

New Trend in Modern Vehicle Transmission “A Brief Review of New Transmission Technology”

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ABSTRACT

Vehicle transmission is definitely needed by the vehicle for two reasons. The first is to damp the engine vibration for general drive train system and the second is to manipulate the engine torque that available in limited range of engine rotation from their idle rpm to their upper limit rpm, to meet the torque requirement as a traction force on the wheel that move the vehicle from rest until vehicle maximum speed. The transmission method to satisfy this second requirement is by creating several gear ratios that can change the engine rpm into suitable wheel rpm in certain condition such as in initial move (slow moving) or cruising in the high way (fast moving). However the clutch is needed to control the condition where the vehicle is completely at rest but the engine is stay running and in the other important condition is at transition stage of moving from rest. In new era of modern technology vehicle, transmissions also designed to meet the requirement of lower the fuel consumption and to reduce the vehicle exhaust emission. In this paper will be reviewed the most advanced vehicles transmission that used by modern vehicle now a days.

Keywords: Vehicle Transmission, Automatic Transmission, Double Clutch Transmission, Continuously Variable Transmission.

1. Introduction

Vehicle transmission is definitely needed by the vehicle for two reasons. The first is to damp the engine vibration for general drive train system and the second is to manipulate the engine torque that available in limited range of engine rotation from their idle rpm to their upper limit rpm, to meet the torque requirement as a traction force on the wheel that move the vehicle from rest until vehicle maximum speed. The transmission method to satisfy this second requirement is by creating several gear ratios that can change the engine rpm into suitable wheel rpm in certain condition such as in initial move (slow moving) or cruising in the high way (fast moving). However the clutch is needed to control the condition where the vehicle is completely at rest but the engine is stay running and in the other important condition is at transition stage of moving from rest.

From figure 1.b we can see that curve a, b, c and d are the manipulated engine torque curve by multiplying the engine torque curve by factor that principally deal with by the 1st, 2nd, 3rd or 4th gear ratio available. This

factor is to convert from angular velocity to linear velocity which come from the equation concerning the final drive ratio in differential, dynamic wheel radius which are both of these value are constant and the gear ratio value that depend on the selected gear. The manipulated engine torque curve used here is in condition of max engine load or wide open throttle.

From the same figure we can see also that the engine torque that transferred to the wheel is continuously decreased in higher gear selected as the vehicle speed increase. Area “a” is the area where the clutch system plays a role in transition vehicle condition from rest to move.

Vehicle automatic transmission is commonly called as simply as automatic transmission. However due to many developments of vehicle transmission in recent year, have arising many terminologies used to describe the automatic transmission mechanism, which will briefly clarify in this following paragraph. Automatic transmission terminologies itself nowadays became very specific to describe one from several type of automatic transmission available in the market.



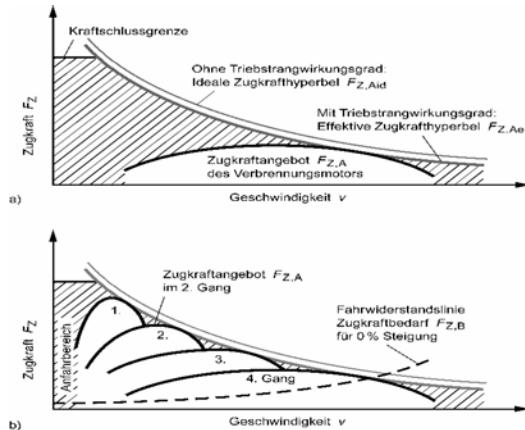


Figure 1. The “Traction Force-Speed” diagram

So called automatic transmission caused by the free of driver act in gear shifting like normally they did on the manual transmission vehicle. Generally the automatic vehicle has only two pedals in the cabin instead of three by removal the need of the clutch pedal.

2. Automatic Transmission (AT)

The main difference between these automatic transmissions with the manual transmission is noticed by the use of torque converters instead of the friction clutch that can guarantee the engine remain running although the vehicle is not in motion. The development of the vehicle automatic transmission results in the general construction of so called automatic transmission (AT) which are mainly using the torque converter and several set of planetary gears, as shown in figure 2.



