A Design and Calculation Method of Disc Brake for Electric Motorcycle

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Abstract. Firstly, the braking performance of drum brake and disc brake is briefly introduced, and then the brakes are classified. This paper mainly deduces the braking force needed by the parameters of electric motorcycle, then designs and calculates the key parameters of disc brake, such as the cylinder diameter of main brake pump and the cylinder diameter of sub-pump, according to the braking force. Finally, the calculation method is demonstrated by a mature product example, and the key parameters are selected. This proves that the calculation method of the electric motorcycle brake is feasible and ensures that the designed brake meets the requirements of the vehicle braking moment. Ensure safe driving performance.

1. Introduction

Electric vehicle is a new type of vehicle. Its load and maximum speed are between bicycle and motorcycle. At present, the main trend of brake is that drum brake is used in front and rear wheels, but its braking effect is not ideal. Brake drum of drum brake is heated quickly, which results in brake force and heat attenuation quickly, heat dissipation is not easy, and brake is extremely unstable; when drum brake is running, water will enter drum brake on rainy day or muddy road surface, which results in the decrease of friction coefficient of drum brake, but with the increase of time, it will cause water recession; and drum brake due to the special structure of the drum brake. Differentiality, basically installed in the wheel hub, mud and water is difficult to come out, drum brake in continuous use process, resulting in poor water recovery.

The brake disc of the hydraulic disc brake of electric vehicle is directly installed on the wheel drum. The brake disc is bare. The friction surface of the brake disc generally designs a lot of heat sink holes. In the course of driving, because the direction of the heat sink holes is the same as the direction of the wheel, the heat sink performance of the hydraulic disc brake is improved by the effect of motion. In contrast, the heat sink of the hydraulic disc brake occurs during braking. Back is much smaller than drum brakes.

Drum brake is simpler than disc brake in design, easier to arrange and install, and lower in production cost. However, it is not as beautiful as disc brake in appearance and less reliable than hydraulic disc brake. However, with the continuous development of the industry and the increasing demand of consumers for braking performance and braking distance, the future trend is to replace drum brake with hydraulic disc brake.
2. Classification of Brakes
Motorcycle brakes are usually open-operated mechanical friction brakes, which can be divided into internal expansion shoe drum brakes and hydraulic disc brakes. In the hydraulic disc brake, the products are classified according to the use characteristics of the brake calipers. The disc brake is divided into two categories: fixed caliper disc brake and floating caliper disc brake.

2.1. Classification of disc brakes
Hydraulic disc brake can be divided into fixed clamp disc type and floating clamp disc type according to its structure

3. Parameter Design and Selection of Hydraulic Disc Brake for Electric Motorcycle

3.1. Braking Performance Explanation of Hydraulic Disc Brake for Electric Motorcycle
The braking efficiency of electric vehicle is mainly evaluated from three aspects: braking efficiency, braking efficiency stability and direction stability when braking. The braking efficiency is evaluated by braking distance S and braking deceleration a (m/s²).

It is necessary to satisfy the requirement of braking efficiency of electric motorcycle and to generate enough braking moment when input constant grip force. Brake efficiency can be evaluated by brake efficiency factor (K).

\[ K = \frac{M_u}{P} = \frac{M_u}{P \cdot R} \]

braking moment, P is the tension applied to two shoe pads, R is the effective braking radius)
For disc brake K=2T/P=2 (is friction coefficient)

3.2. Distribution of braking force between front and rear brakes
The ideal front and rear braking force (when both front and rear wheels are locked at the same time) should satisfy the following equation

\[ F_{u1} + F_{u2} = \varphi \cdot G \]

\[ \frac{F_{u1}}{F_{u2}} = \frac{b + \varphi h_g}{a - \varphi h_g} \]

\( F_{u1}, F_{u2} \) Braking force of front and rear brakes
\( \varphi \) Pavement Adhesion Coefficient
\( G \) Total Mass of Electric Vehicles (Full Load Total Weight)
\( a, b \) Distance from center of mass to front and rear wheels
\( h_g \) Centroid height

Although the ideal braking force distribution of front and rear wheels can be calculated based on the above formula, in fact, it is very difficult for electric vehicles to work according to the ideal braking force distribution ratio of front and rear wheels, regardless of braking system or braking system as a whole.

The existing electric vehicles are basically braked by front and rear wheel braking mode, so it is difficult to get good braking effect. Electric motorcycles can cause changes in front and rear loads and adhesion on different road conditions, Therefore, it is particularly important to choose a reasonable road adhesion coefficient when calculating the power before and after the calculation. The choice of adhesion coefficient determines whether the front wheel is locked first, or the rear wheel is locked first, or the front wheel is locked together in the braking process of the electric vehicle. Usually, the choice of phi is based on the road and the usual speed.

