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Characteristics of transmission for electric motor

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Abstract

As the development of electric vehicle, the power of motor takes more and more important position in the total powertrain. Because the characteristic of motor is totally different from combustion engine, so their requirements to transmission are different too. The development of electric vehicle is limited by traditional transmission which is suitable only for combustion engine. The requirement of vehicle, the different of characteristic between engine and motor, and the characteristic of demanded power of daily driving cycle are analysed in this paper. Compared with engine, the requirements of motor to transmission are less gears, more torque tolerance capacity in input shaft and more efficiency.

Keywords: electric vehicle, traditional transmission, daily driving cycle, less gears, more torque tolerance capacity

1 Introduction

For HEV the engine is big and the motor is small, so the traditional transmission is used to enlarge the performance of engine. Motor has to match the characteristic of traditional transmission, which limited the performance of motor.

For PHEV and EV, the status of motor and engine has changed. Compared with HEV, the motor is larger and the engine is smaller. So the transmission should be matched specially for motor to enlarge the performance of motor.

2 Characteristic of engine and motor

2.1 Different characteristic between engine and motor

The characteristics of engine and motor are different. The engine's external torque characteristic is similar to permanent torque characteristic. The motor's external torque characteristic is permanent power characteristic above the base speed and permanent torque characteristic below the base speed. As shown in figure 2.

2.2 The purpose of traditional transmission

The requirement of vehicle to power system is permanent power characteristic [1]. The engine can't match this characteristic, so it can't drive the vehicle by itself. The purpose of transmission is changing the permanent torque characteristic to permanent power characteristic, As shown in figure 1. So the system including engine and transmission can meet the requirement of vehicle performance.

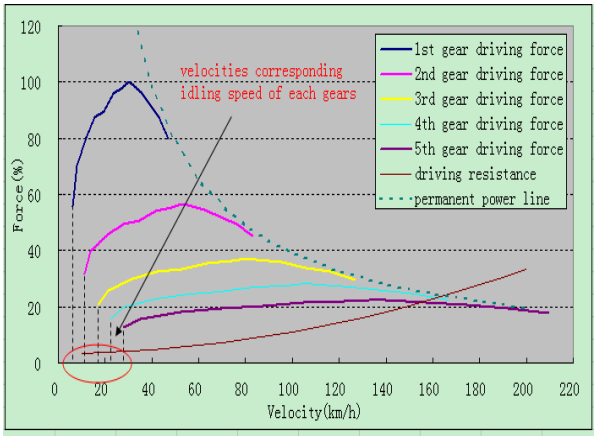

Figure 1: Driving force and resistance force of vehicle the purpose of traditional transmission

2.3 Requirement of motor to transmission

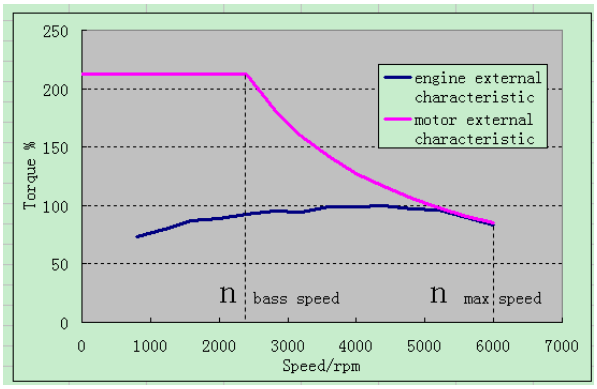

Figure 2: Comparison between external characteristics of engine and motor

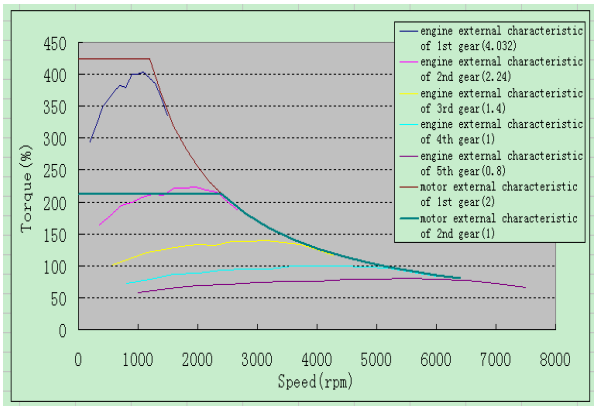

Figure 3: The comparison of external characteristics between motor with two gears and engine with five gears

For motor, in high speed region the torque characteristic is permanent power characteristic. This speed region is determined by the base speed ratio which equals max speed divided by base speed. The base speed ratio is about 2 to 3 for the limit of motor's design [2]. On the other way, motor's max torque is about 2 to 3 times to engine's torque when they have same max power and speed range as shown in figure 2. For the example of passenger car, the ratio range (which equals the lowest gear ratio divided by the highest gear ratio) of traditional transmission is about 5. So the motor can't drive the vehicle by itself too. It also needs transmission. Therefore motor matched a two gear transmission can meet the requirement of vehicle performance as shown in figure 3. The first gear ratio is about 2, and the second gear ratio is 1.

