is installed at the rear of the transmission."

HYDRAULIC CONTROL SYSTEM

The hydraulic control system of the automatic transmission is shown in figure. Which is a simplified diagram illustrating the basic principles. Hydraulic fluid is drawn from input and ensures that pressure is available as soon as the engine starts. The rear pump is driven from the output shaft so that pressure is generated in this pump as soon as the vehicle moves, and this feature provides a means of preventing the reverse and park mechanisms being engaged whilst the vehicle is in motion. Non-return valves ensure that hydraulic pressure can be available from either pump and the joint delivery is regulated to a suitable pressure by a pressure relief valve. The fluid at regulated pressure is fed to the converter which is kept full of fluid and a small flow from the converter is used for lubrication of the gearbox.



The main fluid supply is fed to the manual selector valve which is controlled by a steering-column selector lever, and this may be moved to any of five positions. This valve may direct fluid under pressure to the reverse brake when a reverse ratio is obtained. In the low selection, fluid is applied to both the forward and low brakes and maintains the transmission in low gear. Neutral selection is obtained by removal of pressure from all friction elements, and the park position engages a mechanical lock preventing rotation of the output shaft.

When the Drive selection is made the manual selector applies fluid under pressure to the Forward and Low brakes and also to the governor valve. The governor valve is moved by the combination of an accelerator pedal movement together with the position of a centrifugal governor. At low road speeds the governor valve is blocked and the transmission is retained in low gear. At a higher road speed the governor valve moves to apply fluid at pressure to the multi-plate clutch so as to engage Intermediate gear. As the multi-plate clutch begins to take up the drive the pressure in the clutch rises and becomes sufficient to operate the relay valve and cut off the fluid supply to the low friction brake band. This relay valve carries out the transition from Low to Intermediate clutch. This relay valve corresponds to the more usual shift although in this case the valve is moved by spring force in opposition to hydraulic pressure.

The change into direct drive is effected by the application of fluid pressure to the single-plate clutch by the governor valve. The other friction elements remain in the same condition as for the Intermediate gear so that no transition from one element to another is needed. No smoothing device is incorporated for the take-up of this clutch, which relies on the capacity of the clutch piston to give a steady build-up of pressure. Gear changes to lower ratios operate in the reverse sequence.

The complete hydraulic circuit diagram is only slightly different from the simplified block diagram and a typical system. It will be noted that a hydraulic accumulator is included to give a rapid initial flow of fluid when the selector or governor valves operate, and a converter shuffle valve adjusts the converter pressure to a higher valve in low gear. A small hydraulic detent applies a slight bias to the governor valve so that hunting, or repeated gear changes between two ratios, is avoided. Interlocks are provided to prevent engagement of the mechanical Park interlock mechanism when the rear pump is generating pressure, indicating movement of the output shaft. A similar interlock piston prevents Reverse gear being engaged when rear pump pressure is available. This piston operates so as to block the control line which supplies pressure to the Reverse servo pistons. The relay valve is restored by hydraulic pressure to ensure a rapid operation of the piston return spring when a manual selection of low is made

TOYOTA "ECT-i" A NEW AUTOMATIC TRANSMISSION WITH INTELLIGENT ELECTRONIC CONTROL SYSTEM

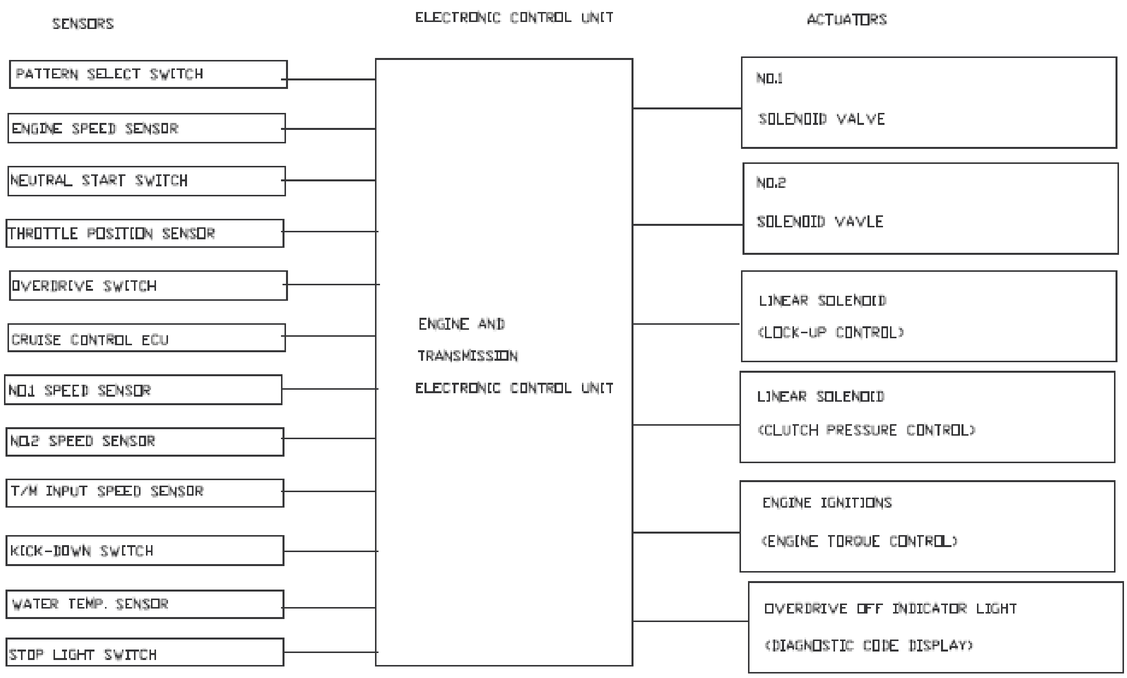
In recent years since the oil crisis, technological developments for automatic transmissions have been aimed mainly at the improvement of fuel economy, with emphasis placed in increasing the efficiency of the complete power transmission system, including the engine. The four-speed automatic transmission, the lock-up clutch and their electronic controls have been developed and their electronic controls have been developed and put into practical application. Currently, efforts are being made to increase the number of transmission speeds for further improvement of drivability and power performance.

The level of vehicle performance required by drivers is also becoming higher and higher. In automatic transmissions higher quality levels are required not only for fuel economy and power performance but also for shift quality noise reduction, etc... Consequently, smoothness and quietness including proper controls for the increased number of gear shift operations required with the increase in transmission speeds are major transmission developments.

