Electric car design based on wheel motor drive

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Electric car design based on wheel motor drive

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Abstract. Under the increasingly severe energy and environmental issues, new energy vehicles are receiving more and more attention. In the new energy vehicle series, new energy vehicles with wheel hub motors as the driving technology are unique. The new energy vehicles of the hub motor have the characteristics of compact structure, independent drive and high integration of the power system. These characteristics make the hub motor have unparalleled advantages in the development of new energy vehicles. By analyzing the principle of the driving mode of the hub motor, the paper draws the limitations of the hub motor itself, and starts from this defect, combined with its own advantages, combining the advantages and disadvantages, thus making a new breakthrough in the car's shape. After the design of the styling was completed by modeling, the appearance of the car was evaluated by the fuzzy evaluation method, and the result was good. This paper combines the design examples with the scientific and theoretical basis to enhance the car's styling image and provide reference and basis for the future design of the wheel hub motor.

1. Introduction

With the diversification of energy sources and the deteriorating environment, people are increasingly paying attention to electric vehicles. This type of car has the characteristics of quiet driving, environmentally friendly and low emissions, high flexibility in body design, and easy weight reduction of the car body. In the car design, most electric cars are more conservative in shape, and the basic model of the design is still the traditional diesel locomotive. This design is not innovative and does not conform to the technological sense of electric vehicles.In addition, the appearance of automotive products has a high-speed update,which will shorten the life cycle of a product, and it will cause waste of various resources and materials.Consequently,this way is not conform to the development concept of green ecology. The hub motor integrates the motor, drive train and brake system into the hub, thus making the vehicle structure simpler and providing a possible split design. Split-type design is a more forward-looking design idea, which not only greatly changes the phenomenon of homogenization of existing models, but also provides new possibilities for future car design [1].

2. Wheel hub motor defect analysis

2.1. Cooling method of the hub motor

*2.1.1. Problems.*The hub motor technology puts the power unit, transmission and brake device together into the hub, which can greatly simplify the original mechanical parts of the car. However, the installation of these components in a small space will inevitably lead to poor air circulation. The problem of not being able to dissipate heat in time. During the operation of the motor, due to the high

electrical load and magnetic load, huge heat will be generated, and at the same time, it will be affected by heat conduction and heat radiation of other components. Therefore, the motor cannot be cooled only by the flow and air cooling. Excessive temperature will have a huge impact on the overall performance of the motor [2], if this heat can not be dissipated in time, it may damage the insulation performance of the winding, reduce the service life of the motor, and may even lead to permanent Irreversible demagnetization of magnets [3].

*2.1.2. Solution.*At present, there are three main heat dissipation schemes for the hub motor, namely air cooling, liquid cooling and gas-liquid mixed cooling. Among them, air cooling includes natural air cooling and forced air cooling. Because of the poor heat transfer capacity of the air, natural cooling is suitable for small hub motors. This method is an ideal method without additional cost. However, for a powerful high-power hub motor, the amount of heat generated by natural air cooling alone is not sufficient to cool the high-temperature gas. Therefore, forced air cooling and liquid cooling are required for timely heat dissipation [4].Forced air cooling is divided into open air cooling and closed air cooling. Open air cooling refers to the use of special ventilation mechanisms such as air slots to achieve internal and external air circulation of the hub motor. According to different ventilation directions, it can be divided into axial type and radial type. The axial type is often used for small motors. In axial ventilation, the heat of the motor is taken away by the wind in the axial direction, which can directly dissipate the stator and the rotor [4]. This method is simple and easy to implement. Although the open air cooling cost is relatively low, it is easy to blow external dust into the motor and it is noisy during operation. Closed air cooling means that air flow is realized inside the motor casing. The advantages of closed air cooling are mainly two points. The motor is relatively clean and the noise is small, but the manufacturing cost is high.

Air cooling has limited heat dissipation capacity. In comparison, the cooling capacity of liquid cooling is much better. Liquid cooling is suitable for high-power permanent magnet motors. Liquid cooling mainly includes oil cooling and water cooling, and oil cooling usually uses transformer oil. Oil cooling is divided into direct cooling and indirect cooling, and direct cooling is divided into oil-injection and fuel-injection [4].