3.3. Brake Torque Calculation of Brake
In order to improve the stability of electric motorcycle in braking process, when choosing phi, the front wheel must be locked first, and the rear wheel must produce the maximum braking moment (phi is generally selected between 0.55 and 0.8). Its value is.
\[ M_{u_{2\text{max}}} = F_{u_2} \cdot r_2 = \frac{G}{L}(a - \varphi \cdot h_g) \cdot \varphi \cdot r_2 \] (4)

\[ M_{u_{1\text{max}}} = \frac{\beta}{1 - \beta} M_{u_{2\text{max}}} \] (5)

\[ \beta = \frac{F_{u_1}}{F_{u_2} + F_{u_1}} \]

Can be launched \( F_{u_2} = \frac{\beta}{1 - \beta} \) Bring in the top form.

\[ M_{u_{1\text{max}}} = \frac{F_{u_1}}{F_{u_2}} M_{u_{2\text{max}}} \] (6)

Combining the formula of braking force distribution:

\[ \frac{F_{u_1}}{F_{u_2}} = \frac{b + \varphi h_g}{a - \varphi h_g} \]

Can be launched

\[ M_{u_{1\text{max}}} = \frac{b + \varphi h_g}{a - \varphi h_g} \cdot \frac{G}{L}(a - \varphi \cdot h_g) \cdot \varphi \cdot r_2 \]

\[ = \frac{G}{L} \varphi \cdot r_2 \cdot (b + \varphi h_g) \] (7)

Known parameters of electric motorcycle:

\( G = 150 \text{Kg} = 1500 \text{N} \)

\( L = 1.2 \text{m} \) (Front and rear wheelbase)

\( a = 0.7 \text{m} \) (Centroid to front wheelbase)

\( r_2 \) (Rear wheel radius)

\( b = 0.5 \text{m} \) (Quality to rear wheelbase)

\( h_g \) (Centroid height)

\( \varphi \) Take 0.82 (look-up table)

Calculated: \( M_{u_{1\text{max}}} = 220.17 \text{N.m} \)

Friction on both sides of the brake disc

\[ T_{\text{max}} = \frac{M_{u_{\text{max}}}}{R} \] (8)

Upper middle (Brake disc \( \Phi 180 \) \( R \) Effective braking radius)

Calculated \( T_{\text{max}} = \frac{220.17}{0.08} = 2752.125 \text{N} \)

Pressure generated by the piston of the pump

\[ F_{\text{max}} = \frac{T_{\text{max}}}{2\mu} = \frac{2752.125}{0.8} (\mu = 0.4) \]

\[ = 3440.156 \text{N} \] (9)

Cylinder Diameter of Subpump Piston

\[ D = 2 \sqrt{\frac{F_{\text{max}}}{3.14 \times P_{\text{max}}}} = 2 \sqrt{\frac{3440.156}{3.14 \times 7 \times 10^6}} \]

\[ = 25.3 \text{(mm)} \] (\( P_{\text{max}} \) Pipeline pressure)

Piston Cylinder Diameter of Divider Pump \( D = 25 \text{mm} \)

### 3.4. Selection and Verification of Brake Parameters
3.4.1. Selection of key parameters

References

Ratio of Outer Diameter of General Brake Disc to Its Rim Diameter \( d / D \), front wheel: 0.45 ~ 0.7; rear wheel: 0.40 ~ 0.50; front wheel: =260mm; be \( d = 117 \sim 182 \text{mm} \) Selection path is \( \phi 180 \). The comparison between electric vehicle, motorcycle and bicycle is between them, so the thickness of selector is 3 mm.

3.4.2. Friction block

According to the shoe structure of motorcycle, the friction coefficient and material are determined.

3.4.3. Brake master pump

Since the space of the car body is only about 70 mm, the total length of the main pump should not exceed 70 mm. The piston area of the main cylinder, stroke, piston area of the sub-pump and stroke should be taken as the piston area in design.

\[
\frac{S_1}{S_2} = 0.1 \sim 0.2 \quad \frac{L_1}{L_2} = 5 \sim 10
\]

Known:

\[
S_2 = \frac{25 \times 25 \pi}{4}
\]

\[
BE: S_1 = (0.1 \sim 0.2) \times \frac{25 \times 25 \pi}{4} = \frac{\pi}{4} d^2 \quad (11)
\]

Master cylinder diameter \( d = \sqrt{25^2 \times (0.1 \sim 0.2)} \equiv 7.9 \sim 11.8 (\text{mm}) \)

Because the diameter of the sub-pump is slightly smaller, the diameter of the main pump \( D \) is on the upper line, so the design can also borrow some existing components of motorcycle to reduce the development cost.

