Design of 235/45 R18 electric car tire

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Abstract: In response to the special requirements of electric car tires, we have independently developed a 235/45R18 tire. The main parameters of the tire's structural design are as follows: outer diameter of 662 mm, section width of 253 mm, tread width of 194 mm, tread camber height of 7.8 mm, bead contact diameter of 460.7 mm, section horizontal axis position (H_1/H_2) of 0.952473, tread pattern featuring asymmetric tread pattern, utilizing a five-pitch design, with a total of 41 composite pitches, and a tread pattern depth of 7.2 mm. In terms of construction design: the upper layer of the tread adopts highly wear-resistant and low rolling resistance tread rubber, while the lower layer adopts low heat generation transition rubber; the belt layer uses two layers of 4×0.225UT high-strength steel cord with a cord density of 79 EPD. The manufacturing process employs a one-step building machine and a hydraulic hot plate curing press. The performance test results of the finished tires show that their key indicators, including outer edge dimensions, strength, bead unseating resistance, durability, high-speed performance, and rolling resistance, all meet or exceed national and corporate standards.

Key words: electric car tires; structural design; construction design

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The wave of electrification is profoundly reshaping the global automotive industry landscape. As the world's largest electric vehicle market, China, driven by both national new energy policies and robust market demand, has not only facilitated the rapid development of complete vehicle manufacturing but also posed new technical requirements and market challenges to the tire industry. The demand for tires from automakers is shifting from the commonly used specifications of traditional fuel vehicles to specific specifications to meet the needs of lightweighting, energy conservation, and cost reduction.

In response to this trend, our company has selected the mainstream specification of 235/45R18 for independent research and development, targeting the specific application scenarios of electric cars. This article will provide a detailed introduction to the entire development process of this tire, from establishing technical objectives, conducting structural design, formulating construction plans, to finally completing performance verification of the finished product.

1 Technical requirements and design objectives

The product design complies with the requirements of GB/T 2978—2024 "Passenger Car Tyres-Specification, Dimensions, Inflation Pressure and Load Capacity". Additionally, based on the experience accumulated by our company in designing similar products and the market demand for this specification of product, we propose design objectives, as detailed in Table 1:

2 Structural design

2.1 Outer diameter *D* and cross-sectional width *B*

Biography: Song Qian (1989-), holds a master's degree and works as an engineer, primarily engaging in fundamental research on tire structure design and technological management.

Table 1 Design indicators

Project	Design Requirements
Standard rim	8J
Inflated outer diameter (mm)	669（663-675）
Inflation section width/mm	236（227-243）
Standard inflation pressure / kPa	250
Standard load / kg	670
Speed level	Y
Pattern type	Asymmetrical pattern
Product weight / kg	10.9
Rolling resistance	≤6.5 (enterprise standard)

The core difference between electric vehicles and conventional cars lies in their energy systems, while their usage conditions and vehicle designs are essentially identical. Given the similarities in driving conditions and vehicle dynamics between electric vehicles and conventional cars, this design adopts the technologically mature semi-steel radial tire structure system and optimizes it for the characteristics of electric vehicles. The outer edge dimensions of the tire after inflation serve as the basis for design. The belt layer of radial tires exhibits extremely strong circumferential rigidity, effectively constraining the expansion of the tire body, resulting in a small expansion rate (D/D) of the outer diameter after inflation. The change rate of the B value is slightly greater than that of D, and the selection of the B value is closely related to the bead contact width (c). Based on our company's similar product design experience and existing production and construction conditions, the specific values are as follows:

D'=669 mm, D'/D'=1.010 574, D=662 mm

B'=236 mm, B'/B'=0.932 806 B=253 mm

2.2 Bead fit width *C*

The C value of a passenger car radial tire directly affects the contour shape of the tire section, the force distribution on the sidewall, and the final performance. When selecting, comprehensive considerations should be made from aspects such as the offset of the horizontal axis of the section, changes in the rigidity of the sidewall, and usage factors of the tire. The aspect ratio of the tire is the "primary benchmark" for selecting the C value, so it is selected based on the aspect ratio of the tire. In this design, the C value is set to be 25.4 mm larger than the standard rim width, taking it to be 228.4 mm.

2.3 Running surface width *b* and camber *h*

The tread width b and camber h are key parameters that determine the tire's ground contact performance: a decrease in b value will result in a reduction in tread width and shoulder thickness, while an increase in b value will increase tread width and shoulder thickness.

The radius of curvature of the running surface is related to the tire aspect ratio and the rigidity of the belt layer. The larger the radius, the smaller the curvature height, and the wider the running surface width.

To ensure the maximum ground contact area between the tire and the road surface within the width of the running surface, it is generally advisable to set h/H to a value between 0.03 and 0.08. The ratio of the running surface width b to the section width B, denoted as b/B, is generally recommended to be between 0.7 and 0.85. In this design, b is set to 194 mm, h to 7.801 mm, H to 100.65 mm, h/H to 0.077506, and b/B to 0.766798.