SPECIFICATIONS OF THE TOYOTA ECT-i TRANSMISSION

S.NO.	SPECIFICATIONS	VALUES
1	Torque Capacity	3.6 kg-m (353 N-m)
2	Torque Converter	3-Element, 2-Phase with Lockup Clutch Type, Impeller Diameter 272mm.
3	Gear Train Gear Ratio	1^{st} 2.531:1 2^{nd} 1.531:1 3^{rd} 1.000:1 O.D 0.705:1 Reverse 1.830:1
4	Friction Element	6 Disc Clutches 1 Band Clutches
5	Shift Positions	6 Positions P-R-N-D-2-3
6	Control System	Electronic Hydraulic Control 19 Valves 2 ON-OFF Solenoids 2 Linear Solenoids
7	Automatic Transmission Fluid	Capacity 8.3 liters
8	Weight	77 kg (755 N)

Under such circumstances, TOYOTA has developed a new automatic transmission, called the A341E. This transmission employs a unique engine and transmission integrated intelligent control system. The main function of the engine and transmission integrated intelligent control system are engine torque control and clutch hydraulic pressure control. And the "super Flow" Torque converter has a modified geometry optimized by the analysis of internal flow by means of computer simulations, attaining the highest efficiency in the world. With the use of such systems, this new automatic transmission has attained very smooth shift changes over system life.



ENGINE AND TRANSMISSION INTEGRATED INTELLIGENT CONTROL SYSTEM

SCHOOL OF MECHANICAL ENGINEERING

DEPARTMENT OF AUTOMOBILE ENGINEERING

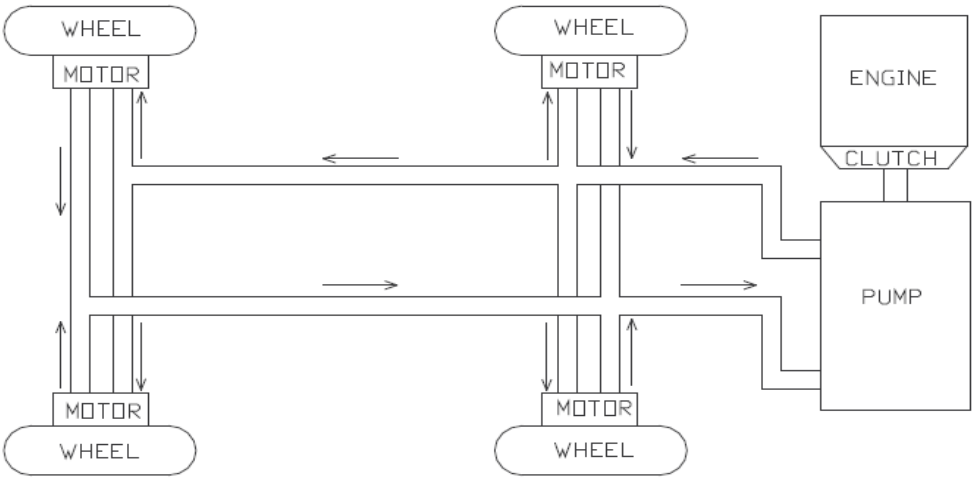
UNIT-V

HYDROSTATICS DRIVE AND ELECTRIC DRIVE

HYDROSTATIC DRIVE

In this type of drives a hydrostatic pump and a motor is used. The engine drives the pump and it generates hydrostatic pressure on the fluid. The pressurized fluid then fed to the motor and the motor drives the wheel. In these transmissions mechanical power is generated in the motor as a result of displacement under hydraulic pressure. The fluid, of course, also carries kinetic energy, but since it leaves the motor at the same velocity as that at which it enters, there is no change in its kinetic-energy content, and kinetic energy plays no part in the transmission of power.

PRINCIPLE OF HYDROSTATIC DRIVE SYSTEM

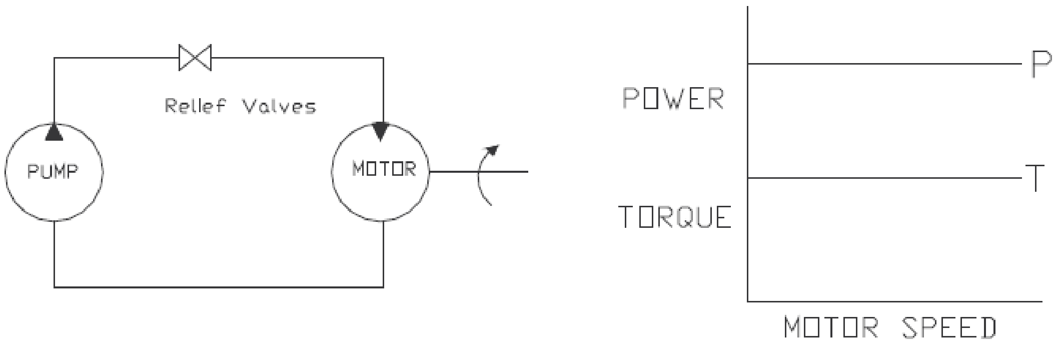


LAYOUT OF HYDROSTATIC DRIVE SYSTEM

It consists of a pump, which converts torque and rotation of mechanical shaft into flow of pressurized fluid combined with a hydraulic motor, which converts fluid flow under pressure into rotating torque on the output shaft. The pump and motor are identical in construction but they may vary in size and displacement, particularly when torque multiplication is needed. By employing variable delivery of hydraulic units, it is possible to obtain a wide range of output ratios.

VARIOUS TYPES OF HYDROSTATIC SYSTEMS

1. CONSTANT DISPLACEMENT PUMP AND CONSTANT DISPLACEMENT MOTOR

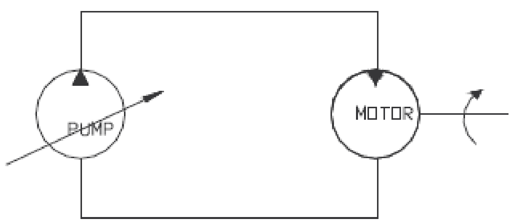


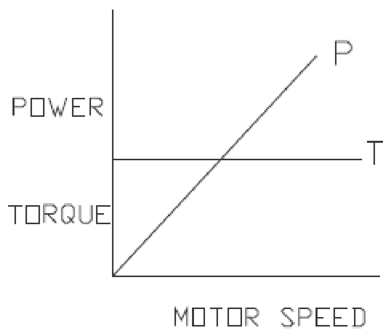
Here both of the pump and motor are constant displacement type. Hence, variation of output torque or speed is not possible. So, this system is not used. This system suffers loss of power due to the provision of intermediate relief valves. Such a transmission is similar to a very flexible mechanical drive shaft except for slight speed loss as load increases due to slip both in the pump and in the motor.

2. VARIABLE DISPLACEMENT PUMP AND CONSTANT DISPLACEMENT MOTOR

With a variable displacement pump and fixed displacement motor, it is possible to obtain variable output speed from motor, which can be smoothly controlled from the designed maximum value to zero. This system provides a constant output torque throughout the speed range.

