DESIGN STUDY OF AN AUTOMATIC TRANSMISSION GEAR HAVING PLANETARY GEARS

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ABSTRACT

This paper gives a detailed description about the working and the components present in an automatic transmission gear using planetary gears in order to ascertain its operating principle as well as efficiency. The automatic transmission device changes gear ratios automatically, according to the increase or decrease in speed and load of the engine. This ensures that the engine is running at its efficient speed to deliver maximum efficiency. This paper identified the two main types of automatic transmissions; the planetary gear type and the continuously variable type gear which contains mechanical systems, hydraulic systems, electrical systems and computer controls, all working together in perfect harmony.

Keywords: Automatic, transmission, planetary, variable, hydraulic, controls

1 INTRODUCTION

A transmission is a device that is used to provide a set of discrete angular velocity outputs from a constant velocity source. It is connected to the output of the engine and delivers the power from the engine to the drive wheels. The transmission uses gears to make more effective use of the engines torque and to keep the engine operating at an appropriate speed An automobile engine runs at its best efficiency at a certain Revolutions Per Minute (RPM) range and it is the transmission's job to make sure that the power is delivered to the wheels while keeping the engine within that range. It

does this through various gear combinations. In first gear, the engine turns much faster in relation to the drive wheels, while in high gear the engine is loafing even though the car may be travelling at higher speeds. In addition to the various forward gears, a transmission also has a neutral position which disconnects the engine from the drive wheels, and reverse, which causes the drive wheels to turn in the opposite direction allowing to reverse the direction of the car. An automatic transmission is much easier to drive than a manual transmission, because they do not have a clutch pedal or gearshift lever. An automatic transmission does the work all by itself. The first automatic transmission appeared in 1939. Automatic transmissions automatically change to higher and lower gear ratios with changes in the speed of the car and the load on the engine. These transmissions are also aware of how far down the accelerator have been pushed, and shift accordingly.

2 LITERATURE REVIEW

Related study and investigations have been conducted on automatic gear to ascertain the level of performance viz a viz efficiency. Some reserchers have used vibration response analysis method for the analytical analysis of car gearbox system. They performed analytical and experimental analysis of a car transmission system. By using physical properties, they calculated the radiation efficiency, and the vibration response was measured [1]. Alexander [2] presented the implementation of a simplified engine-driveline model to complete an existing vehicle dynamic model. The engine model is based on maps which are expressed as function of engine speed and load. Kei-Lin-kuo [3] studied the dynamic characteristic of the simple transmission gearbox casing with constraint bolt position. Grey cast iron HT200 was used as transmission casing material. The FEM based simulation method was used and the simulation result was verified with experimental results. For experimental analysis the transmission casing was constraint on a hanging base. The excitation was provided using hammer.

3 RESEARCH METHODOLOGY

This research utilized the qualitative research methodology. The instruments used to collect data were internet surfing, sale broachers and observation. Internet surfing and sale broachers were to find the car specs. The qualitative data for this research is come from observation of the gear system.

4 FINDINGS AND DISCUSSIONS

4.1 Design Concept and Analysis

4.1.1 CLASSIFICATION

The Automatic transmissions are mainly classified into two types according to the type of systems used in it. They are classified as

- Automatic transmissions using planetary gears
- Continuously variable transmission(CVT)