Figure 2. Automatic transmission (AT) named “7G-Tronik” from Mercedes-Benz

3. Automated Manual Transmission (AMT)

In near recent years there are some developments on the basically manual transmission construction, which are using the friction clutch and several pair of gears, so

it can be operated automatically called automated manual transmission (AMT). This technology of the AMT is coming from the race world, although they are not fully automatic in the actual race, but rather to remove the need of clutch pedal action in gear shifting process.

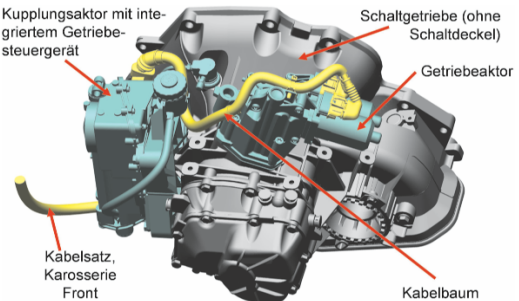


Figure 3. AMT named “easytronic” from General Motor Europe

This AMT technology is well applied to the serial mass vehicle production by implementing the control device so it can be operated fully automatic like regular AT. Thanks to hydraulically controlled actuator mechanisms that conveniently replace the need of driver action in shifting and in declutch or also known as shift by wire, with the additional advantages of the responsive friction clutch action rather than slip phenomena caused by the torque converter. This AMT as shown in figure 3 is look very similar to manual transmission despite the existed control module and automatic actuator mechanism.

4. Dual Clutch Transmission (DCT)

Again from the race world technologies which need to shift the gear extremely fast, there are continues development on the AMT scheme by using two clutch mechanisms which one clutch serve and only connected to the odd gear and the other to the even gear. This idea basically like combining two different gearboxes which is odd gear gearbox and even gear gearbox into a very compact one gearbox construction. This technology is called dual clutch transmission (DCT) as shown in figure 4 below from Volkswagen with its brand name DSG which stand for “Direktschaltgetriebes” in German language mean direct shift transmission.



Figure 4. DCT transmission named DSG from Volkswagen.

The rapid shifting time take place due to the readily available pre-select gear (2/even gear for example) that already connected to the disengage clutch that can rapidly receive torque flow from other engaging clutch (which serve the 1/odd gear for example) that previously engage to the engine when shifting is done. Comparing to the shifting process on AMT, the only one clutch should disengage first, following than by select the next intended gear (of course after off from the previous selected gear) and finished by the engaging the only one clutch again. In simple words there is only one step in DCT gear shifting, which is shift the torque flow from one engaging clutch to the other disengage clutch that already connected to selected gear, but it takes several steps in AMT which are disengage the only one clutch, off from the selected gear, select the new intended gear and finished by engaging the only one clutch again. This is why DCT become popular in high performance car such as Bugatti Veyron which seriously pays attention on shifting speed.

5. Continuously Variable Transmission (CVT)

Apart from AT, AMT and DCT, there is one more vehicle automatic transmission available in the market called continuously variable transmission (CVT) which shown in figure 5 below. This kind of automatic transmission have an enormous different concept in mechanism with the AT, AMT and DCT, by using the belt and pulley construction rather than a several set of gears as a transmission mechanism, although some CVT also use the different construction like using the cone and ring rather than using the belt and pulley as shown in figure 6. This transmission type generally using the torque converter as an engine-transmission coupling device like the automatic transmission (AT) use beside several others also use the friction clutch like CVT named multitronic from Audi.



Figure 5. CVT named “multitronic” from Audi which Installed

in A4 and A6.

The main advantages of this CVT is the free of the transmission gear ratio combination can be managed and that is why the terminology of “continuously” used, to express the ability of this transmission to manage several gear ratio without necessarily exact gear ratio combination selected or infinitely variable transmission ratios can be employed between established minimum and maximum rotation ratio, the CVT also known as step less automatic transmission due to this phenomenon. This kind of transmission produce new challenge to the control engineering to design the appropriate transmission ratio that can satisfy the fuel consumption and drive ability over commonly fix gear ratio transmission or so called the discrete-ratio transmission. Some methodology to answer this challenge is developing in [71]. Nevertheless CVT is not covered in this report concerning the research area of the Institute is not including this type of vehicle automatic transmission.