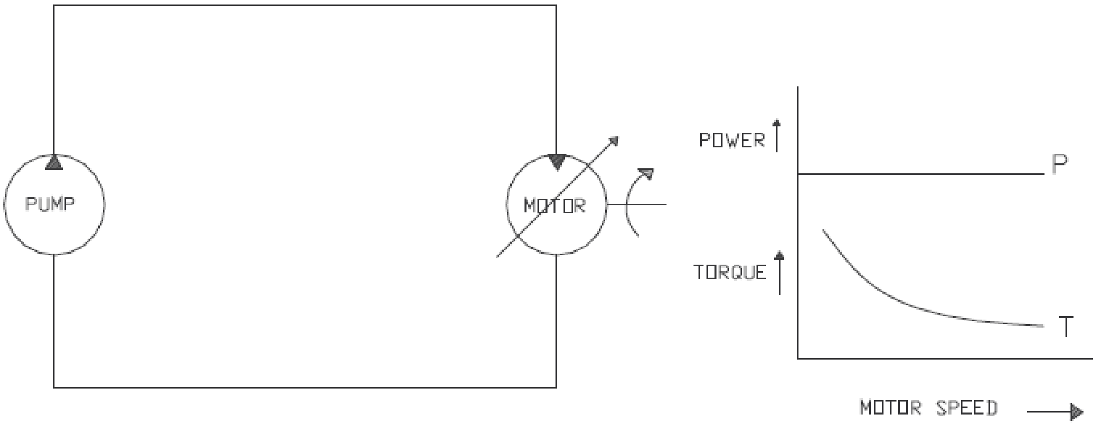
It can be used to drive one or more hydraulic motor, and it gives equal performance in both forward and reverse speeds. Power output varies in direct proportion with output speed. This system can be advantageous in tractors and construction equipments. With the pump at zero output an idling condition is produced which is analogous to a disengaged clutch. The transmission can be reversible without the need for a directional control valve simply by reversing the pump.





Pump displacement in cc	***Motor displacement in cc***	***Speed ratio***
0	**0**	**0**
75	**375**	**5**
375	**375**	**1**

3. CONSTANT DISPLACEMENT PUMP AND VARIABLE DISPLACEMENT MOTOR

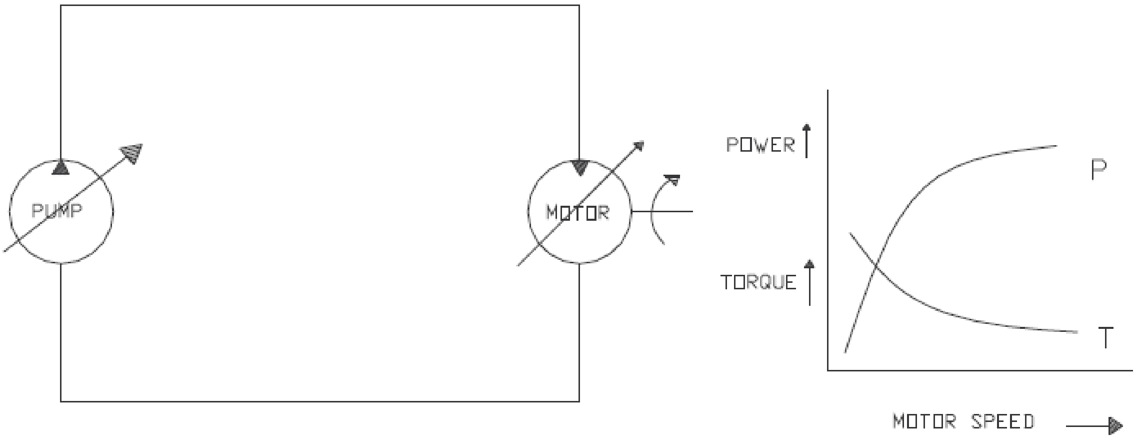


Fixed displacement pump and variable speed motor, capable of giving constant power output, which is independent of output speed. Output torque and speed can be continuously varied. This transmission can be used with advantages along with a governed engine to ensure the application of constant input power to transmission.

Crank radius of pump is fixed. So, displacement 375 cc is governed at maximum BHP level. If power is more important than torque this system is applied in such situations.

4. VARIABLE DISPLACEMENT PUMP AND VARIABLE DISPLACEMENT MOTOR

This combination can give either a constant power or a constant torque drive. A wide range of speed variation may be obtained, the maximum motor speed being with the pump at full output and the motor at minimum displacement per revolution and vice-versa for minimum speed.



The torque capacity is in inverse proportion. Since both are variable type, the torque ratio can be varied widely. When both the pump and motor are of variable displacement type, possibilities of infinite variation of output speed and output torque are available.

ADVANTAGES OF HYDROSTATIC DRIVE

1. Hydrostatic drive eliminates the need for mechanical transmission components like clutch and gearbox as well as allied controls.
2. It provides for smooth and precise control of vehicle speed and travel.
3. This system ensures faster acceleration and deceleration of vehicle
4. It offers better flexibility in vehicle installation because of wide range in choice of pumps and motors of different capacities and of fixed or variable displacement type. Besides hydraulic fluid pipes lines replace mechanical transmission drive line components
5. The ease with which the reverse drive can be obtained makes the hydrostatic drive more attractive. This drive is fully reversible from maximum speed in one direction to zero speed and to maximum speed in the reverse direction.

LIMITATIONS OF HYDROSTATIC DRIVE

1. Noisy in operation
2. Heavier in weight and larger in bulk
3. Costlier when compared to other types of transmission
4. Manufacturing of pump and motor requires high precision machining of components and skilled workmanship
5. In view of high pressure employed in system, the working components are heavier. It also possesses problem of oil leakage through oil seals.