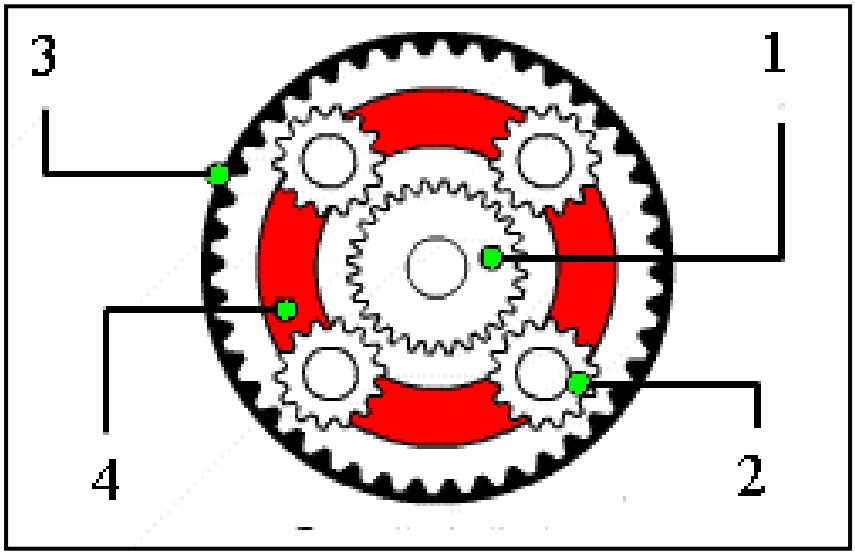
4.1.2 AUTOMATIC TRANSMISSIONS USING PLANETARY GEARS

The modern automatic transmission is one of the most complicated mechanical components in today's automobile. Automatic transmissions contain mechanical systems, hydraulic systems, electrical systems and computer controls, all working together in perfect harmony. This automatic transmission obtains different gear ratios using planetary gears. The main components in these systems are

- **Planetary Gear Sets**
- **Torque Converter**
- **Hydraulic System**
- **Governor**
- **Computer Controls**

4.1.3 PLANETARY GEAR SET

Automatic transmissions contain many gears in various combinations. In a manual transmission, gears slide along shafts as the shift lever is moved from one position to another, engaging various sized gears as required in order to provide the correct gear ratio. In an automatic transmission the gears are never physically moved and are always engaged to the same gears. This is accomplished through the use of planetary gear sets. The basic planetary gear set consists of a sun gear, a ring gear and two or more planet gears, all remaining in constant mesh as shown in Fig.1 The planet gears are connected to each other through a common carrier. The carrier allows the planet gears to spin on shafts called pinions, which are attached to the carrier. Each of these three components can be the input, the output or can be held stationary. Choosing this determines the gear ratio for the gear set



