Research on Modeling and Lightweight of Automobile Hub

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Abstract: This paper studies the application of industrial design concept in automobile hub design, and uses the localized design method to integrate Chinese cultural elements into the hub design and complete the creative hub design. The radial load and bending moment load of the hub are analysed by finite element method to verify the safety of the hub structure, and the lightweight design of the hub is carried out by analysing different materials.

1 INTRODUCTION

The development of wheels has gone through a long time. In ancient times, they were made of wood, but now they are made of aluminium alloy. In some western countries, the development history of wheels can be traced back to a hundred years ago. Aluminum alloy wheels appeared in 1920 (Yi, Deng Li, 2012). They were originally manufactured by sand casting and were only used in racing cars. In 1930, aluminium rolled rims and steel spoke wheels were introduced and implemented in some simple automobiles, which was a prerequisite for the development of aluminium alloy wheels later. Due to the impact of the global energy crisis, the automotive industry has put forward an urgent need for "lightweight", and aluminum alloy wheels have begun to be widely used in ordinary automobiles (Parry G, Roehrich, Jens, 2013).

China develops its own automobile brand by drawing lessons from foreign advanced automobile design and manufacturing technology. In order to rapidly develop the automobile industry, China constantly introduces foreign advanced technology and cooperates with foreign enterprises. Therefore, more and more automobile brands have entered China and occupied the majority of the Chinese automobile market. With the development of domestic brands and the limitation of automobile brand technology patents, Chinese manufacturers have to pay high technology costs to foreign enterprises. Therefore, it is of practical significance to study the shape and lightweight of wheel hub for the localization of automobiles.

2 MODELING DESIGN OF AUTOMOBILE HUB

National culture is a culture created by a long-term campaign and productive working country, which brings together the wealth and resources of the country. Chinese national culture is composed of 56 beautiful Chinese cultures. There are 56 different cultures and related species, which are composed of China's long-standing culture. Chinese elements are built from Chinese national culture, which is a symbol of Chinese national culture. In short, it is a microcosm of national culture. It embodies the spirit of national culture and is recognized by Chinese and overseas Chinese.

2.1 Hub Modeling Scheme

Modeling design can choose words or graphics with Chinese characteristics, contouring the selected objects to reflect the characteristics of the selected objects, and then simplifying their contours into lines and graphics for early drawing design.

Scheme 1: The Chinese character "中" is used as the design element, and "中" also represents a spirit of the Chinese people. In ancient China, the doctrine of the mean was regarded as a virtue by scholars and the highest virtue by Confucianism. As shown in the Figure 1.

Scheme 2: The design element is "flame" totem. The ancients got inspiration from the sun and created the decoration of "flame". The characteristic of flame totem is circular, which conforms to the

design requirements of wheel hub. It refines and simplifies the pattern form, and completes the design conception of the early drawing. The fire in the picture revolves around the center circle and is full of dynamic feeling. There is a kind of combination of rigidity and softness in the overall form, which is in line with the Chinese aesthetics, and reflects the concise sense of modern design. As shown in the Figure 2.

Scheme 3: The design elements are "Pentagon" pattern. "Pentagon" is a very solemn and sacred pattern for Chinese people. The national flag of China is a "five-star red flag" with Pentagon pattern. The features of the pentagonal star pattern are concise, clear and concise, and an outer circle can be drawn on the pentagonal star, which is fully connected with the pentagonal star. Therefore, the pattern is very suitable for the shape characteristics of the hub. As shown in the Figure 3.
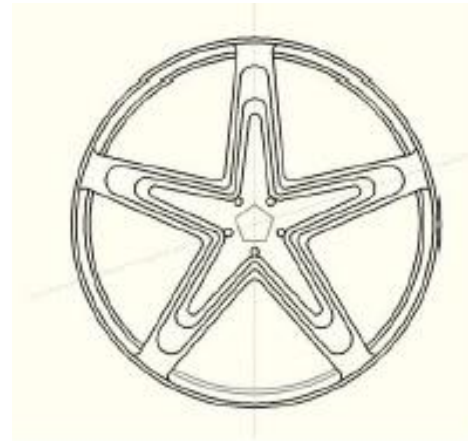

Figure 1. "中"scheme.

Figure 2. "Flame" scheme.

Figure 3. "Pentagon" Scheme.