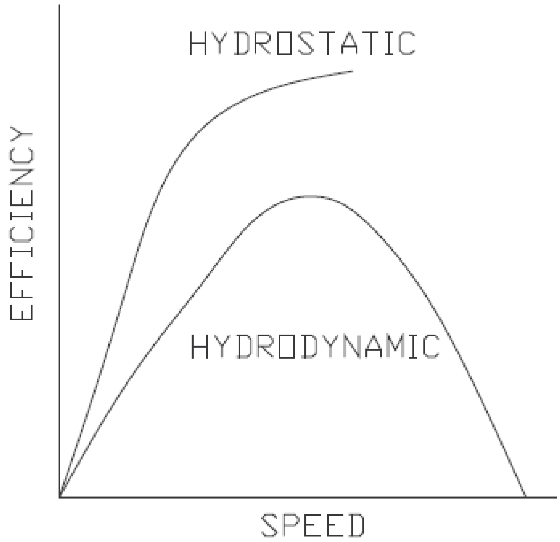
APPLICATIONS OF HYDROSTATIC DRIVE

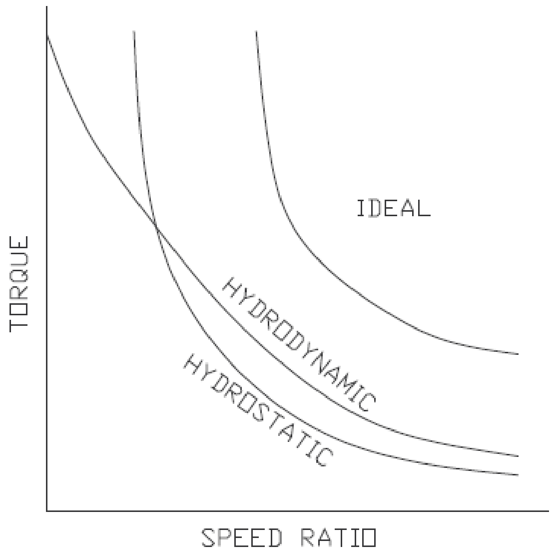
1. It is used to move the machine tools accurately.
2. Used in steering gears of ship.
3. Used in war ships to operate gun turrets.
4. Used in road rollers, tractors, earth movers, heavy duty trucks.

COMPARISON OF HYDROSTATIC DRIVE WITH HYDRODYNAMIC DRIVES

1. Torque ratio is lesser in hydrostatic drives for different speed ratios
2. Hydrostatic offers high efficiency over a wide range of speeds when compared to hydrodynamic drives.
3. Vehicle with hydrostatic drive has no tendency to creep unlike hydrodynamic drive during idling.
4. Dynamic braking of vehicle is an inherent feature of hydrostatic drive. This feature helps to eliminate conventional shoe or disc type of brakes. Creep is caused to drag torque, movement of vehicle during idling

5. Throughout the operating torque range, the vehicle operates at almost constant speed, whether the vehicle is moving uphill or downhill or when the load is suddenly removed.
6. Pressure relief valve as a basic part of any hydrostatic transmission and this provides complete overload protection to the engine as well as hydraulic system.





JANNEY HYDROSTATIC DRIVE

CONSTRUCTION AND WORKING

A hydraulic transmission known as the Janny has long been built by the Waterbury Tool Co. of Waterbury, Conn., for various industrial uses, and it has been applied also to motor trucks, rails and diesel locomotives.

PUMP: Nine cylinders, axially disposed, variable stroke, swash plate type.

MOTOR: Nine cylinders, axially disposed, swash plate type, constant stroke.

A longitudinal section through the whole assembly is shown in figure. Practically the only difference between pump and motor is in former inclination of swash plate is adjustable while in latter it is not. Referring to the drawing Both the pump and the motor unit have central shafts which project at one end only, each shaft is supported by plain bearing in housing and a roller bearing in valve plate. To the inner end of shaft is keyed, a cylinder block in which there are 9 bores forming the working cylinder. The bores are parallel with the axis of rotation and equally spaced around it.

When the cylinder block revolves, cylinder head slide against the valve plate. A port in each of cylinder head registers alternatively with two annular ports in valve plate for admission and delivery of oil, respectively. Each port extends over approximately 125°, and since there is port opening from the time the cylinder port begins to register with the valve plate port to the time it passes out of registry therewith port opening extends over nearly 180°.

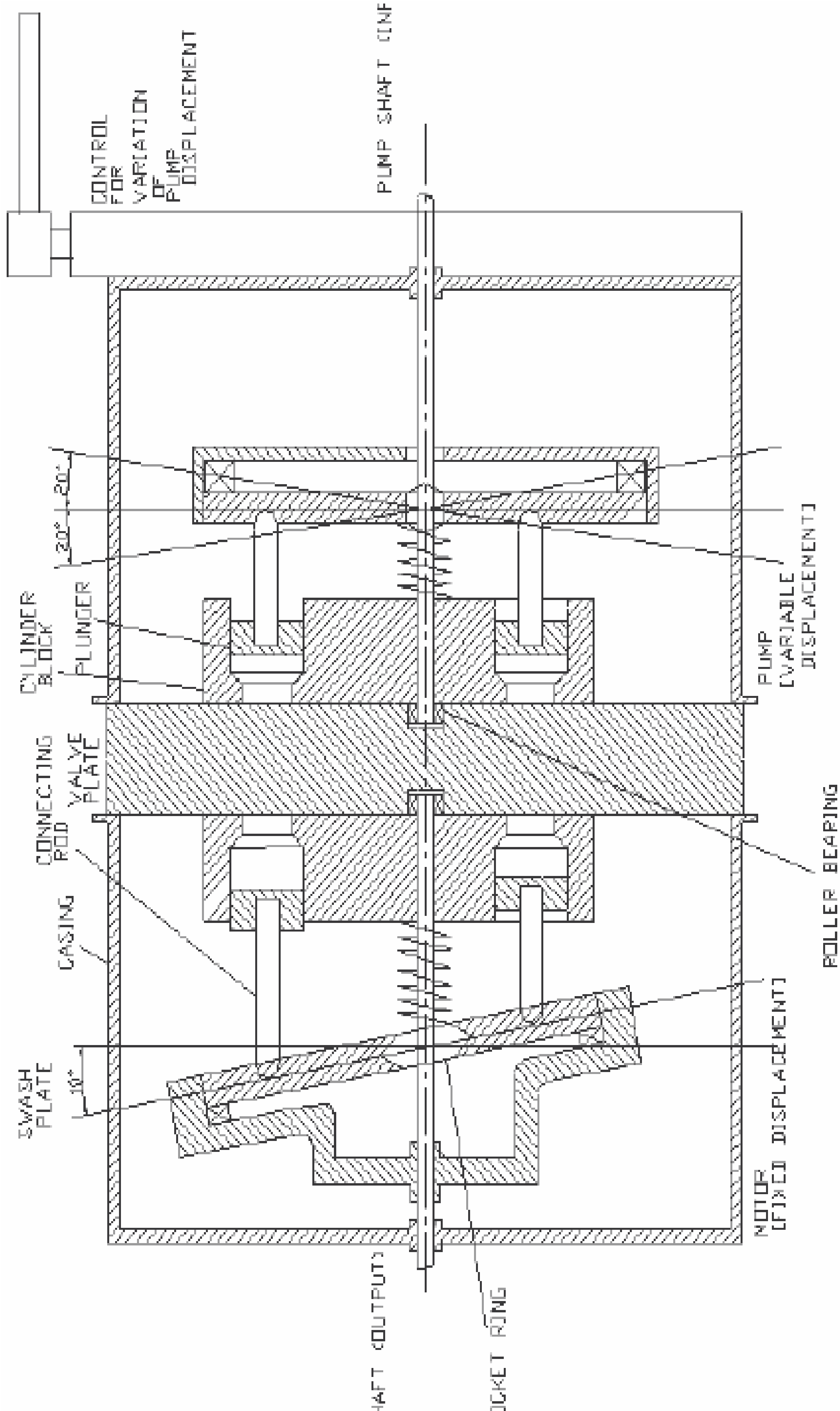
The spring surrounding the shaft, serve to press the cylinder block against valve plate when no load is transmitted. During transmission of power, the fluid pressure keeps all parts in close contact. The cylinder block is so mounted on the shaft that it can slide thereon, and also it can rock slightly. This enables the block to seat correctly on valve plate even if there should be slight misalignment, or if wear should have occurred.