*2.1.3. Selected plan to determine design ideas.*The front face of a conventional diesel locomotive often has an iconic intake grille designed primarily to cool the cooling water tank. Now, the air intake grille on the front of the car has become an important element in the design of the car, and each car company has a relatively stable style. For electric vehicles, there is no need for a cooling water tank, and a large area of the intake grille is no longer needed. The hub motor on an electric vehicle usually uses a high-power motor, and the heat dissipation requirement is very high. Therefore, in the design process, forced air cooling or liquid cooling is adopted to control the temperature, so for the electric vehicle, a small area of the intake grille is still needed to direct the airflow for forced air cooling.

Congxi Jiang, one person at key laboratory for aerodynamic and thermal environment simulation of ground vehicles in Shanghai, has studied the heat dissipation law of electric vehicle hub motors. He found that if the front compartment parts of the car can be arranged in a regular order, the high-temperature cooling gas is When the chassis is out, it can reduce its influence on the motor temperature.

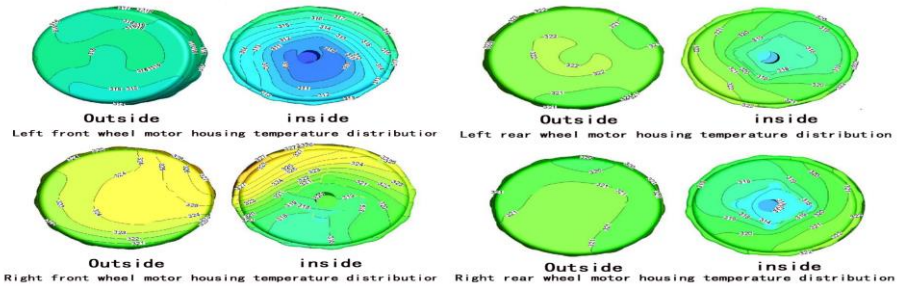

Figure 1. Motor case temperature distribution

As can be seen from Figure 1, the surface temperature of the left front wheel motor is lower than that of the rear wheel. As can be seen from Figure 2, the surface air mass flow rate near the front wheel motor is higher than that of the rear wheel, so that better ventilation and heat dissipation conditions can be obtained. In Figure 2, the maximum mass air flow in the lateral air mass flow at different vehicle speeds is the right front wheel. The inflow in the front end is a high temperature gas, and most of this gas will flow to the area of the right front wheel, in which case the temperature of the motor rises. In the low speed range, the air flow rates of the left front wheel and the left rear wheel are similar, but due to the presence of the inflow, the intake air amount of the left front wheel increases significantly as the vehicle speed increases. It can be seen that the inflow has an important influence on the wheel flow field and thermal management.

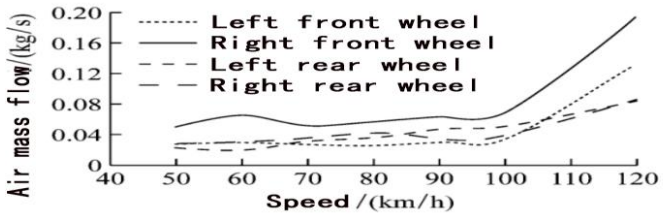

Figure 2. Horizontal air mass flow of the wheel at different speeds

Considering the above factors, when designing the appearance of the car, the shape should be aerodynamic service, so that the front wheel of the electric car is moving forward, so that the front wheel has sufficient air intake to cool. There are two main methods commonly used: the design method of opening holes in the front part of the car or the design structure and design mode of the spokes and wheel covers are improved, and the air flow is directed to the motor surface to increase the intake air amount of the cooling air of the wheel.

2.2. suspension optimization of hub motor

*2.2.1. Problems.*The hub motor and its accessory parts are complex in structure, large in size and high in quality, and are significantly different from conventional diesel locomotives. The main performances are: the hard points of the suspension and steering system components change, the wheel span becomes wider, the unsprung mass increases significantly, the vehicle mass distribution changes significantly, and the steering characteristics are also affected. The large increase in the quality of the unsprungs will bring great inconvenience to the comfort and handling of the car, and also cause safety hazards in the process of driving the car [5].

*2.2.2. Solution.*In order to meet the requirements of the hub motor system in layout, four-wheel independent drive and the driving performance of the electric vehicle, combined with the structural characteristics of various independent suspensions, it is proposed to use a double wishbone torsion bar spring independent suspension. Shi Tianze of Jilin University has optimized the traditional suspension system for loading hub motors and designed a new double-arm suspension system. The system is hinged to the steering knuckle by two lower control arms, while the intersection of the two control arm extension lines forms a "virtual hinge point". The virtual hinge point and the connection point on the mounting point on the suspension form a suspension kingpin. With the properly designed double-arm suspension structure, the virtual hinge point can be located in the wheel, and the actual hinge points of the two control arms and the steering knuckle are still outside the wheel, so that the position of the suspension kingpin is not limited to the physical structure. Constraint, thus providing a larger space inside the wheel, meeting the installation requirements of the hub motor, and not changing the overall parameters such as the wheel track of the vehicle under the premise of ensuring the parameters of the kingpin.