2.2 The Choice of Final Scheme for Hub Modeling

When choosing the hub modeling scheme, the method of questionnaire is used to select the hub. Create a questionnaire about hub shape, and put the model effect maps of three schemes into the questionnaire, and release the questionnaire. The results of the questionnaire are shown in Figure 4.
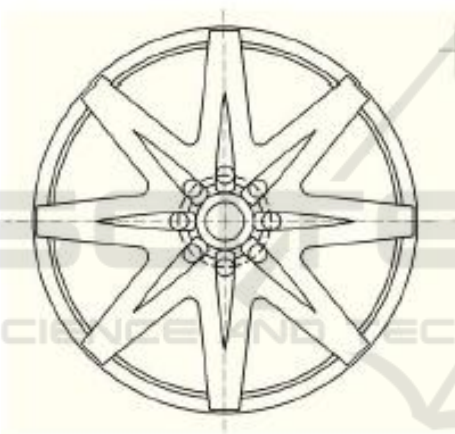

Figure 4. Questionnaire results.
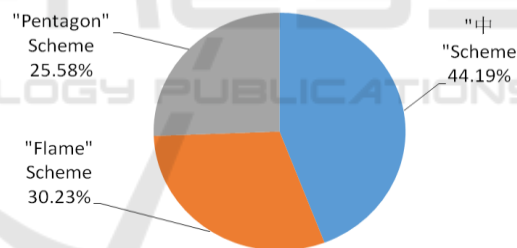
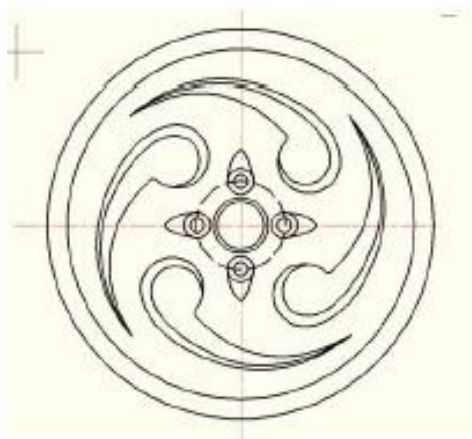## 3 FINITE ELEMENT ANALYSIS OF HUB BASED ON HIGH STRENGTH STEEL

In this section, the hub material is Q460 high strength steel, and its performance parameters are as shown in Table 1.

Under the actual operating conditions, the movement of the bolt hole surface is restricted in all directions. Therefore, the surface of the bolt hole is restricted, and the six degrees of freedom of the conical surface of eight bolt holes are restricted.

3.1 Finite Element Analysis of Radial Load

Taking a certain vehicle as an example, according to the configuration parameters of the vehicle, the vehicle's complete mass is 1278 kg, and the mass at full load is 1800 kg. Then the vehicle's weight is W = 12525N, and the load at full load is G = 17640N. According to the fatigue test criteria of car wheels, the maximum load on the hub is calculated by formula (1).

$$F_{max} = \frac{W \cdot n_i}{3} + \frac{G}{6} \qquad (1)$$

ni - Load impact factor, with a value of 1.21 (LI Qiushi, LI Simin, PAN Tianyu, 2018).

The maximum load of hub calculated by substitution data is 7992N.

As can be seen from Figure 5, the maximum displacement of the hub is 0.18062 mm, the deformation is small, and the requirement of the hub is that the strength and deformation are small, so the stiffness of the hub meets the requirement. From Figure 6, it can be seen that the maximum stress is 136.78 Mpa, which is less than 250 Mpa of cyclic yield strength of high strength steel. Therefore, under this load condition, the structure can operate safely and steadily without yield failure, and the hub strength meets the requirements.
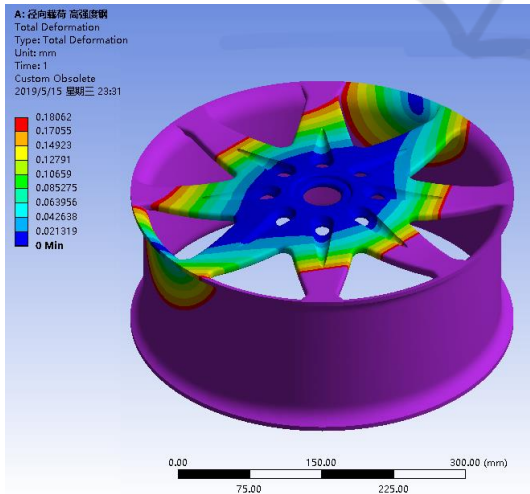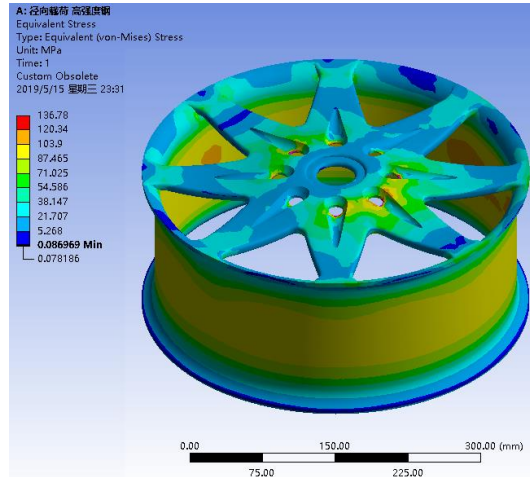