The plunger is lapped into bores to a clearance of 0.001". Each plunger is connected to socket ring by a connecting rod with spherical heads. The rods have drill holes extending through their shanks, and there is a small drill hole also in the head of the piston, hence the bearings of the connecting rod are lubricated with the oil in the power transmission circuit, and the pressure under which lubricant is supplied to the bearing surfaces is proportional to the load.

Each socket ring is connected to shaft by means of universal joint, so that while it revolves with the shaft, its plane of rotation may bear any angle with the axis of the shaft. In case of pump unit, angle of socket ring can be varied between 0deg and 20deg in either direction by means of control lever connected to roller bearing tilting box. In motor unit, the angle box is secured to housing and has a fixed inclination of 20deg.

PUMP

If the angle box is set of right angles to the shaft, there will be no reciprocation of plungers in cylinder when cylinder block is revolving, and, consequently, no oil will be moved. When the angle box is set to make an angle with the shaft, the plungers begins to reciprocate in the cylinders as they revolve around with the block. Each cylinder draws oil through the port in valve plate during one half of the revolution and delivers oil through delivering port in valve plate during next half of revolution.


CONTROL FOR VARIATION OF PUMP DISPLACEMENT
PUMP SHAFT (INF
20°
20°
CYLINDER BLOCK
PLUNGER
PUMP (VARIABLE DISPLACEMENT)
CONNECTING ROD
VALVE PLATE
ROLLER BEARING
CASING
SWASH PLATE
10°
MOTOR (FIXED DISPLACEMENT)
HAFT (OUTPUT)
OCKET RING

MOTOR

The motor unit is merely an inversion of the principle of the pump unit, oil entering the cylinder under pressure forcing the plunger outward and the reaction between socket ring and swash plate causing cylinder block and its shaft to revolve. If the angle plate of pump unit is set to the same angle as that of motor unit, then the motor will turn the same speed as pump unit and any speed lower than this can be obtained on motor shaft by merely reducing the angularity of auto angle box.

HYDROSTATIC TRANSMISSION

INTRODUCTION

Hydrostatic transmissions are hydraulic systems specifically designed to have a pump to drive a hydraulic motor. Thus, a hydrostatic transmission simply transforms mechanical power into fluid power and then reconverts the fluid power back into shaft power. The advantages of hydrostatic transmissions include power transmission to remote areas, infinitely variable speed control, self-overload protection, reverse rotation capability, dynamic braking, and a high horsepower-to-weight ratio. They are used in applications where lifting, lowering, opening, closing, and indexing are required. Specific applications include materials handling equipment, farm tractors, railway locomotives, buses, automobiles, and machine tools.

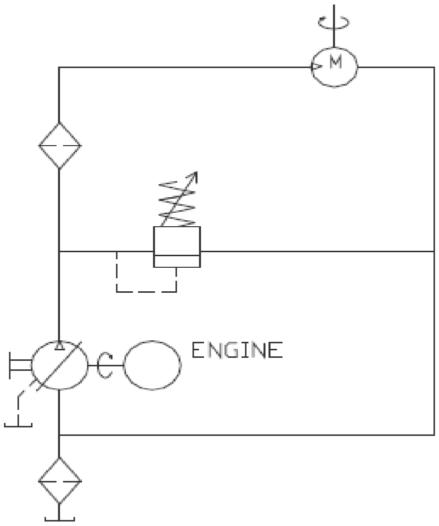
A system consists of a hydraulic motor, and appropriate valves and pipes can be used to provide adjustable-speed drives for many practical applications. Such a system is called a "Hydrostatic Transmission." There must, of course, be a prime mover such as an electric motor or gasoline engine. Applications in existence include tractors, rollers, front-end loaders, hoes, and lift trucks. Some of the advantages of hydrostatic transmissions are the following:

1. Infinitely variable speed and torque in direction and over the full speed and torque ranges.
2. Extremely high horsepower-to-weight ratio.
3. Ability to be stalled without damage.
4. Low inertia of rotating members permits fast starting and stopping with smoothness and precision.
5. Flexibility and simplicity of design.

The internal features of a variable displacement piston pump and affixed piston motor used in a heavy–duty hydrostatic transmission. Both pump and motor are of the swash plate in-line piston design. This type of hydrostatic transmission is expressly designed for application in the agricultural, construction, materials-handling, garden tractor, recreational vehicle and industrial markets.

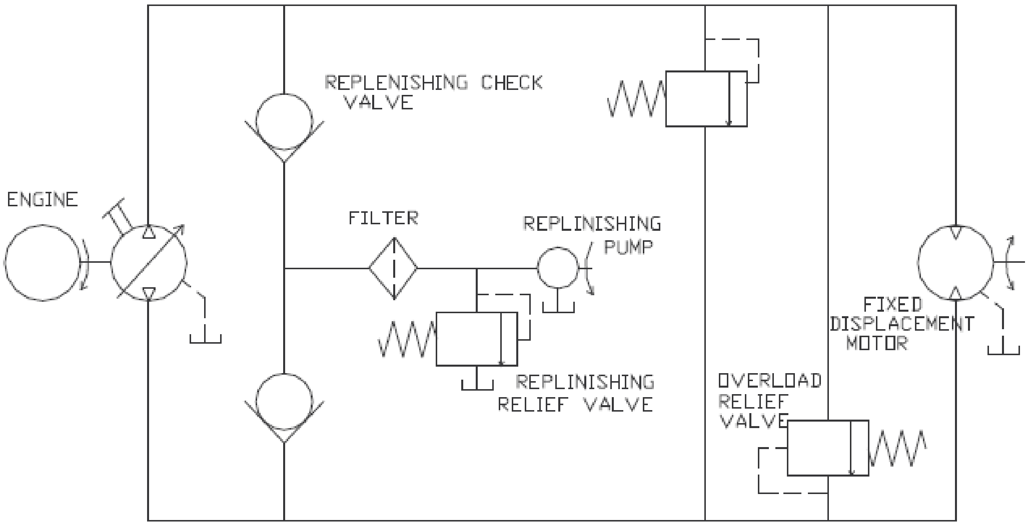
The operator has complete control of the system, with one lever for starting, forward motion, or reserve motion. Control of the variable displacement pump is the key to controlling the vehicles. Prime mover horse power is transmitted to the pump. When the operator moves the control lever, the swash plate in the pump is tilted from neutral. When the pump swash plate is tilted, a positive stroke of the pistons occurs. This, in turn, at any given input speed, produces a certain flow from the pump. This flow is transferred through high pressure lines to the motor. The ratio of the volume of flow from the pump to the displacement of the motor determines the speed at which the motor will run. Moving the control lever to the opposite side of neutral causes the flow through the pump to reverse its direction. This reverses the direction of rotation of the motor. Speed of the output shaft is controlled by adjusting the displacement (flow) of the pump.