2.4 Position of horizontal axis of section (H_1/H_2)

The horizontal axis of the tire section is the horizontal auxiliary line at the widest point of the tire section, and its position is represented by the ratio H_1/H_2. This parameter has a significant impact on tire performance: when $H_1/H_2 < 1$, the high-speed performance of the tire can be improved; when H1/H2 > 1, the tire has superior load-bearing capacity. Considering that electric cars often need to travel at high speeds, and based on the company's design experience, H_1/H_2 is set to 0.952473 in this design to ensure stability under high-speed conditions.

2.5 Bead fit diameter *d*

The design of the bead seating diameter (d) requires a balance between the convenience of tire assembly and disassembly and the tight fit between the bead and the rim. Generally, the bead seating diameter corresponding to a flat-base rim should be 1~3 mm smaller than the rim diameter. If the fit is too loose, it can easily lead to movement, deformation, and even tire blowout risks during tire operation. To avoid such issues, d is set to 460.7 mm in this design to ensure a stable fit between the bead and the rim.

2.6 Tread pattern design

The tread pattern primarily features four longitudinal straight grooves, effectively enhancing drainage and heat dissipation capabilities. Additionally, transverse grooves are incorporated to increase friction between the tire and the ground, thereby improving grip performance. The overall pattern adopts a closed shoulder strip design, with a pattern depth of 7.2 mm, a pattern saturation of 74.2%, and a circumferential pitch of 42 composite pitches. This design boasts four major advantages:

(1) The overall horizontal grooves of the pattern feature an extremely narrow groove design, which minimizes air flow and reduces noise generation to the greatest extent possible.

(2) The walls of the longitudinal grooves in the pattern feature vertically arranged noise-reducing lines, which can disrupt the rebound path of air within the grooves.

(3) The pattern pitch adopts a composite pitch of 5 sizes, arranged and combined, totaling 42 pitches.

(4) To increase the rigidity of the outer tread blocks, the lateral grooves in the outer shoulder tread blocks are cut to be half as deep as those in the inner tread blocks.

The tread pattern is shown in Figure 1.

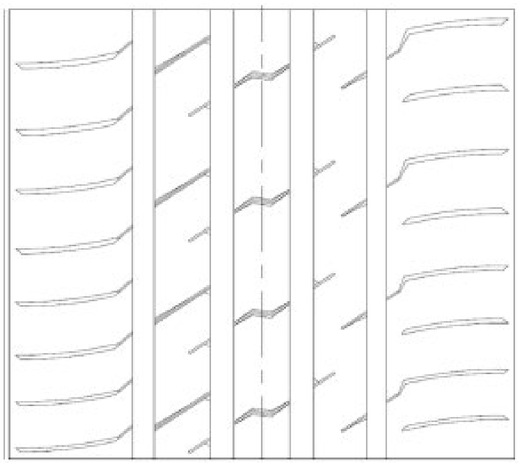

Figure 1 Pattern style

3 Construction design

The tire design features a wider tread area. Firstly, this increases the ground contact area, ensuring better lateral stability during high-speed lane changing and cornering. Secondly, by reducing the unit normal pressure and shear force on the ground contact area, it slows down tread wear, further extending the tire's service life.

3.1 Tread

To balance the wear resistance, low rolling resistance, and safety of the tire, the tread adopts a three-layer rubber structure, consisting of four parts: crown rubber, middle layer rubber, wing rubber, and base rubber

(1) Upper tread layer (tread cap rubber): The solution-polymerized styrene-butadiene rubber compound is selected, with the addition of an appropriate amount of silica, providing both high abrasion resistance and tear resistance, ensuring high-speed driving performance.

(3) Lower tread layer (middle rubber layer): Low heat build-up buffer rubber is used to reduce heat build-up defects in the tire shoulder during driving and extend service life.

(3) Base rubber: The thickness is set to 0.8 mm, penetrating the tread rubber to create a "chimney effect" that can discharge ground static electricity, enhancing safety during use.

The tread rubber extrusion process adopts a four-composite extrusion technology to ensure tight adhesion of the rubber compound; the sidewall is composed of sidewall rubber and wear-resistant rubber, and the shoulder rubber compound adopts a low heat build-up formula to meet the high-mileage driving requirements of electric cars.

The tread structure is shown in Figure 2.

Figure 2 Tread structure diagram

3.2 Carcass

This specification chooses polyester fiber as the carcass material. The main reason is that polyester fiber has excellent heat resistance and thermal conductivity, high strength, and minimal temperature influence. It has high resistance to deformation when subjected to external forces, with minimal elongation, which can avoid problems such as driving deviation and uneven tread wear caused by dimensional deformation, and is conducive to tire dimensional stability.

The carcass is made of double-layer polyester fiber cord fabric with a specification of 1300D/2. After calculation, the safety factor reaches 9.3, meeting the design requirements. The cord fabric is coated using a double-sided coating method and produced on an S-type four-roller calender, achieving excellent coating quality and a calender thickness controlled at 1.15 mm.