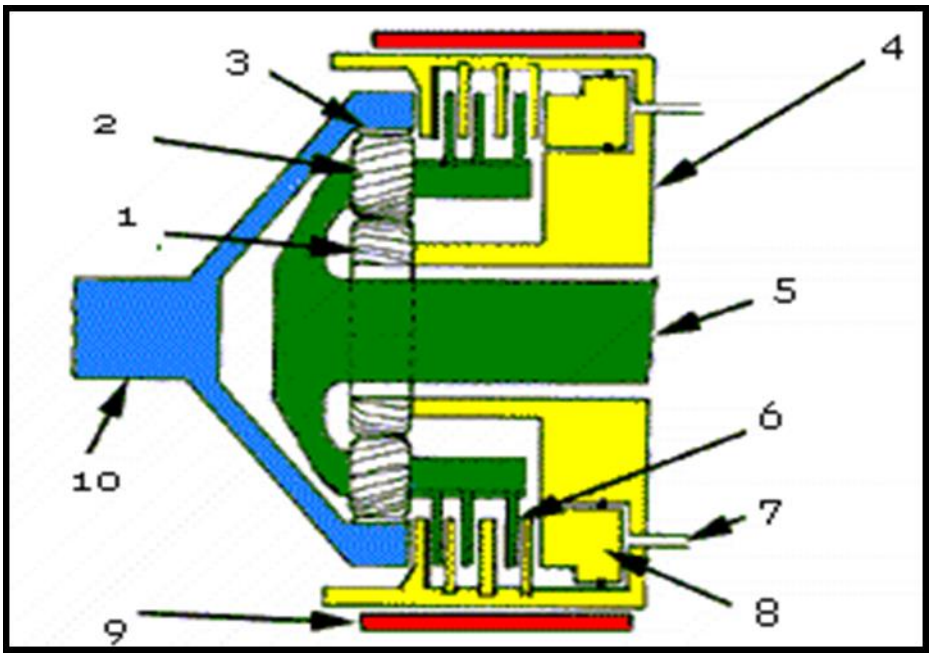
1 sun gear 2 planet gear 3 ring gear

Figure 1 Planetary gear system

One way that this system can be used is by connecting the ring gear to the input shaft coming from the engine, connecting the planet carrier to the output shaft, and locking the sun gear so that it can't move. In this scenario, when the ring gear is turned, the planets will move along the sun gear (which is held stationary). This causes the planet carrier to turn the output shaft in the same direction as the input shaft but at a slower speed causing gear reduction (similar to a car in first gear).

If we unlock the sun gear and lock any two elements together, this will cause all three elements to turn at the same speed so that the output shaft will turn at the same rate of speed as the input shaft. This is like a car that is in third or high gear. Another way that we can use a Planetary gear set is by locking the planet carrier from moving, then applying power to the ring gear which will cause the sun gear to turn in the opposite direction giving reverse gear.

The illustration on Fig.2 shows how the simple system described above would look in an actual transmission. The input shaft is connected to the ring gear. The Output shaft is connected to the planet carrier, which is also connected to a Multi-disk clutch pack. The sun gear is connected to a drum that is also connected to the other half of the clutch pack. Surrounding the outside of the drum is a band that can be tightened around the drum when required to prevent the drum with the attached sun gear from turning. The clutch pack is used, to lock the planet carrier with the sun gear forcing both to turn at the same speed. If both the clutch pack and the band were released, the system would be in neutral. Turning the input shaft would turn the planet gears against the sun gear, but since nothing is holding the sun gear, it will spin free and have no effect on the output shaft.



1. Sun gear 2. Planet gear 3. Ring gear 4. Drum connected to sun gear 5. Output shaft and planet carrier 6.Clutch pack 7. Oil line 8. Clutch piston 9. Band 10. Input shaft

Figure 2 planetary gear system (Side view)

5 WORKING PRINCIPLE

Each member of the planetary gear set can revolve or be held at rest. Power transfer can only take place when one of the members is held at rest or if two of the members are locked. Depending on which member is the driver, which is held, and which is driven, either a torque increase or a speed increase is produced .The different gear ratios are given below.

- **First Gear**. In first gear, the smaller sun gear is driven clockwise by the turbine in the torque converter. The planet carrier tries to spin counterclockwise, but it is held still by the one way clutch (which only allows rotation in the clockwise direction) and the ring gear turns the output (counterclockwise). This results in maximum gear reduction. Here the input speed is high but the output speed is low.

- **Second Gear.** In the second gear the input is the small sun gear; the ring gear is held stationary by the band, and the output is the planet carrier. The planetary carrier is the output in this case. This gives a reduction, but it is smaller than the first gear.

- **Third Gear.** Most automatic transmissions have a 1:1 ratio in third gear. This is obtained by locking any two members together. The planetary gears and the ring gears are held together. This causes everything to spin as a unit, producing a 1:1 ratio.