Load (working Pressure) is determined by the external condition (grade, ground conditions, etc.), and this establishes the demand on the system. The shutoff valve is included to facilitate a filter change without a large loss of fluid from the reservoir. The heat exchange ensures that the maximum continuous oil temperature will not exceed 180°F.



OPEN TYPE ONE WAY HYDROSTATIC TRANSMISSION

There are two types of hydrostatic transmission system. They are closed and open circuit drives. In open circuit drive the pump draws its fluid from the reservoir. Its output is then directed to a hydraulic motor and discharge from the motor back into the reservoir. In a closed circuit drive, exhaust oil from the motor is returned directly to the pump inlet. The figure gives a circuit of a closed circuit drive that allows foe only one direction of motor rotation. The motor speed is varied by changing the pump displacement. The torque capacity of the motor can be adjusted by the pressure setting of the relief valve. Makeup oil to replenish leakage from the closed loop flows into the low-pressure side of the circuit through a line from the reservoir.



CLOSED TYPE REVERSIBLE HYDROSTATIC TRANSMISSION

Many hydrostatic transmissions are reversible closed circuit drives that use a variable displacement reversible pump. This allows the motor to be driven in either direction and at infinitely variable speeds depending on the position of the pump displacement control. The Figure shows circuit of such a system using a fixed displacement hydraulic motor. Internal leakage losses are made up by a replenishing pump, which keeps a positive pressure on the low-pressure side of the system. There are two check and two relief valves to accommodate the two directions of flow and motor rotation.

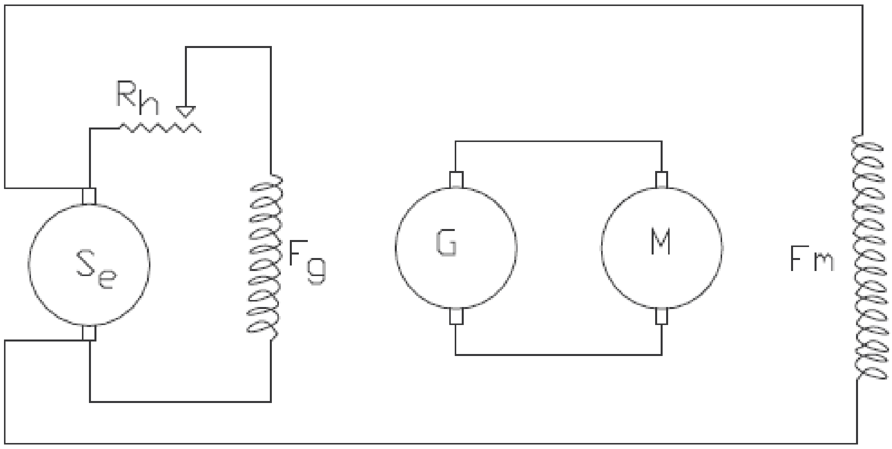
ELECTRIC DRIVE

Electric drive equipment for transportation units consists of a generator driven by the prime mover, a motor or motors in direct connection with the driving wheels of the unit and supplied with current from the generator and the necessary control apparatus. In locomotives the generator is separately excited, as a rule, and the equipment then includes a small additional generator, the exciter.

PRINCIPLE OF ELECTRIC TORQUE CONVERSION

With electric drive, speed control of the vehicle can be done either electrically or by varying the speed of prime mover. In the first the engine and direct connected generator operate at constant speed under the control of a governor. This system was in favor during pioneer days, when gasoline engines had very little flexibility. The other system, in which practically all speed control of the vehicle is effected by means of the engine throttle or fuel control rack was used exclusively during the later days of bus electric drive.

EARLY WARD LEONARD CONTROL SYSTEM



An early method of obtaining a variable speed drive electrically from a constant speed prime mover is known as the Ward Leonard system. It comprises a generator whose field current is obtained from a separate exciter. Generator terminals are directly connected to the terminals of the motor, whose field is also separately excited, from the same source as the generator field. But whereas the field of the motor is at all times excited to the point of saturation, the field current of the generator is controlled by means of a rheostat.

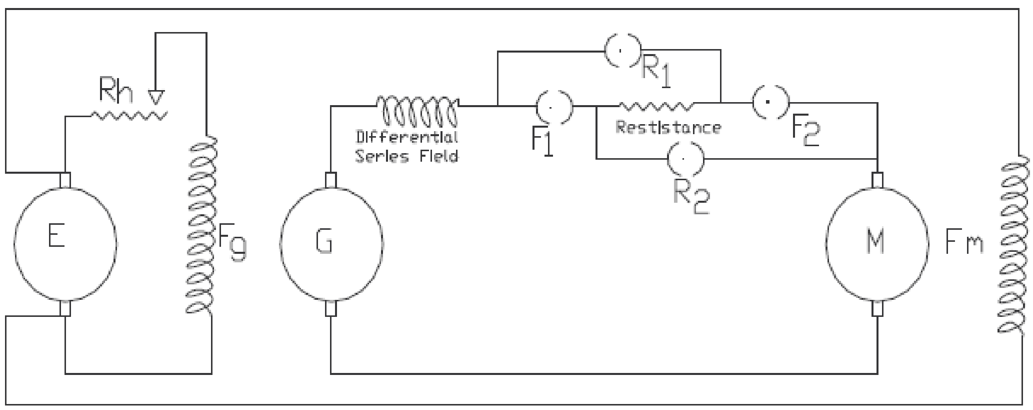
With the generator driven at constant speed, its voltage and output will vary with the field strength, which in turn varies with the exciting current, and with the motor field maintained at constant strength by the exciter, the speed of the motor will vary almost in direct proportion to the generator voltage, and the motor torque in direct proportion to the current passing from the generator to the motor. With this system, the reversal of drive is effected by reversing the direction of current flow through the generator field.

MODIFIED WARD LEONARD CONTROL SYSTEM

For application in the traction or transportation field, certain modifications have been made in the original Ward Leonard system. In the first place, the field polarity of the generator is not changed, and reverse is achieved by reversing the direction of current flow through the field coils of the motor.

The motor moreover is a series motor, as generally employed for traction purposes. Generator speed being constant, the torque load on the engine varies with the excitation of the generator field and the current output of the generator.