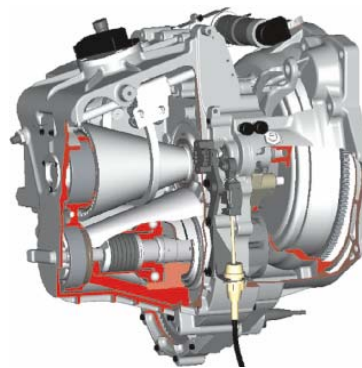


Figure 6. Cone-ring CVT transmission.

Like other relatively new automatic transmission, most of CVT available on market also provide by manually shift operated option to meet some of enthusiast driver wants.

6. Automatic Transmission Shifting

Shifting in automatic transmission is controlled by Transmission Control Unit (TCU) concerning several parameters input. Those inputs will be calculated and noticed by the TCU as a control parameter to decide when the gear shifting taking place and how.



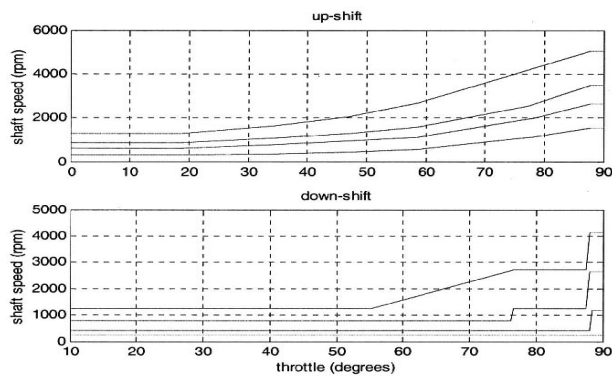


Figure 7. Gear shifting map of automatic transmission.

Generally TCU programmed for gear shifting based on shift map concerning to the vehicle speed and the throttle open position as engine load as shown in figure 7 above. It is shown that up-shift have different mode with down-shift and special shifting treatment also exist in the way of kick-down or step the gas throttle pedal flat against the cabin floor. Several shift strategy are also programmed by the vehicle manufacturer in example is in downhill or uphill condition.

7. Control System

To improve the fuel efficiency, shift quality and vehicle reliability, modern automatic transmissions are using the electronic control called Transmission Control Unit (TCU). This TCU control the automatic transmission by energizing several combination of solenoid valve that regulate the hydraulic pressure to actuate the clutch/brake that hold the gear rest or allow it free to rotate.

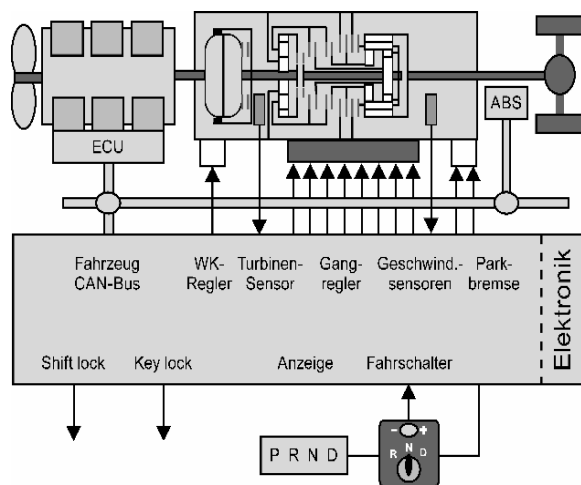


Figure 8. Scheme of electronic control in modern vehicle.

The AT control system receive several input parameter from vehicle general system which are engine torque, throttle position, engine rpm, transmission input and output rpm, vehicle speed, transmission oil temperature and several others to control which gear ratio will be automatically select by TCU.

