

# Application of Wheel Hub Motor Direct Drive in Automobile

Yuechao Sun<sup>1, a</sup>

<sup>1</sup>School of Mechanical and Electrical Engineering, Lingnan Normal University, Zhanjiang, 524048, Guangdong, China

<sup>a</sup>email: yuechaosun@sina.com

## Abstract

Pure electric vehicles serve as the main development direction of new energy vehicles, and the direct drive technology of wheel hub motor is one of the hot issues in the current research of pure electric vehicles. The car directly driven by the hub motor has many advantages, such as compact structure, high space utilization of the body, low center of gravity, good driving stability and easy intelligent control. By explaining the development and characteristics of hub motor drive technology and its application in electric vehicles, it is expected that after solving the several key technical bottlenecks restricting the development of electric vehicles, the pure electric vehicles with direct hub distribution drive will be popularized and applied in the future.

## Keywords

Electric Vehicle; Wheel Drive; Distribution Drive; Electric Drive.

## 1. INTRODUCTION

Hub motor integrates 2 or more motors inside the wheel hub, which has a great advantage over internal combustion engine vehicles and single-motor centrally driven electric vehicles [1]. The hub motor was invented in the 1950s by American Robert, who integrated the motor, transmission system, and braking system into the vehicle hub, and patented it. In 1968, the electric wheels were applied to in large mining dump trucks [2], which started the application of hub motor technology in automobiles. Since the 1990s, Japan has introduced a series of hub-motor system-driven electric vehicles, such as the TEPCO's IZA, and, more recently, new models like Mitsubishi's Colt and Honda's FCX concept. Hub motor can give full play to the huge functions and advantages of electric vehicles, because they do not need the clutch, transmission on the traditional internal combustion engine, which can significantly enhance the mechanical efficiency and work efficiency, so that the cost of the vehicle is significantly reduced. Although the hub motor can highly integrate the power, transmission and braking system, reduce the transmission components, reduce the quality of the vehicle, and improve the efficiency and interior space, the current wheel motor technology is still in the engineering sample and prototype commissioning and verification stage. With the increasing maturity of battery, motor and control technology and the rapid promotion and popularization of new energy vehicles, the hub motor will get close attention and continuous investment in research and development from experts, scholars and vehicle and parts manufacturers at home and abroad with its outstanding advantages and characteristics. Hub motor and drive system are also one of the key goals of drive motor technology route of Made in China 2025.

## 2. HUB MOTOR AND DRIVE MODE

The hub motor system integrates the motor, drive and braking mechanism into the hub, called the wheel motor electric wheel, but also called the wheel motor, wheel motor and other [3]. The

hub motor drive system is usually composed of drive motor, deceleration mechanism, shock absorption system, brake and heat dissipation system, and some have no deceleration mechanism. The hub motor drive system can be divided into two categories: deceleration drive and direct drive. The deceleration drive hub motor mostly adopts the internal rotor structure to achieve the deceleration drive. Due to the high motor speed, it is necessary to configure the reducer to reduce the output speed and increase the torque to meet the output demand of the wheel. According to the type of deceleration mechanism, the hub motor can be divided into the hub motor of coaxial pendulum line reducer, coaxial planetary gear reducer hub motor and partial axial hub motor [4]. Direct drive type mostly adopts external rotor structure to achieve direct drive, without deceleration mechanism, which can realize the drive system structure of simple chassis lightweight, but the electric car equipped with direct drive hub motor has poor when starting. [5]

The hub motor of high speed rotor has the advantages of high specific power, light quality, small volume, high efficiency, small noise and low cost. However, there are disadvantages of using deceleration device to reduce efficiency and increase non-spring load quality, and the maximum speed of the motor is limited by coil loss, friction loss and bearing capacity of the speed change mechanism. The outstanding advantage of high-speed internal rotor motor deceleration drive for electric vehicles is that it has high specific power and efficiency, small volume, light quality, good climbing performance, and can obtain large and stable torque when the car runs at low speed.

The low speed outer rotor motor is simple structure, small axial size and high than power, which can control torque in a wide speed range and fast response speed, the outer rotor is directly connected to the wheel, no speed mechanism and high efficiency; the disadvantage is that to obtain large torque must increase motor volume and quality, high cost, low efficiency at acceleration and high noise. The outstanding advantages of electric vehicles driven directly through the low-speed external rotor motor are their fast dynamic response, higher transmission efficiency, small axial size, simple and compact drive wheels, and low maintenance cost.