According to the area \( \frac{L_1}{L_2} = 5.165 \) ratio of \( S1/S2 \), the maximum working stroke of the main cylinder. piston can be calculated, that is, the piston of the main cylinder moves 5.165 mm and the piston of the sub-pump moves 1 mm.

Master cylinder diameter

3.4.4. Brake handle

In the design of handshake, the distance between the center of ball head and the center of grip is between 100 and 150 mm, and the lever ratio is between 4 and 5.5. The lever ratio is 5:1.

3.4.5. Verification calculation

We take the Suzuki King motorcycle as an example to verify the design theory to ensure that the parameters of the electric motorcycle designed meet the requirements of the braking moment.

\[
G = 265 \text{Kg} = 2650 \text{N}
\]

\[
L = 1.265 \text{m} \quad (\text{Front and rear wheelbase})
\]

\[
V_{\text{max}} = 90 \text{Km/h} \quad (\text{Maximum speed})
\]

\[
a = 0.843 \text{m} \quad (\text{Centroid to front wheelbase})
\]

\[
r_2 = 0.32 \quad (\text{Rear wheel radius})
\]

\[
b = 0.422 \text{m} \quad (\text{Quality to rear wheelbase})
\]

\[
h_g = 0.7 \text{m} \quad (\text{Centroid height})
\]

\[
\varphi \quad \text{Take 0.76 (look-up table)}
\]

According to formula.

\[
M_{u1_{\text{max}}} = \frac{G}{L} \cdot \varphi \cdot r_2 \cdot (b + \varphi h_g)
\]
Calculated: \( M_{u_{\text{max}}} = \frac{2650}{1.265} \times 0.76 \times 0.32 \times (0.422 + 0.76 \times 0.7) = 486.06 \text{N.m} \)

Formula for generating friction on both sides of brake disc (9) \( T_{\text{max}} = \frac{M_{u_{\text{max}}}}{R} \)

Upper middle (Brake disc \( \Phi 180 \quad R \) Effective braking radius)

Calculated: \( T_{\text{max}} = \frac{486.06}{0.098} = 4959.79 \text{N} \)

Pressure generated by the piston of the pump

\[
F_{\text{max}} = \frac{T_{\text{max}}}{2\mu} = \frac{4959.79}{0.8} = 6199.7\text{N}(\mu = 0.4)
\]

Cylinder Diameter of Subpump Piston

\[
D = 2 \sqrt{\frac{F_{\text{max}}}{3.14 \times P_{\text{max}}}} = 2 \sqrt{\frac{6199.7}{3.14 \times 7 \times 10^6}} = 33.6(\text{mm})
\]

Piston Diameter of Actual Subpump for Suzuki King Motorcycle D=34mm, The results are in good agreement with the calculation results

Master cylinder diameter \( d = \sqrt{34^2 \times (0.1-0.2)} \approx 10.75 \sim 15.2(\text{mm}) \)

The piston diameter of Suzuki King Motorcycle's actual main pump is taken. In the range of calculation, the correctness of the initial design can be indirectly proved by the above calculation.

Because the speed of the electric vehicle does not exceed 40 km/h, the influence of inertia on the calculation results is not taken into account in the calculation process, but the influence of inertia has to be taken into account in the motorcycle calculation.

4. CONCLUSION:

In recent years, due to the frequent traffic accidents of motorcycles, some cities are prohibiting motorcycles. The state advocates the development of new energy vehicles. The speed and environmental protection of electric motorcycles meet the requirements of national policies. Electric motorcycles have developed rapidly in recent years, and electric motorcycle brakes often use drum brakes. The braking performance and safety are not guaranteed. Stable. While some motorcycle enterprises are transforming to produce electric motorcycles, the state must standardize and improve the overall development of electric motorcycles. Those enterprises with motorcycle qualifications will certainly optimize the performance and product quality of electric motorcycles, including safety performance. In that way, electric motorcycles will inevitably use more and more disc brakes in the future. The brake safety performance is designed and demonstrated. According to the vehicle parameters, the matching of brakes is calculated theoretically whether it meets the braking requirements, so as to improve the stability of braking performance of electric motorcycles.

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