Figure 3. Double-section arm suspension and virtual hinge point

Xinbo Chen and others from Tongji University have designed a new suspension of "double wishbone suspension - torsion bar spring - electric wheel module". The suspension structure is relatively compact and consists of a double wishbone suspension, a torsion bar spring, a shock absorber, a rotational speed sensor, a brake disc (clamp), an outer rotor DC brushless hub motor and wheels. The outstanding feature of the suspension is that it can realize the flat generalization of the chassis structure. For the electric vehicle, solving the problem of the chassis is equivalent to providing a split design for the electric vehicle [5].

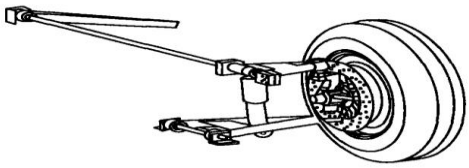

Figure4. Torsion Bar Spring - Electric Wheel Module Structure

*2.2.3. design plan.*The elastic, damping and unsprung mass of the suspension are the few relevant parameters that have the greatest impact on ride comfort. The roll center and roll stiffness are the main indicators for evaluating the handling stability of the car [7]. At the same time, it is also necessary to refer to the influence of the change of the camber angle of the wheel on the ride comfort. The double wishbone independent suspension is selected for the car design. The main positioning parameters include: the camber angle and the toe angle of the wheel, the caster angle and the camber angle of the kingpin [8].In the design, in order to optimize the layout of the shock absorber and reduce the non-suspended mass, a longitudinally arranged torsion bar spring can be used as the elastic element, and the energy per unit mass is high. The shock absorber uses a single cylinder hydraulic shock absorber. In the specific structural design, it is necessary to study the positioning parameters of the upper and lower control arms of the suspension.

2.3. Aerodynamic design of the hub motor

*2.3.1. Problems.*The aerodynamics and body shape of the car are closely connected [9]. Aerodynamics is an important branch of mechanics, which not only directly affects the design of an electric car, but also has inextricably linked with air resistance [10]. At present, the cruising range of electric vehicles is generally not high, so under the existing battery technology conditions, electric vehicles must be as energy-saving as possible. In the power-saving measures, it is most effective to reduce the running resistance of electric vehicles and design a low-resistance shape. The design of the car is a split-type design, which is a brand-new field of car design. It has a breakthrough significance in car styling, but one of the most prominent problems in this type of design is that the wind resistance is usually higher than that of ordinary cars. Therefore, how to achieve a low-resistance design of the split-type car design is an urgent problem to be solved.

*2.3.2. Solution.*When designing a car, consider the aerodynamic factors. At the time of design, the designer needs to consider two criteria: first, through the streamline design of the car shape to reduce the air resistance when the car is running, and secondly, the car will be subjected to lift and side force when driving. The role of the designer, therefore, the designer should focus on reducing the role of

these two forces to ensure the stability of the car. Usually when designing a car, designers will follow a line of thinking: adopt an overall optimization method, starting with a basic shape with low resistance, and gradually designing features such as cabin, cabin and luggage compartment in combination with the practical requirements of daily life. In this process, the drag coefficient of the car gradually reaches the requirement [11].

The reason why the car is subjected to various forces and moments during the driving process is mainly due to the influence of the external flow field of the car [12]. Nowadays, when people study automotive aerodynamics, they use fluid state analysis, and through flow analysis, people can recognize important flow processes [13].

*2.3.3. design plan.*In the design of the hub spoke of the vehicle body, on the one hand, the heat dissipation of the motor can be carried out through a reasonable and effective wheel spoke shape, and the trapezoidal opening design is mainly adopted, so that the cooling capacity of the motor can be improved. On the other hand, it is also possible to dissipate heat by adding a braking force feedback system. Excessive wheel hub spoke openings have a large impact on the degree of freedom of design. Therefore, in the design process of the automobile, the combination of the braking force feedback system and the opening method can be adopted, and under the heat dissipation of the braking force feedback system, the size of the opening of the hub spoke is appropriately reduced, so that in the design process There will be a higher degree of design freedom.

