FEATURES OF HYBRID ELECTRIC VEHICLE (HEV) TRANSMISSION

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Abstract: The transmissions of HEVs or so-called hybrid transmissions (HT) are essentially power split transmissions, which almost always require planetary gears to split or sum up power. An essential prerequisite for reading and studying hybrid transmissions is the knowledge of planetary gear function and calculation. For example, the Toyota hybrid system can only be clarified using the principles of the planetary mechanism. In addition to Toyota’s decision, there are two modes of transmission (BMW, Daimler and GM) and many patent applications with similar ideas.

Technically speaking, these solutions are power split transmissions that turn into a hybrid system by adding an electric motor (EM), a generator (G) and an electric storage battery (SB). These transmissions perform the functions required for vehicles with an internal combustion engine, such as the HEV.

These functions are launching, torque and speed conversion, reverse gear, and rapid gear-shifts in ascending or descending order. In addition, the requirements for HT are realized with the help of electronic control. For parallel HEV, a conventional gearbox plus EM is used. The automatic transmissions used in the mixed HEVs are designed with planetary gearboxes and are also known as automatic HTs. This article discusses the features of planetary gearboxes used in HEVs transmissions.

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Introduction
Almost all today’s automatic transmissions use planetary gears for torque conversion. Depending on the switching device of individual planetary gears, both multi-disc brakes and multi-disc clutches [1,2,3,4] are used.

There is another application for planetary gearboxes, suitable for distribution of the power flow in HEV. Here, the possibility of torque distribution and, in the case of HEV speed control, is used in two branches - the internal combustion engine (ICE) and the electric motor/generator (MG).

This allows to improve the efficiency of transmission components, which may be mechanical, hydrostatic, hydrodynamic or electrical. Such systems are increasingly being used today. Thus, this application can be found in hybrid drives and stepless hydrostatic gearboxes. Planetary gearboxes are flexible and suitable, especially for power transmission gearboxes, because in this case they are a central component.

Features of an 8-speed gearbox for a hybrid electric vehicle

In order to better understand the characteristics of the HEV gearboxes, the example of the 8-speed automatic transmission ZF (Zahnradfabrik Friedrichshafen) [1,5] was used. This product can be fitted as a “classic automatic transmission” (8 hp) as well as a hybrid solution (8P). Several combinations can be selected. Figure 1 shows an embodiment as a hybrid transmission.

Fig. 1. Hybrid transmission box 8p70h from ZF [1]

With four planar rows and five friction elements, eight forward gears and one rear gear are formed. This new structure is developed using computer programs that create and compare all possible connectivity options. Appropriate criteria, such as speed and torque adjustments, determine variants for gear shifting.

A very large number of bindings must be examined, so only with powerful computer systems. Top software products such as CATIA V5, which is a leading product for almost all industrial enterprises [6], and the high-end PTC Creo software development software [9] apply. This includes design offices performing specialized activities such as tolerance analysis, specialized strength calculations and so on. [7]. Strong analysis and assessment of the load and the dangerous sections and sections is a final stage and a verification of the design results [8].

This gear box is a base for a series of power ranging from 140-300 kW and inputs from 300-1000 Nm with four planned dimensions. The design of automatic transmissions for HEV depends on the drive structure. In these cases, the hydrodynamic torque transformer is no longer needed and in this transmission the multi-disc oil trough clutch is offered as a source element in a neutral way. It is also possible to install an MG to start the ICE and also transmit power at parallel HEV between the ICE and the mechanical transmission. The all-wheel drive variant is part of the scope of the program in these transmissions, as the share of all-wheel drive vehicles is growing among the more powerful HEVs.

Figure 2 shows a sectional view of this gearbox with all indications. The brakes A and B, the clutches C, D and E and the planet rows 1 to 4 are respectively indicated. Instead of the hydrodynamic component, it is possible to integrate a multi-disc clutch into an oil tank or, in a hybrid construction, to place the MG in the existing installation space. This has the advantage that the manufacturer has virtually no installation problems, as the hybrid version is almost identical to the standard transmission.

Fig.2. A section of the 8-speed automatic transmission for HEV [1]
Transmission technology requires an additional electric oil pump. It is located parallel to the oil pump with mechanical drive. The reason is that MG generates HEV zero torque (idle) and the transmission has to drive the corresponding shifting gears. This is advantageous for increasing the moment when starting in MG mode.

The scheme of this automatic gearbox is shown in Figure 3.