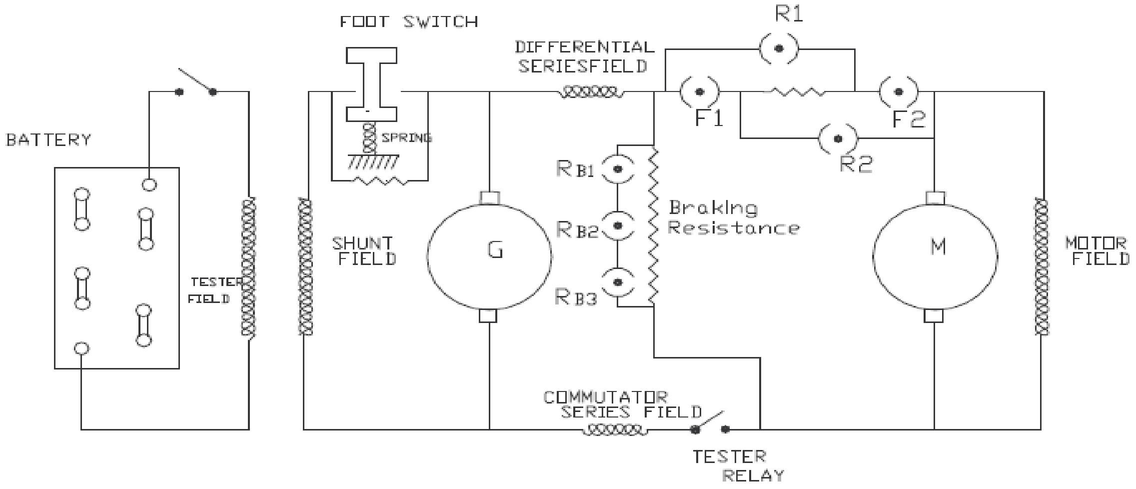
In some cases, the separately excited field coil is supplemented by a differential series field coil, that is, a coil through which the main current from the generator flows, but in such a direction that it tends to demagnetize the filed. This differential series field is so proportioned with the engine running at its normal speed, and the throttle wide open, the generator supplies its full load current at the normal emf to the motor.



Vehicle speed can be controlled manually by means of a rheostat in the exciter circuit, and the differential series field automatically takes care of any change in traction resistance. For instance, if the vehicle encounters a grade, it will slow down, and so will the motor, which is geared to it directly. An increased current then flows from generator to motor, but this increased current, passing through the differential series field coil, weakens the field of the generator, thereby reducing the voltage of the generator and limiting it output. As the generator field is weakened, the engine speeds up, and at higher speeds the engine generates more power, which takes care of the increased load due to the grade.

In the design of such drives, the aim is so to proportion the two source of the field excitation that as the current output of the generator increases in a certain proportion, the generator voltage drops in the inverse proportion, so that the output remains constant. If this object is attained, then the electric drive can absorb the maximum engine power under all driving conditions, if necessary. Engine output and vehicle speed can always be controlled by means of rheostat in generator field.

ELECTRIC DRIVE FOR BUSES



Electric drive systems generally consist of shunt wound generators and series wound motors. However, the generator field may be provided also with a so-called teaser winding, through which current from the car battery flows for a short time, while the engine is being accelerated. A differential series wounding may also be used, but it is generally omitted.

The generators and the motors are always provided with commutating poles, to make possible sparkles commutation. The reason for the teaser winding is that a conventional shunt wounding generator, when speeded up, picks up voltage gradually, and with such a generator there is a tendency for the engine to "race" when the accelerator pedal is depressed.

With the teaser winding, the full voltage of the car battery is applied as soon as the accelerator is depressed beyond the idling position; hence generator field strength and voltage build up rapidly. As the engine gains speed, the teaser circuit is interrupted automatically by a switch actuated by a relay connected across the generator mains.

ADVANTAGES OF ELECTRIC DRIVE

1. In the bus field the electric drive replaced a conventional geared transmission, over which it had certain operating advantages.
2. It afforded continuous acceleration throughout the entire speed range, and the shocks sometimes experienced in a bus with mechanical drive when resuming after a gear change were eliminated. Such shocks were particularly annoying to passengers who had just entered and not yet seated. Passengers, generally, therefore preferred the electric drive.
3. Another advantage was greater ease of operation. In city operation the driver of a bus had to make several thousands gear changes a day, each shift preceded by disengagement of the clutch against a spring pressure of the order of 50 lb. With electric drive there were no such tiring operations, consequently the driver was less fatigued, and accident hazards were said to be reduced.
4. As all of the engine power was absorbed by the generator, which was connected directly to the engine, there was no torque reaction on the frame, and the power plant could have a very flexible mounting, which reduced noise and vibration in the bus.

5. Electric drive also eliminated both the exhaust fumes, which frequently annoyed passengers when a gasoline bus was brought to a stop and the smoky exhaust of the diesel engine when operating at low speed under heavy torque load. The fumes were due to incomplete combustion occurring when the throttle was closed and the engine driven by the vehicle, and diesel exhaust smoke was eliminated or least reduced because with electric drive the engine speed is not reduced in direct proportion to bus speed.

LIMITATIONS OF ELECTRIC DRIVE

1. Excessive weight of the equipment, high production cost, and relatively low efficiency over the greater part of the speed range.
2. With the introduction of hydraulic torque converter drives, which were much lighter, less expensive to produce, and more efficient, electric drive disappeared from bus field.

PERFORMANCE CHARACTERISTICS OF ELECTRIC DRIVE

When the vehicle encounters increased resistance to motion, the motor is pulled down in speed, develops less counter-electromotive force, and draws more current. Since the current can come only from the generator, the output of the latter will be similarly increased. In fact, the current received by the motor is exactly the same as that delivered by the generator, except for the small amount required for the generator shunt field.

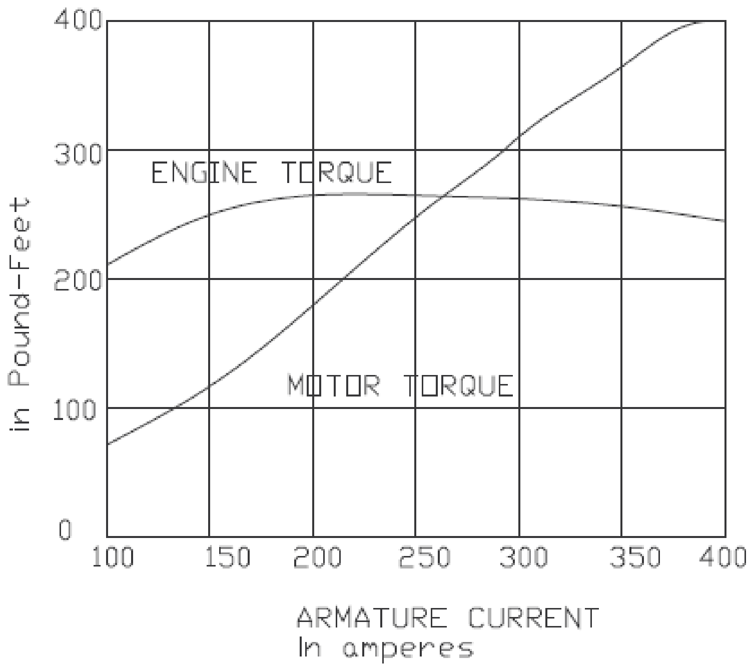
If the field strength were constant, generator voltage would be directly proportional to armature speed, and generator current to torque impressed on the generator armature in excess of that necessary to overcome bearing and brush friction. But the field strength is not constant in either the generator or the motor.