### **3. FEATURES OF HUB MOTOR DIRECT DRIVE IN AUTOMOBILE**

#### **3.1. Drive Advantages**

Compared with the traditional internal combustion engine vehicles, the pure electric vehicles driven by the hub motor have the advantages of zero emission, quiet interior environment, smoother acceleration, and simple driver operation. In addition, the use of the car using hub motor direct drive, can make the chassis transmission system more simplified, completely cancel the clutch, transmission, transmission and half shaft and other transmission system components, so that the chassis structure is simple, transmission efficiency improved, the car space greatly increased, and reducing the quality of the whole vehicle.

Because the hub motor drive completely cancels the drive system parts, the drive motor, suspension system and brake system can be placed in the rim at the same time, making the car structure compact, the center of gravity reduced, and improving the driving stability. The hub harness is connected between the motor and the power battery and controller to facilitate intelligent and electrification control of the chassis. Hub motor drives the interior space layout more flexible, lower bottom plate and chassis flat, improve the ride comfort. At the same time, each wheel movement is independent of each other, no rigid mechanical connection, through the computer and motor control system of the wheel driving force and braking force according to the vehicle driving state, easy to realize line control steering, ABS, TCS and ESP functions, making the car steering spirit, reliable dynamic performance and good operation stability [6].

Direct drive of hub motor can also switch between front drive, rear drive or full-wheel drive according to actual road conditions, reduce the turning radius of the vehicle, specially configured vehicles can even realize lateral movement and situ steering, and the hub drive can realize electric braking, electromechanical composite braking and braking energy feedback, conducive to accurate control of wheels, energy recovery and intelligent development of pure electric vehicles.

### **3.2. Drive Shortcomings**

Although the hub motor drive car performance outstanding, but because the hub motor, brake system and even suspension system concentrated on the wheel at the same time, the quality under the spring and wheel rotation inertia significantly, thus increase the vertical vibration of the car, lead to the car ride comfort and control stability, even affect the tire attachment, is not conducive to the control of the car.

Because the hub motor operates in a high temperature environment for a long time, poor heat dissipation will cause thermal magnetization of the permanent magnet, and even lead to irreversible magnetization, which seriously affects the performance of the motor. Wheels are the most bad part of the working environment in the car. To integrate the motor into the hub, it must consider the waterproof, dust prevention and corrosion prevention of the hub motor, and take certain shielding measures to increase the difficulty of heat dissipation. Due to the limited internal space of the hub, after the hub, motor, suspension and other components are highly integrated, the internal gap is extremely small, so the cooling of the motor becomes a big problem.

Although the wheel motor directly driven car for lightweight, traditional car advantages on skid control, but braking will consume electric energy, affect the electric vehicle mileage, and regenerative brake can effectively recover braking energy, can save or increase the battery power, and can reduce the burden of hydraulic brake, improve car brake comfort, so it is necessary to carry out the research of regenerative brake.

The use of the hub motor occupies a lot of space inside the wheel, which is not conducive to the installation of the internal brake inside the wheel. How to solve the manufacturing and maintenance of the brakes inside the hub motor has brought difficulties to the developers.

## **4. THE BOTTLENECK OF DIRECT DRIVE ABOUT HUB MOTOR IN AUTOMOBILE**

In view of the disadvantages of the direct drive of the hub motor, the following key problems to directly drive the hub car need to be solved. In terms of chassis structure design, due to the limited space inside and outside of the wheel, the layout of the hub motor needs to meet the requirements of the vehicle suspension, steering and braking performance. The particularity of the installation position of the hub motor can realize the multi-freedom control of the wheel swing and rotation, which increases the difficulty of integrated design. In order to integrate the hub motor into the wheel, the chassis parts need to be developed in secondary times, and the hub motor leads to a substantial increase in the non-sprung mass, which makes the suspension design more difficult. A specific brake system also needs to be designed for the hub motor drive to meet the for braking performance and space layout requirements.

In terms of integrated vehicle control, the hub motor drive can achieve more advanced motor control compared with the traditional electric motor motor control. Based on distributed torque control, it is still exploring experiments in driving torque distribution, drive / brake anti-skid control, and vehicle stability control, and a large number of motion and power control problems need to be solved urgently. Compared with traditional cars, hub motor electric vehicles have more degrees of freedom, which will lead to high-speed driving or slippery road surface, and

other dangerous working conditions such as tail swing and side slip. Therefore, the motion control requirements of hub motor and electric vehicles are more demanding. It is necessary to deeply study the torque vector control, motor TCS control, motor ABS control, motor ESC control and others [7], so as to realize the safety control of wheel-driven vehicles.