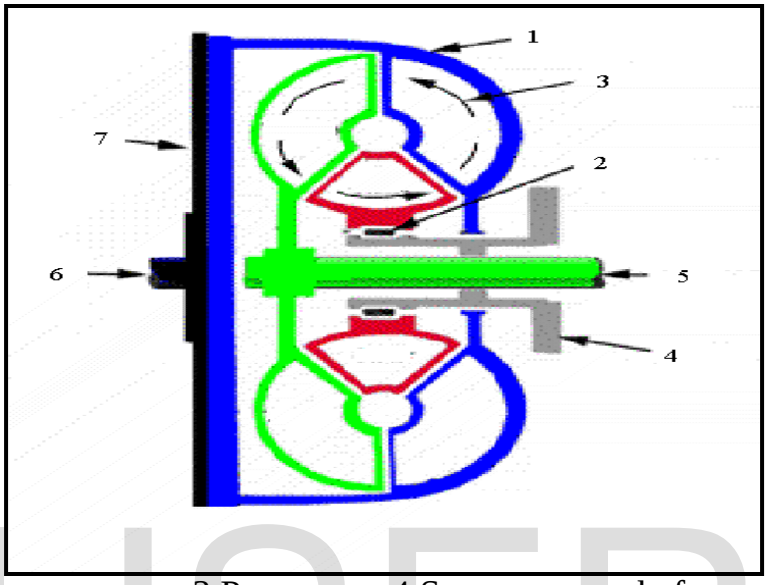
- **Overdrive.** By definition, an overdrive has a faster output speed than input speed. It's a speed increase. This is obtained by holding the ring gear and rotating the planetary gear. Here the sun gear is the output and planetary gear is the input. This results in maximum speed increase.

- **Reverse.** Reverse is very similar to first gear, except that instead of the small sun gear being driven by the torque converter turbine, the sun gear is held, and the carrier rotates the freewheels in the opposite direction. A reverse band holds the planet carrier to the housing .The number of teeth in each gear is selected according to the gear ratios required. Usually the ring gear is of 72 teeth and sun gear is of 30 teeth

5.1 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 the blade is grabbed on the unplugged fan, it does not turn but when it is let free 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 make it more precise.



1. Turbine 2.Stator 3.Pump 4.Stator output shaft 5.Turbine output shaft 6. Housing 7.Flywheel

Figure 3 Torque converter

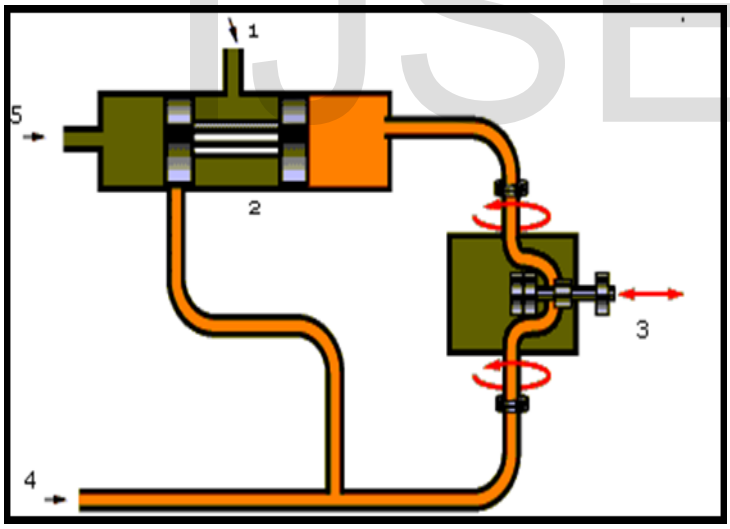
5.2 THE HYDRAULIC SYSTEM

The Hydraulic system is a complex maze of passages and tubes that sends transmission fluid under pressure to all parts of the transmission and torque converter. The newer systems are much more complex and are combined with computerized electrical components. Transmission fluid serves a number of purposes including shift control, general lubrication and transmission cooling.

- **Oil Pump**. The transmission oil pump (not to be confused with the pump element inside the torque converter) is responsible for producing all the oil pressure that is required in the transmission. The oil pump is mounted to the front of the transmission case and is directly connected to a flange on the torque converter housing.

- **Valve Body.** The valve body is the brain of the automatic transmission. It contains a maze of channels and passages that direct hydraulic fluid to the numerous valves which then activate the appropriate clutch pack or band servo to smoothly shift to the appropriate gear for each driving situation. Each of the many valves in the valve body has a specific purpose and is named for that function.