In the exterior design of the car body, if you want to achieve the smallest wind resistance of the car, you need to design in a streamlined shape. Figure 5. is based on the design principle of reducing the resistance, based on the original appearance of the car. When designing the front end of the car, avoid the bumps in the small parts [13].

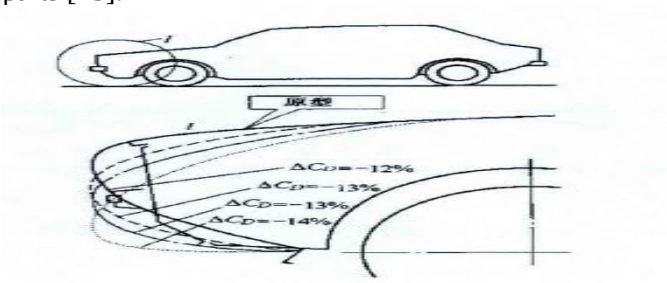

Figure 5. Example of changing the front end shape to reduce aerodynamic drag

2.4. Layout and modeling of electric vehicles loaded with hub motors

*2.4.1. Arrangement of internal combustion engine vehicles.*Conventional internal combustion engine vehicles have great limitations in the design of automobiles because of the necessary mechanical mechanisms. Nowadays, the traditional diesel locomotives produced by the car companies not only occupy a considerable space for the engine, but other accessory components also have an impact on the car space. However, in new energy vehicles that load hub motors, these traditional automotive components will be replaced by mechanical changes, which will bring greater interior space and design possibilities for new energy vehicles.

*2.4.2. Arrangement of electric vehicles for loading hub motors.*The hub motor electric vehicle no longer uses the previously inherent mechanical structure as the power source and transmission mechanism, and the power system is integrated into the wheel. Because the engine and transmission mechanism were simplified in the design, a major change occurred in the overall layout of the vehicle.

Wei Zhang of Beijing Hyundai Motor Technology Center has proposed an innovative design of electric chassis - skateboard chassis, which has many advantages, including: high degree of freedom of design, chassis and body independent, strong handling, safety Good performance and other aspects. The front and rear weight of the chassis is 1:1. If the car collides with an accident during driving, the

chassis can absorb a large number of impacts in a short period of time to prevent deformation of the passenger compartment. Finally, the skateboard chassis is highly integrated, reducing the complexity of the manufacturing and handling process.

Tongji University's "Chunhui No.3" is the first four-wheel independent fuel cell vehicle with wire-steering in China. The chassis of the car adopts a double-layer frame structure, which can make the power battery, fuel cell and drive control. The system is placed in it. This flat generalized structure and its separation from the body structure make it suitable for the development of various models of different shapes and uses, which is conducive to shortening the development cycle of new automotive products.

*2.4.3. Design plan.*In the design of the chassis, the arrangement of the battery pack is the first problem to be considered. In electric vehicles, the tiling method is usually adopted, but this method has drawbacks and has a relatively large impact on the passenger's seating space. Therefore, in the design process, the designer needs to pay attention to compensate for the defects by coordinating the layout of the car. Secondly, the battery pack should be placed in a distributed manner as much as possible in the process of placing, so that the space in the car can be enlarged. In addition, there are many outstanding advantages in the dispersion of the battery: reducing the friction of the battery. The risk of collision, maintaining global stability, etc.

In order to improve the performance and fuel economy of electric vehicles, designers need to consider the lightweight work of the vehicle chassis. In the design process, the chassis should adopt advanced technology and materials. The materials are mainly made of aluminum alloy and magnesium alloy, and the structure is mainly hollow structure.

3. New energy vehicle design based on hub motor drive

3.1. Inspirational exploration and hand-painted design

Designed with the target user in mind, the design inspiration can come from any item that the user likes, extracting the elements and shapes of the design from the user's favorite items, and using this to explore the sketch. In the process of sketching, combined with various defects and compensation measures in the electric motor driven by the hub motor, the shape of the car is continuously optimized. The design of electric vehicles is a multi-culture, multi-disciplinary and multi-functional combination, which not only requires aesthetics, but also aesthetics, but also meets the requirements of practicality and other conditions. Sometimes it is necessary to combine the unique culture of the region where the designer is located. Art form [16]. Therefore, after a deep analysis of the practical requirements of automotive design and the aesthetics of Chinese residents, after many sketches and modifications, the sketches of electric vehicles are shown in Figures 6 .