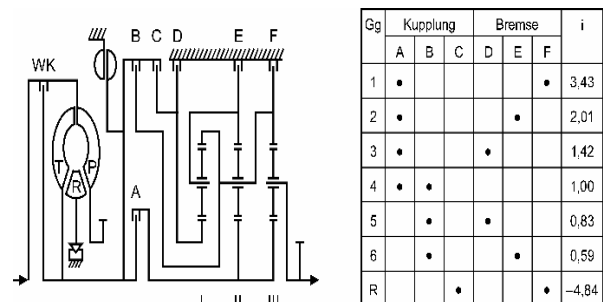
All general input parameter data are sending by sensors to Control Area Network (CAN) that will be assessed by Engine Control Unit (ECU) or TCU to get the information. This CAN also transmit control instruction to the equipment.

8. Shifting Process

The gear shift process basically is a changing condition from several clutches/brakes from engage to disengage or in opposite fashion, in controlling the gear component of the planetary gear set to produce different gear ratio.

It is very depend on the design of the automatic transmission in producing several gear ratios, but normally there are two types of automatic transmission concerning the way to produce different gear ratio, which are "single transition shift" or "double transition shift". In single transition shift there is one pair of clutch/brake that while one clutch/brake changing their state from disengage to engage, the other clutch/brake changing from engage to disengage. On the other type, there are two pairs of clutch/brake which changing their state in shifting process. It is called transition due to the condition from stick to slip before it is completely free, or in the opposite fashion, from free condition to slip before it is completely stick or engage.

To ensure the good shifting process, the changing state of clutch/brake of both types (single and double transition shift) is occurred simultaneously in one time duration. So it can be said that for the single transition shift type for the example, while one clutch/brake is engaging, the other is disengaging simultaneously in the same transition time period. This condition also occurred in double transition shift type.



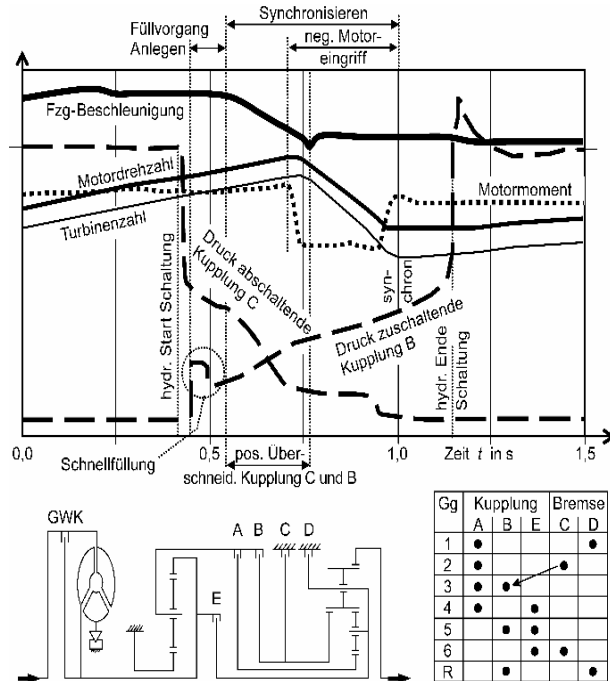


Figure 9. Work characteristic of "Automatic Transmission".

The transition period actually consist of two conditions which are torque phase and inertia phase for both engaging and disengaging clutch/brake. But the real condition is quite different between engaging and disengaging clutch/brake as shown in figure 9. In the simple words, the torque phase is the condition which engine torque still influencing the disengaging clutch/brake or on the other hand, engine torque starts to influence the engaging clutch/brake. Meanwhile the inertia phase is the second transition condition where inertia of each elements are still influencing in sliding clutch/brake before it is completely stick in the engaging clutch/brake or completely free for the disengaging clutch/brake. The different fashion as shown in figure 9 for engaging and disengaging clutch/brake occurs due to the different characteristic of build up pressure in engaging clutch/brake with pressure loss in disengaging clutch/brake beside the friction phenomena that also different for engaging or disengaging clutch/brake. This transition period actually plays important role in automatic transmission shift quality.

Due to the different fashion between engaging and disengaging clutch/brake produce the interruption or superposition between them. To satisfy the process, engine torque should be reduced in torque phase. Several researches concerning the shift characteristic as a system model have been made, as in [30], [31], [32], [79] for single transition shift and in [83], [97] for double transition shift.