Using the scheme according to FIG. 3, a Wolf diagram is produced (Fig. 4) and the number of teeth is entered.

The first gear (Fig. 5) is almost classic with the brakes A and B and clutch C. The sun wheel on the fourth row is connected to the clutch C. The advantage of this switching is about 2.5 times less torque input the transmission for the brake B at a total gear ratio of 4.7.

The second gear is also formed by the brakes A and B, now the clutch E is engaged and the ring wheel of the second row is connected to the sun wheel the fourth row (Fig. 6).

In the third gear, brake A is off and clutch C is on. This leads to a connecting shaft between the two sun wheels on the 1st and 2nd planet rows. To offset the torque (-2) of the ring wheel of the second row, the difference must be supplemented by the torque of the engine to the sun wheel of the last row (+0.81) (Figure 7).

The fifth gear is formed by changing the clutches E and C. The clutch C is switched on and the clutch E is off. All planet rows are involved in this gear. In addition to the second planet row torque, the engine must also maintain the torque applied to the clutch shaft between the third row ring wheel and the fourth row sun wheel via clutch C (Fig. 9).
5th gear brake B and clutches C and D are engaged

\[ i_5 = \left| \frac{-9,027}{7,029} \right| = 1,284 \]

Fig. 9. ZF 8-speed automatic transmission for HEV - fifth gear [1]

The sixth gear is the result of clutch E engaged and brake B disengaged. Now all the clutches are engaged and a direct gear with a ratio of \( i_6 = 1 \) is obtained. In this case, the third planet row operates, with the clutches C and D, transmitting the full torque of the engine. Clutch E must absorb the proportional torque from the sun wheel (on a third planet row). This is 38.3% of the input torque (Figure 10).

The 6th gear clutches C, D and E are engaged

\[ i_6 = \left| \frac{-1}{1} \right| = 1 \]

Fig.10. ZF 8-speed automatic transmission for HEV - sixth gear [1]

By disengaging the clutch E and engaging the brake A, the seventh gear is obtained. Only second and third planet rows are used to make this gear. Only the division of incoming torque through the fixed connection (guided on 2nd and 3rd planar row) and the clutch C (Fig. 11) should be taken into account here.

7th gear brake A and clutches C and D are engaged

\[ i_7 = \left| \frac{-5,217}{6,217} \right| = 0,839 \]

Fig.11. ZF 8-speed automatic transmission for HEV - seventh gear [1]

The eighth and thus “fastest” driving speed is the result of the switching of the clutches C and E, where C is disengaged and E is engaged. In place of clutch C, clutch D is engaged. Like the fourth gear, the clutch shaft between the second row sun wheel and the third row sun wheel is critical. Since the relation between the sun and ring wheels of the 3rd planet row is, the factor x and the output torque can be determined (Figure 12).

8th gear brake A and clutches D and E are on

\[ i_8 = \left| \frac{-2}{3} \right| = 0,667 \]

Fig.12. ZF 8-speed automatic transmission for HEV - eighth gear [1]

The required reverse gear - with the reversal of the direction of rotation in the same direction of torque transmission - is formed by both the brakes A and B and the clutch D. Starting from the drive on the second planet row, respectively, the third and fourth planet row perform the reverse gear (Figure 13).

R gear brakes A and B and clutch D engaged

\[ i_R = \left| \frac{+9,891}{3} \right| = 3,297 \]

Fig.13. ZF 8-speed automatic transmission for HEV - reverse gear [1]

The diagram in Fig. 14 shows the variants of ZF 8-speed automatic transmission for HEV.

As shown in Figure 14, there are eight harmonic stepped ratios that make sense for the modern vehicle transmission. The condition that a switching element is always switched off and another is switched on in ascending order with one gear is clearly visible in this diagram. In principle, three of the five switching elements are always included, and therefore only two elements are always excluded.
Conclusion

The mention above certainly has advantages in reducing unavoidable idle losses. Together with this very "clever" clutch structure and extended oil spreading, a 6% saving potential is achieved compared to the 6-speed automatic transmission, this 8-speed automatic transmission is no more severe than the 6-speed automatic transmission. With this product, the number of planetary rows and XPS planetary gearbox sizes will continue to grow. In addition to this ZF product, an eight-speed Aisin gearbox has been developed and Daimler AG already has a 9-speed automatic transmission in its program. The management of these planetary gearboxes is inextricably linked to actuators, which are essentially electromagnetic devices [10] activated by the HEV electronic control unit.

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LITERATURE