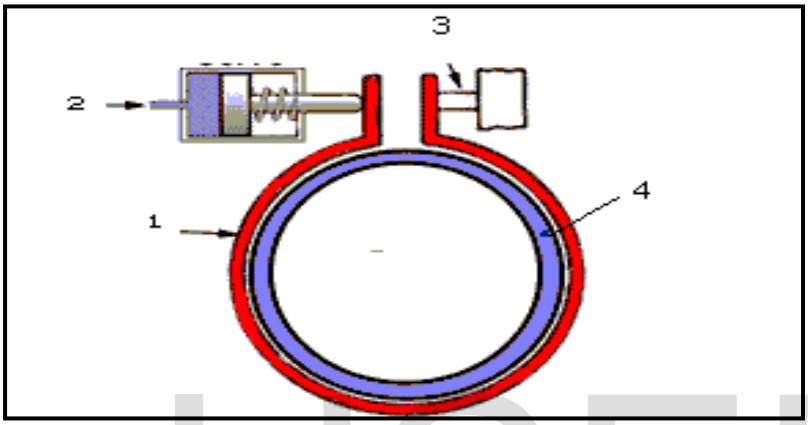
- **Shift valves.** Shift valves supply hydraulic pressure to the clutches and bands to engage each gear. The valve body of the transmission contains several shift valves. The shift valve determines when to shift from one gear to the next. For instance, the 1 to 2 shift valves determines when to shift from first to second gear. The shift valve is pressurized with fluid from the governor on one side, and the throttle valve on the other. They are supplied with fluid by the pump, and they route that fluid to one of two circuits to control, which gear the car, runs in.



1. Fluid to clutches and bands 2.Shift valve 3.Governor 4.Fluid from pump 5.Throttle pressure

Figure 4 The shift circuit

- **Bands**. A band is a steel strap with friction material bonded to the inside surface. One end of the band is anchored against the transmission case while the other end is connected to a servo. At the appropriate time hydraulic oil is sent to the servo under pressure to tighten the band around the drum to stop it from turning.



1 band 2 oil 3 anchor 4 drum

Figure 5 Band

5.3 GOVERNOR

The governor provides the inputs that tell the transmission when to shift. The governor is connected to the output shaft and regulates hydraulic pressure based on vehicle speed. It accomplishes this using centrifugal force to spin a pair of hinged weights against pullback springs. As the weights pull further out against the springs, more oil pressure is allowed past the governor to act on the shift valves that are in the valve body which then Signal the appropriate shifts. Of course, vehicle speed is not the only thing that controls when a transmission should shift, the load that the engine is under is also important. The more load place on the engine, the longer the transmission will hold a gear before shifting to the next one. There are two types of devices that serve the purpose of monitoring the engine load: the Throttle Cable and the Vacuum Modulator.

5.4 CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

The CVT or the Continuous Variable Transmission is an ideal design, it varies the transmission ratio continuously so that it is an automatic transmission with infinite no of gear ratios. As the result, at any time the most suitable ratio can be chosen so that performance and energy efficiency are both optimized.

The CVT can be classified into two main types

- The CVT using belts
- The CVT using Double-Idler Assembly

5.5 CVT USING BELTS

This type of CVT consists of a driving belt running between two pulleys, one connect to the engine output and one to the drive shaft (fig 6). Each pulley comprises of two pieces of disc, with slope surface. When the discs are positioned far away from each other, the belt runs in an orbit with relatively small diameter that is equal to a small gear of a conventional gearbox. When the discs are pushed towards together, the belt is pushed outside and runs in an orbit of large diameter, which equals to a big gear. As a result, pushing or easing the discs can vary the transmission ratio. When one pulley is varied, the other pulley must adapt itself