In the energy management system, because the hub motor is distributed in the wheel position, it brings many problems to the energy management of the whole vehicle. It is necessary to establish an energy distribution model suitable for the distributed drive system, study the optimal control strategy of the distributed drive energy distribution and braking energy recovery, explore the power coupling regression between wheels and axes of the distributed electric drive system, analyze the interconversion law between electric power and mechanical power, and formulate the corresponding power cycle energy loss control strategy [8].

In terms of the suspension structure performance, the hub motor greatly increases the mass of the vehicle under the spring, resulting in the poor operation stability of the vehicle. Therefore, it is necessary to overcome the negative effect caused by the hub motor, and it is necessary to study and design the high intelligent electronic suspension. The suspension system can sense the road conditions in real time, support the independent control of the suspension damping adaptation, and achieve the body roll, pitch and swing control with high accuracy and optimized performance. The hub motor drive control will have an impact on the suspension system, so the coordination mechanism of the distributed torque control and the adaptive control of the suspension system should be studied to optimize the vehicle operation stability and smooth [9, 10].

## 5. APPLICATION OF DIRECT DRIVE ABOUT HUB MOTOR IN AUTOMOBILE

Due to the outstanding advantages and development potential of hub motor to directly drive vehicles, there are many scientific research institutes and enterprises at home and abroad that are engaged in the research and development of hub motor drive vehicles. In foreign countries, Scheffler, Protean, Toyota and other companies have developed wheel motor drive car prototypes and even products. The fuel cell concept car introduced by Toyota Motor Company used hub motor drive technology. Protean is the representative of the direct drive, with integrated inverter, controller and brake system.

French TM4 company designed and manufactured the integrated wheel motor, using external rotor permanent magnet motor, the motor rotor housing directly with the rim, motor housing as part of the wheel rim, the motor rotor and drum brake drum integration, realize the rotor and brake motor rotor, greatly reduce the integrated hub motor system quality, integration degree is quite high.

Domestic researchers on the direct drive application of hub motor are mostly concentrated in universities and well-known automobile manufacturers. The EV96-1 electric vehicle developed by Aiyang Electric Vehicle Research Institute of Harbin University of Technology also adopts the external rotor wheel motor drive system, using a permanent magnet motor called "polymorphic motor", with the dual characteristics of synchronous motor and asynchronous motor, integrated disc brake, air cooling and heat dissipation. The "Chunhui No.1" and "Chunhui No.2" motors, independently developed by Tongji University in 2002 and 2003, are directly driven by four low-speed permanent magnet and brushless DC hub motors. Tsinghua University, Huazhong University of Science and Technology, Jilin University, Chongqing University and other universities are also actively studying the hub motor technology.

In 2004, BYD launched a four-wheel distributed drive prototype ET, with four hub motors of 25 kW and an 100 km acceleration time of 8.5s. Faw group based on the pendulum line hub motor, developed the hub motor chassis system, realize four-wheel electric drive and four-wheel independent control, hundred kilometers acceleration time less than 6s, with understand

the coupling braking system to realize braking energy recovery, and on the basis of the motor to realize the E-TCS electric traction control, optimize the wheel attachment rate to improve the vehicle acceleration, steering, climbing performance.

GAC Group has launched a GE3 pure electric vehicle, driven by PMSM, with a peak power of 132 kW, a peak torque of 290 N m, and a maximum speed of 156 km / h. At the 14th China (Guangzhou) International Automobile Exhibition in 2016, GAC Group exhibited the world's first EnLight Zhailian electric concept car, which is a leading concept sports car independently developed by GAC Research Institute. It is a four-wheel independent drive, with the dual control mode of driverless and manual driving mode, both the comfort of intelligent travel and the passion of a sports car. The EnLight concept car represents the future electric and intelligent development concept of GAC Group.

Although the hub motor can directly highly integrate the power, transmission and braking system, reduce the number of drive and transmission components, reduce the quality of the vehicle, improve the vehicle efficiency and improve the available space in the car, but the current wheel motor technology is not mature, and the production cost is still very high. In addition to the wide application in large mine transport vehicles, the application in the automobile field is still in the research and test stage, and there is a long way to go before the promotion and application.

## 6. CONCLUSIONS

Hub motor drive has the advantages of compact structure, convenient control, high transmission efficiency, torque distribution and flexible steering, and can increase the freedom of vehicle layout and design, which is an important development direction of new energy electric vehicles. With the future traffic system intelligence, operation efficiency requirements are higher and higher, hub motor distributed drive will get great development, believe that in the near future, will get mature application in pure electric vehicles, and unmanned, artificial intelligence and other emerging technologies perfect fusion, better serve our life.

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