The motor has a series field winding, and if its armature current increases, the current through its field coils increases equally. Therefore, since more torque is proportional to both armature current and strength of magnetic field, it always increases faster than armature current, and a curve of motor torque with respect to current flow is convex toward the current axis over the range of currents corresponding to normal loads.

The exact opposite holds in the case of generator. Field excitation of the generator is derived from the shunt winding connected across the generator means. When the current delivered by the generator increases there is an increase in potential drop in armature windings, and consequently a decrease in terminal voltage and in field excitations due to shunt coils.

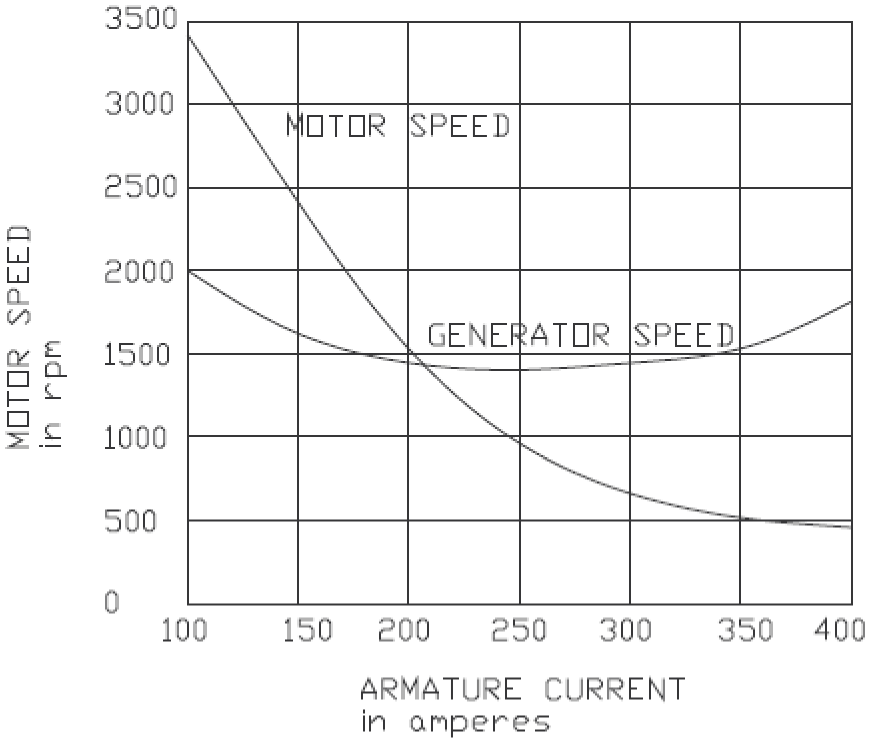
Hence even if the generator speed remained absolutely constant, the field strength would decrease with an increase in armature current. However, with increased torque load on the engine due to the greater armature current, the engine speed will drop, which results in a further decrease in terminal voltage and in field strength.

Thus there is an inherent tendency for the field strength of the generator to decrease with an increase in armature current. The horsepower output of the generator is proportional to the product of voltage and current, and if the generator voltage drops while the current increases, there is a tendency for the engine load to remain constant regardless of rear axle torque. If this tendency is not sufficiently pronounced it can be strengthened by providing the generator with the small reverse series winding which tends to demagnetize the field.



CURVES OF GENERATOR INPUT TORQUE AND MOTOR TORQUE vs. ARMATURE CURRENT

This automatic change in the ratio of torque conversion by the electrical system is well illustrated in figure, which represents torque curves of generator input (engine torque) and of motor output. It will be noticed that with a current flow of 120 amps the generator torque is about 220 lb-ft, and that there is only little variation in the generator torque from this point on, the maximum value being a little more than 250 lb-ft. on the other hand, the motor torque, which is about 85 lb-ft with a current flow of 120 amps, becomes 410 lb-ft with a current flow of 400 amps. Thus at 120 amps, the torque is decreased as it would be with a mechanical overdrive having a ratio of 0.385:1.00, while at 400 amps, when the generator torque is 230 lb-ft, the torque is multiplied the same as with a mechanical reduction gear with a ratio of 1.78:1.00. At 400 amps, therefore, the torque conversion ratio is about 4.6 times as great as at 120 amps.



CURVES OF GENRATOR SPEED AND MOTOR SPEED vs. ARMATURE CURRENT

The variation of the generator and motor speeds with current flow is shown in figure. It will be seen that generator speed is nearly constant over a wide range of current flow, from which it follows that with electric drive the engine runs at nearly constant speed.

Moreover, with both the speed and the torque of the engine output is practically constant under all operating conditions. The motor speed, on the other hand, varies inversely as the motor torque, high motor speed, corresponding to a small current and a low motor torque, and low motor speed to high motor torque.

SEPARATE EXCITATION

When it was first attempted to connect a vehicle motor directly to a generator driven by a combustion engine without having a battery floating on the line, one difficulty that was experienced was that when the driver opened the throttle quickly for a rapid get-away, engine would be momentarily without adequate load and would "race" which not only injurious to its mechanism, but resulted in unpleasant vibration. This difficulty was overcome by providing a certain amount of separate excitation, the current for which, must come from a battery. The teaser current from the battery is kept flowing for a short time only, until the voltage across the generator mains has built up sufficiently, and thereafter the generator is self-excited. Interruption of the teaser current is brought about by a cut-out are teaser relays. If the teaser cut-out is provided with a shunt coil and a series coil, the time the teaser coil continues to carry current depends not only on the rate at which the generator is accelerated, but also on the load it carries.

ELECTRIC BRAKES

When there is no direct mechanical connection between the engine and the driving wheels, the engine cannot be used as a brake. The electric motor, however, lends itself to the same purpose. It can be used either as a mild brake, to prevent the bus from attaining too high a speed in descending grades, or as a severe brake, for emergence. In the first case the motor is merely disconnected form the generator and its circuit is closed through a resistance. The braking power of an engine can be varied by means of the throttle. Ordinarily however, only one step is provided. Emergency braking is effected by connecting the motor to the generator in reverse, with a resistance in circuit. The braking effect then depends on the throttle position, and can be controlled by means of the throttle.