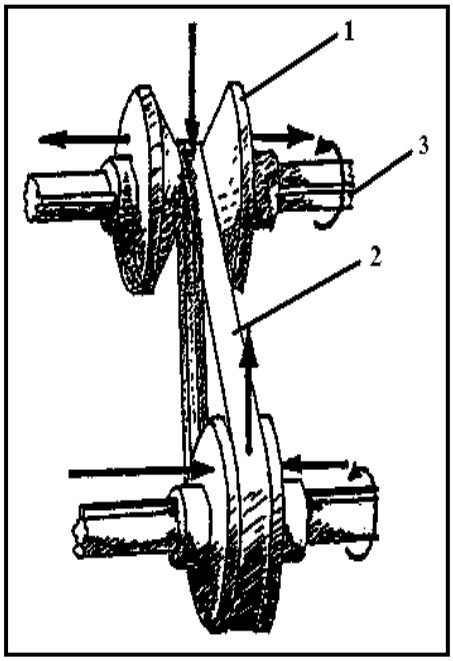


Figure 6 Continuous Variable Transmission

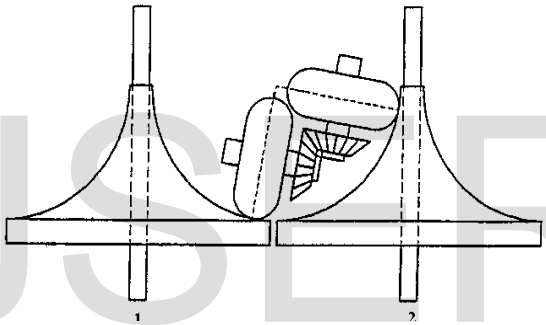
5.6 CVT USING DOUBLE-IDLER ASSEMBLY

CVTs using belts had a problem in delivering the required torque since excessive amounts have caused the belts to fail. To address this problem CVT using double idler is effective which was not based on a belt system. This design is more versatile and safer to use. The double idler consists of two polyurethane rubber wheels positioned at 90 degrees to one another and connected by a pair of mitre gears. This assembly results in a 1:1 angular velocity ratio between the input and output wheels. Depending upon the orientation of this assembly, the aforementioned velocity ratios between the cones may be achieved. To obtain the desired output ratio, the idler is oriented by a speed control mounted on the main housing. This design consists of three components: the torque conversion cones, the double-idler assembly, and the main housing.

- **Torque Conversion Cones**. The concept of the CVT design is based upon two aluminum cones which, when placed together, form a semicircular profile and produce the required angular velocity ratios, due to their varied surface diameter. They are mounted on steel rods and supported by both radial and thrust bearings.

- **double idler.** The double idler consists of two polyurethane rubber wheels positioned at 90 degrees to one another and connected by a pair of mitre gears. This assembly results in a 1:1 angular velocity ratio between the input and output wheels

- **Main housing.** The main housing encases the double idler assembly and torque conversion cones in a small and easily mountable envelope.



1. Output shaft 2.Input shaft

FIGURE 7 DOUBLE IDLER ASSEMBLY

5.6.1 ADVANTAGES

A computerized automatic transmission has different shifting programs for different requirements For instance, if you select Sport mode, the gearbox up shift at higher engine speed to make better use of power band hence enhances acceleration. On the contrary, choosing Economy mode will ease the pressure to the engine, thus enhance smoothness, quietness and save fuel.

5.6.1 DISADVANTAGES

Because it employs a lot of planetary gears and clutches inside, it is considerably heavier and several folds more expensive then manual gearbox.The use of torque

converter instead of clutch makes them less responsive than manual gearbox, moreover, they used to offer one less ratio, thus offer poorer acceleration and consume slightly more fuel.

6. CONCLUSION

This paper investigated the design of an automatic transmission gear using planetary gears and then identified the two main types of automatic transmissions; the planetary gear type and the continuously variable type gear which contains mechanical systems, hydraulic systems, electrical systems and computer controls, all working together in perfect harmony.

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