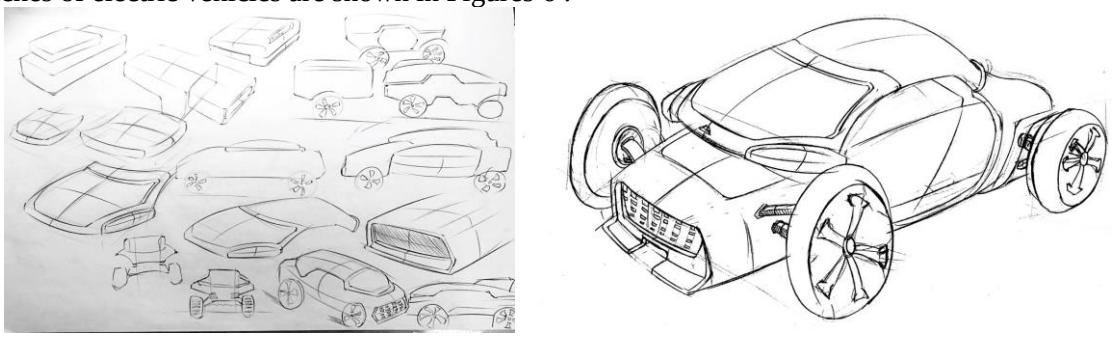

Figure 6. Sketch of electric vehicle modelingconcept and Hand-painted overall renderings

Overall, the car is a two-door compact car with a split design. The car body adopts a sliding plate chassis and is effectively drained at the front opening of the chassis. The passenger compartment has a sleek design, which can reduce the air resistance when the car is running, and can also give a smooth and silky design. Guohua Wang of Jilin University pointed out in the paper "Wheel Air Drag Reduction and In-Wheel Heat Transfer" that the aerodynamic drag coefficient of the trapezoidal

opening is generally lower than that of other shape openings, that is, the piston with trapezoidal opening is aerodynamically reduced. Resistance can have a better effect. The spokes are of a five-spoke design with a trapezoidal vent at the end of the opening.

3.2. Modeling through modeling software

After collecting enough inspiration, we can paints by divergent thinking. In the process of hand-painting, the general outline of the car shape needs to be outlined first, and there is no need to consider engineering problems such as manufacturing process, cost and technical difficulty. In the design process, a process of gradual transformation from whimsical to realistic, in the initial stage, the designer needs to conceive the shape, proportion, structure and other elements of the car body. After that, the designer needs to carry out various design constraints according to the previous article. Corrected. After completing the preliminary hand-drawn draft, the design was put into 3D effects through modeling software. In this design, the body mainly adopts black as the main color, and the black gives a calm and steady feeling, which meets the psychological aesthetic needs of most people. The car is designed with a separate chassis, and the chassis and passenger compartments are mounted above and below. The headlights are horizontally stripped. This design can illuminate the road at night to ensure basic driving safety.

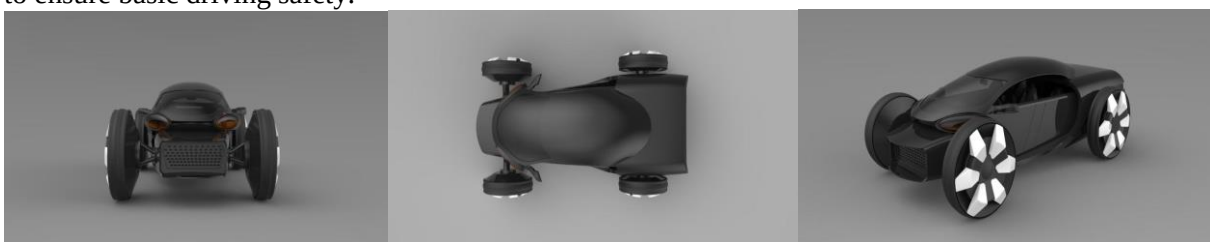

Figure 7. Body View

The design adopts a small slip-back shape in the design. The main body line is the contour curve of the car body from the front face to the rear of the car. The overall shape gives a sense of impact, and the visual effect is given in the movement. A steady and steady atmosphere, the business combines the rhythm of youthful speed. The vehicle uses four huge wheels, which improves the passability of the car. At the same time, the spokes are designed with a trapezoidal reference on the opening according to aerodynamics. They are decorated with silver and are very visually stunning. The body is made of black metallic paint, which shines under the sunlight, giving people a very smart feeling and good flow. The chassis of the vehicle is separated from the passenger compartment. The chassis is provided with an opening at the front end. On the one hand, it is designed to meet the heat dissipation requirements of the battery pack and the motor. On the other hand, it also plays a decorative role to avoid the structure that does not occur because the electric vehicle does not have an engine compartment. Coordination phenomenon.