3.3 Belt layer

The belt layer is the core load-bearing component of radial tires. Its ability to restrain carcass deformation and its stress-carrying capacity directly determine the handling, durability, and safety of radial tires. Under the premise of meeting safety performance requirements, using lighter belt steel cord can not only reduce costs but also help reduce tire rolling resistance

The belt structure primarily refers to the number of ply layers, cord angle, density, as well as the structure and type of cords used. This design adopts a 2-ply belt structure: both 1# and 2# belt layers utilize 4×0.225UT steel cord, with a density of 79 EPD, a belt angle of 24°, and a tire safety multiple of 8.5 times.

3.4 Bead

The design and strength of the tire bead directly determine whether the tire can work stably and safely with the rim. It bears the internal pressure, braking torque, centrifugal force, and interference force of the rim during tire operation. The bead wire adopts Φ1.30 mm bead wire, with a rubber covering diameter of 1.60 mm, arranged in a 4-5-4 hexagonal pattern, with a total of 13 pieces. The inner diameter of the bead wire is designed to be 466.9 mm, with a safety factor of 9.0. The winding method uses a single bead wire, ensuring uniform stress during winding to ensure sufficient rigidity and strength when the tire bead is fitted with the rim. The height of the apex is 30 mm, which meets the design specification requirements.

3.5 Molding and vulcanization process

3.5.1 Forming process

Using a one-step building machine, the deformation and misalignment issues during component transfer are reduced. The head diameter is 442 mm, and the building method is crown-side, ensuring precise fit of various components of the tire body.

3.5.2 Sulfurization process

Using a hydraulic curing press and employing a conventional nitrogen curing process, the curing parameters are set as follows: external steam pressure (0.1±0.02) MPa, external temperature (178±2) ℃ , internal pressure (2.4±0.05) MPa, internal temperature (200±2) ℃ , and a curing time of 12 minutes, ensuring sufficient tire curing and stable performance.

4 Finished product performance

4.1 Outer edge dimensions

Mount the finished tire on a standard rim and measure under standard inflation pressure: the inflated outer diameter is 668 mm, and the inflated section width is 236 mm, both within the design requirements and meeting the expected goals.

4.2 Strength performance

The strength test was conducted in accordance with GB/T 4502—2023 "Laboratory Test Methods for Passenger Car Tyres Capabilities". The test conditions were: inflation pressure of 220 kPa and a pressure head diameter of 19 mm. The results showed that the average failure energy of the tire reached 545 J (touching the rim), meeting the national standard requirements and proving the excellent strength of the tire.

4.3 Bead unseating performance

The bead unseating performance test was conducted in accordance with the GB/T 4502—2023 "Laboratory Test Methods for Passenger Car Tyres Capabilities" standard. The test conditions were as follows: inflation pressure of 220 kPa, and a horizontal distance of the pressure block P=318 mm. The test results indicated that the maximum bead unseating resistance of the tire was 15586 J (already unseated), significantly exceeding the regulatory requirement of 11120 J, reaching 140% of the regulatory standard. The bead unseating performance is safe and reliable.

4.4 Durability

The durability test was conducted in accordance with the GB/T 4502—2023 standard titled "Laboratory Test Methods for Passenger Car Tyres Capabilities". The test parameters were set as follows: inflation pressure at 220 kPa, test speed at 120 km/h, and rated load at 750 kg. After completing the 35.5-hour procedure specified by the national standard, the test continued for four additional phases, with each phase lasting 8 hours. The test concluded when the total operating time reached 67.5 hours, with the actual cumulative driving time being 67 hours and 30 minutes.

After the test, the tire exhibited no visible damage, with its durability meeting 190% of the national standard requirements, and demonstrating an excellent service life.

4.5 High-speed performance

The high-speed performance test was conducted in accordance with GB/T 4502-2023 "Laboratory Test Methods for Passenger Car Tyres Capabilities", and the test conditions are shown in Table 2.

The results showed that the tire achieved a maximum test speed of 290 km/h, and after continuous running for 1 hour, its appearance remained undamaged, with good high-speed performance, meeting the Y-grade speed standard requirements

Table 2 Test conditions for high-speed performance of passenger car tires with speed symbol Y

Trial phase	Test Speed / (km·h^{-1})	Test Duration/min
1	0~260	10
2	260	20
3	270	10
4	280	10
5	290	10

Note: Inflation pressure is 360 kPa, and rated load is 750 kg

4.6 Rolling resistance

According to the provisions of GB/T29040, the rolling resistance of the test tires was measured, and their rolling resistance coefficient was calculated. The determination value was calculated according to the provisions of GB/T29042. The average rolling resistance coefficient of the finished tires is 6.28 N·kN, which meets the development target requirements for electric car tires.

5 Conclusion

235/45R18 is a typical specification for mid-to-high-end passenger car tires. The product developed this time meets the design goals and national standards in terms of inflated outer edge dimensions, strength performance, bead unseating performance, durability, high-speed performance, and rolling resistance, satisfying the requirements for safety, durability, and energy efficiency in tire use. The beautiful pattern design can meet consumers' demands for a "personalized and high-end" appearance. The sales of this product can enhance both our company's market competitiveness and economic benefits, making it a mature product that aligns with the current trend of electrification.