Figure 5. Displacement nephogram.

Figure 6. Stress nephogram.

3.2 Finite Element Analysis of Bending Moment Load

The moment M applied to the load is determined by equation (2):

$$M = (R \cdot \mu + d) \cdot F_{max} \cdot S \qquad (2)$$

R-static load radius, 0.35; μ-Friction coefficient, 0.7; D-Hub offset,0.035;S-Safety factor, 1.6 (Zhao O, Gardner L, Young B, 2016).

The bending moment load of hub calculated by substituting numerical value is 3581N.m.

As can be seen from Figure 7, the maximum displacement of the hub is 0.48726 mm, the deformation is small, and the rigidity of the hub meets the requirements. From Figure 8, it can be seen that the maximum stress is 188.45 Mpa, which is less than 250 Mpa of cyclic yield strength of high strength steel, and the hub strength meets the requirements.

4 LIGHTWEIGHT DESIGN OF WHEEL HUB BASED ON ALUMINIUM ALLOY

In this section, the hub material is 6061 aluminium alloy, and its performance parameters are as shown in Table 2.
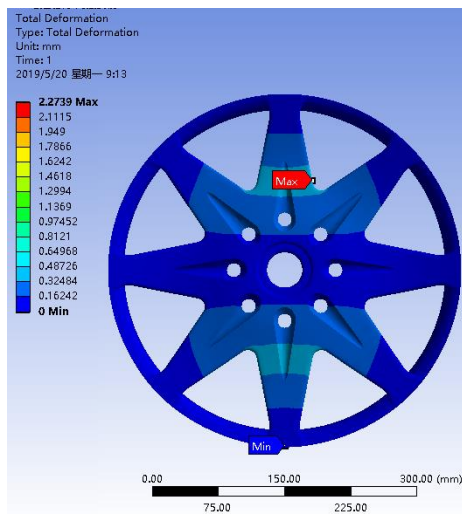
Figure 7. Displacement nephogram.

Figure 8. Stress nephogram.

4.1 Finite Element Analysis of Radial Load

As can be seen from Fig.9, the maximum displacement of the hub is 0.53664mm, the deformation is small, and the rigidity of the hub meets the requirements. It can be seen from Fig.10 that the maximum stress is 136.17 Mpa, which is less than the cyclic yield strength of aluminum alloy material 280 Mpa, and the hub strength meets the requirements.

4.2 Finite Element Analysis of Bending Moment Load

According to the analysis results, it can be seen from the displacement nephogram that the maximum

displacement of the hub is 0.84975mm, the deformation is small, and the rigidity of the hub meets the requirements. From the stress nephogram, it can be seen that the maximum stress is 202.21 Mpa, which is less than the cyclic yield strength of aluminum alloy material 280 Mpa, and the hub strength meets the requirements.
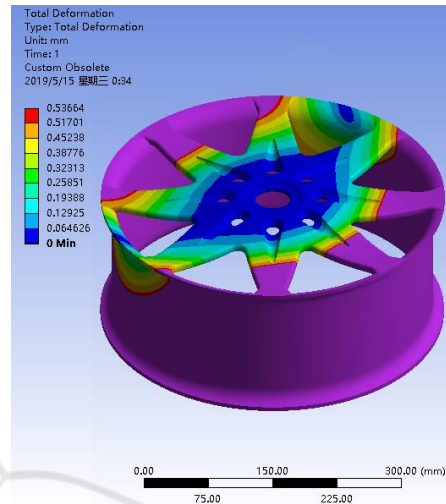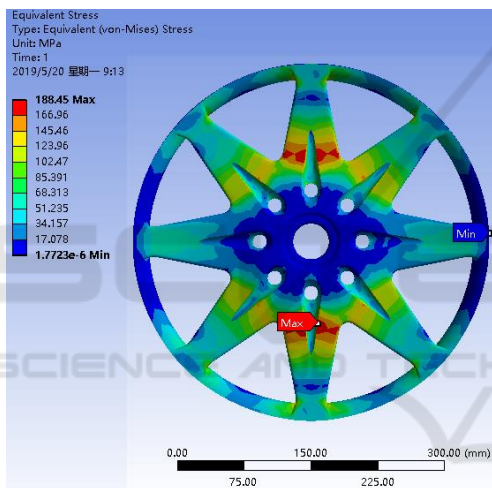