There is another reason why the engine needs a traditional transmission. As shown in figure 1. The engine can't output torque below idling speed. The speed ratio can lower the vehicle velocity which correspond the idling speed. The speed ratio is bigger, the velocity is lower. This can help the engine start the vehicle. Different from the engine, the motor can output the torque in zero speed. So it can start the vehicle without the transmission which has a big speed ratio.

Compared with the engine with same max power and speed range, motor's max torque is about 2 to 3 times to engine's torque. So the torque tolerance of new type transmission's input shaft is about 2 to 3 times to traditional transmission.

The transmission efficiency should be high to reduce power loss.

3 Analyzation of daily driving cycle

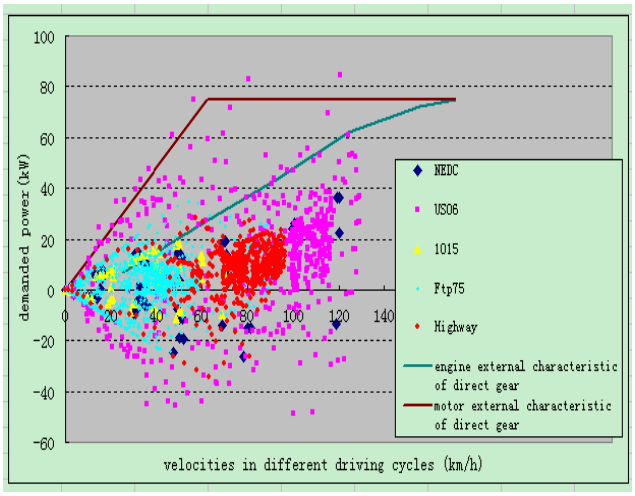

Figure 4: Relationship between demanded power and velocities in different driving cycles

There is a power statistics to some driving cycles for a A-class vehicle. These cycles are NEDC,

US06, Jan-1015, Ftp75 and Highway. As shown in the picture 4, the x-axis is the velocity; the y-axis is the demanded power. The point in the picture stands for the demanded power at each velocity of the driving cycle.

The demanded power of the driving cycle has several characteristics:

The higher the velocity is, the bigger the demanded power is. In the low velocity region, the demanded power is very low.

The engine with the 4th gear (direct gear) of the traditional transmission can generally meet the demanded power above 25 km/h except US06. And the motor with the 2nd gear (direct gear) of the two gear transmission can generally meet the demanded power in the all velocity region.

Compared with demanded power of dynamic performance, the demanded power of daily driving cycle is much smaller except US06.

4 Analyzation of tradition transmission

4.1 The function of each gear

For a traditional vehicle, each gear has specialized use. Take A-class vehicle with a 5 gears transmission for instance.

The functions of the 1st gear are starting the vehicle and climbing.

The functions of the 2nd and the 3rd gear are constant driving below 25km/h and acceleration.

The functions of the 4th gear are constant driving above 25km/h and keeping the max velocity. But its accelerating ability is worse.

The functions of the 5th gear are constant driving above 30km/h. It has better fuel economy than the 4th gear. But its accelerating ability is the worst.

4.2 The analysis of each gear

For A-class vehicle, the power of driving resistance is less than 2kW below 25km/h in constant driving. At this moment the load of engine is very low. Therefore the efficiency of engine is very low. When the vehicle accelerates below 25km/h, the higher the load of engine is, the bigger the acceleration is, and the shorter the acceleration time is, but the more severely the load and speed of engine is changing. The efficiency of engine is low too, because the transient oil consumption. The transient oil consumption is different from statics oil consumption got from engine map, and it influences the characteristic of torque response.

From the analysis above, working in the 5th gear the engine's load is the highest, the engine's speed is the lowest, and the engine's efficiency is the highest. But working in the 5th gear the engine can not start the vehicle, the vehicle can not drive at low velocity, and the vehicle can not meet the performance of acceleration and climbing. So the engine needs the 1st, 2nd, and 3rd gear to do those job. Therefore the function of the 1st, 2nd, and 3rd gear is to meet the dynamic performance, but has nothing with the fuel economy.

The motor need a two gear transmission which also has the similar functional characteristic. Working in the 2nd gear, the load of the motor is higher, so the efficiency is higher too. Because the motor can work in the zero speed, the motor in the 2nd gear can start the vehicle, and the vehicle can drive at low velocity. The motor with only one gear which is the 2nd gear of the two gear transmission can meet the power requirement in daily driving cycle.

The motor with the only direct gear can meet the demanded power of daily driving cycle. The big speed ratio gear is not needed. But the motor need a gear that the speed ratio is about 2 to meet the demanded power of dynamic performance. So the motor needs a new type transmission with two gears.

5 Summary

The requirements of motor and engine to transmission are different.
The motor with the only direct gear can meet the demanded power of daily driving cycle.
The requirements of motor to transmission are less gears, more torque tolerance capacity in input shaft and more efficiency.

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