In the basic determination stage of the sketch form, the heat dissipation form required for the pure electric vehicle driven by the hub motor is adopted. In this design, the cooling of the hub motor can provide a variety of cooling methods, including the air inlet of the chassis part of the front part of the chassis, the guide channel of the car bottom, the liquid cooling and the air intake of the hub for cooling; suspension and shock absorption The system uses double wishbone shock absorption.

4. Fuzzy evaluation method evaluation design

4.1. Determine the indicator set U

The indicator set sorts and sorts the factors to be evaluated. First, collect sensible image vocabulary about electric vehicles. Perceptual image vocabulary refers to the comprehensive performance of the user's perception of the appearance and color of the car.

In order to collect representative vocabulary, it can be done in the following ways: (1) access to relevant literature; (2) through structured access with consumers and use of self-administered

questionnaires; (3) through network search Related terms. In the end, we collected a total of 112 related vocabulary, and after the vocabulary screening, we got 64 sensible vocabulary words. The KJ method and the cluster analysis method are used to screen the vocabulary again. Finally, 16 image semantic space tables are obtained. As shown in Table 3, they are sorted into four categories, which are the contents of the evaluation index set U.

Table 1. Sensual Image Semantics Glossary

Sensual imagery	Style vocabulary
Lovely, warm, friendly, at home	Nearly human - annoying
Muscular, speedy, offensive, smooth	Dynamic - still
Simple, generous, beautiful, clean	Simple—complex
Personal, novel, trendy, unique	Innovative - stale

*4.1.1. Establish evaluation matrix and calculation decision matrix.*Invite 30 electric car owners to participate in structured visits and self-administered questionnaires. The comment set is set at 5 levels, which are very good, good, average, poor, and very poor. The evaluation index set U and the comment set V are combined to price each evaluation, and the percentage of the number of the reviews in each indicator is counted to form an evaluation matrix R. 30 evaluators were invited to give weights to the evaluation indicators according to the survey data, which is 0.3 for the near person, 0.3 for the dynamic, 0.3 for the innovation, and 0.1 for the simple one, then W={0.3,0.3,0.3,0.1}; therefore, the decision matrix scheme has :

$$B = WR = [0.3 \quad 0.3 \quad 0.3 \quad 0.1]\begin{bmatrix} 0.41 & 0.33 & 0.06 & 0.04 & 0.01 \\ 0.45 & 0.38 & 0.02 & 0.01 & 0.00 \\ 0.43 & 0.37 & 0.05 & 0.03 & 0.01 \\ 0.52 & 0.34 & 0.04 & 0.01 & 0.00 \end{bmatrix}$$

$$= [0.423 \quad 0.423 \quad 0.085 \quad 0.056 \quad 0.014]$$

B and the V^t vector are subjected to a point multiplication operation, and the comprehensive evaluation value is $B \cdot V^t = 7.9675$.

It can be seen from the calculation results that the final score of the design scheme is 7.9695, which is a relatively good score. Therefore, the scheme has market value and has certain feasibility, and can be subsequently optimized.

5. summary

With its independent and integrated features, the hub motor drive will become the best driving method for electric vehicles in the future. Although there are still many technical obstacles to be overcome in the current hub motor, such as the increase in unsprung mass, sealing problems, heat dissipation problems, etc., with the advancement of technology, the optimization of the automobile structure, in the electric vehicle, the hub motor will be fully development of. Through rational analysis, this paper systematically proposes the modeling method of the electric motor driven by the hub motor, and designs the suspension system of the double-arm suspension-torsion spring-electric wheel module based on the sliding plate chassis. The electric vehicle with split design was used, and then the fuzzy evaluation method was used to evaluate the design of the car. With the increasing number of automobiles, the continuous consumption of natural resources, and the increasing environmental pollution, vehicles powered by clean energy such as electricity are receiving more and more attention from countries and enterprises. The electric motor driven by the hub motor has provided a higher degree of design freedom for the electric vehicle because of its new technology, which has brought about tremendous changes in the inherent body design of the diesel locomotive. Through researching this topic, it aims to provide reference for the appearance design of electric vehicles driven by current hub motors, and also hopes to provide more reference value for automotive shape design research.

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