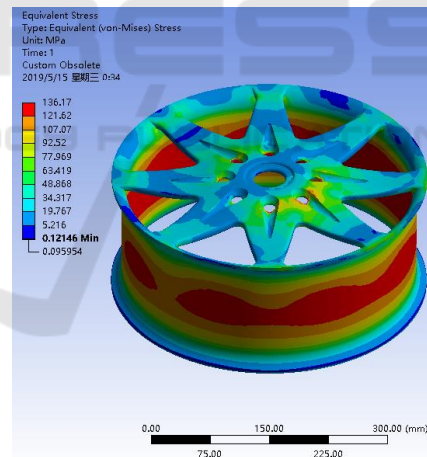Figure 9. Displacement nephogram.

Figure 10. Stress nephogram.

5 COMPARISONS OF HUB MATERIAL ANALYSIS RESULTS

5.1 Comparison of Finite Element Analysis Results

It can be seen from Table 3 that in the finite element analysis of radial load and bending moment load, the

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Table 1. Material properties of Q460 high strength steel.

Material	Density (g/cm3)	Young's modulus (MPa)	Yield strength (MPa)	Tensile strength (MPa)	Poisson ratio
Q460	7.85	2.06×105	460	550	0.35

Table 2. Material properties of 6061 aluminium alloy.

Material	Density (g/cm3)	Young's modulus (MPa)	Yield strength (MPa)	Tensile strength (MPa)	Poisson ratio
6061	2.77	7.1×104	280	310	0.33

maximum displacement deformation of the two materials is smaller and the stiffness meets the requirements, but the deformation of the aluminum alloy is larger than that of the high strength steel; the maximum stress of the two materials is smaller than that of the cyclic yield strength of the material, so the two materials are stronger. All degrees meet the requirements. In the radial load, the maximum stress of the two materials is basically the same, so the strength of the two materials has little difference. In the moment load, the maximum stress of the aluminum alloy is greater than that of the high strength steel. The reason for this phenomenon is that the deformation of the aluminum alloy is larger than that of the high strength steel, which leads to the material need. It takes more force to restore deformation under load. Aluminum alloy has better toughness and impact strength than high strength steel, so it is more suitable for use as hub material than high strength steel.

5.2 Comparison of Finite Element Analysis Results

As can be seen from Tab.4, the price of aluminium alloy material is much higher than that of high strength steel, while the cost of aluminium alloy in manufacturing is lower than that of high strength steel, while the quality ratio of aluminium alloy is smaller. Therefore, the total cost of the two materials is similar, and the total cost of aluminium alloy is slightly higher than that of high light steel. However, according to the comparative analysis of Table 1, Table 2 and Table 3, the performance and economy of aluminium alloy are better than that of high strength steel.

Table 3. Comparison of finite element analysis results.

Material	Maximum displacement(mm)		Maximum stress	
	radial load	bending moment load	radial load	bending moment load
steel	0.18062	0.48726	136.78	188.45
6061	0.53664	0.84975	136.17	202.21

Table 4. Material price comparison.

Material	Mass ratio	Material price	Manual Hours Cost	Total cost
steel	0.8	3.4	0.88	2.38
6061	0.56	8.2	0.56	2.54

6 CONCLUSIONS

Based on the aesthetics of industrial design, the hub is modeled by extracting elements from traditional Chinese culture. The strength performance of the hub is analyzed by finite element analysis method. Then, through the performance analysis and comparison of different materials, the design method of integration of hub modelling and lightweight is discussed.

ACKNOWLEDGEMENTS

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