9. Shift Quality

Shift process denoted as optimal if this process is felt comfort by the driver and passenger. There are two parameters in evaluate the shift quality which are the stability and rapidity. Stability mean that the jerk occurred in shifting process is low and rapidity means that the transition period is short thus this process is greatly influenced by the transition phase.

However these two parameters are contradictive one to another. To achieve high stability, the transition period should be longer that will decrease the rapidity beside also will produce large friction that can damage to the clutch/brake friction components. On the other hand, high rapidity will introduce large impact and high jerk.

There are several strategy applied to reach optimum shift quality. One of the strategy is by control the engine torque lower during torque phase as mentioned earlier beside the other strategy is by improving the shifting calibration process concerning the automatic transmission control system. Many research mainly in control area have been done for improve the shift quality like in [12], [22], [26], [45], [52], [78] and [86]. The researches that mentioned in chapter 3.2 mostly are also motivated to improve the shift quality.

Other vehicle comfort are further assessed using the human body model in response the vibration occurs in vehicle are also done in [60] and more related to the shift comfort also assessed by human neck model in which is reaction in [58].

10. Shift Strategy

Shift strategy is more related to the general behavior of the automatic transmission in vehicle operation or in their drivability. This theme is quiet challenging due to the duplicating of the human behavior in general in driving the vehicle. Shift strategy is more focusing on when the gear shifting taking place rather than how is the gear shifting that mainly discuss in shift quality in comfort.

The strategy including in the several road condition like uphill, downhill, combination on climbing and descending road, bend/turning road. On past era of automatic transmission many drivers are frustrated by the transmission behavior in always changing the gear reacting to the input parameter received by the system. Thanks to many research that have been done to upgrades the system intelligent like in [17], [64], [74] and [91] which are mostly using the Fuzzy logic approach to program the TCU result to the smart automatic transmission that even easier to use. The system now can match the inferred intentions of the driver under certain above mentioned road conditions. The fuzzy logic program also used to predict the road conditions from sensor outputs on vehicle acceleration



and the throttle opening angle.

However, to satisfy many enthusiast drivers that vary in judgment and behavior, some modern automatic transmission offer the manual gear shift operating option beside the fully automatic gear shift operation. This is because no matter how smart the system is, there is still some lack of several judge input parameter compare to the human which using their ability in see, hear and feel before taking a decision in gear shifting.

11. Summary

Transmission is absolutely needed by the vehicle to manipulate the available engine torque in certain rpm range to the torque needed by the vehicle as a traction force in the vehicle wheel. This requirement however accomplish by employing several gear ratio available in the transmission system. The other use of the transmission is also as an engine vibration damper in the vehicle drive train system.

To make the vehicle become easier to drive, some vehicles manufacture offering the automatic transmission in their product to the market next to the well-established and with economic selling price the manual transmission.

In the recent years have recorded that the selling of automatic transmission car has continually increased, thanks to improved automatic transmission that become more and more intelligent today beside also more automatic transmission type available to choose in the market that meet some specific market demand such as the high fuel efficiency or sport character.

There is several kind of automatic transmission available in the markets today which are AT, AMT, DCT and CVT. Each of it has their own advantages beside also their disadvantages. AT are relatively the oldest type of automatic transmission that became quit established in their development and now are even available in 8 speed. AMT and DCT are relatively new development of the very established manual transmission structure with intelligent control and efficient actuator. The unique step less CVT automatic transmission also offers the superb ability in managing the transmission ratio to meet highest possible fuel efficiency as well as to the sport performance and become more popular in certain country.

Above all there are two automatic transmission characters that evaluate mainly by the customers. First is when the gear shift occurs in what road condition, which is related to the shift strategy and the second is how the gear shift occurs that greatly related to the shift comfort.

Many research and improvement have been developed to the transmission control system as a control program, the control actuator device and transmission mechanism to improve the quality in all area as mentioned in previous chapter. Related

researches such as the use of Fuzzy logic in control program, system modeling to study the transmission behavior, evaluating of the shift quality, all are to produce better shift strategy and quality.

It is not impossible that the automatic transmission vehicle will available in more and more economical price in the near future concerning to the better fuel efficiency offered and more market demand.

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