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Research on lightweight of automobile body based on multi material structure

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ABSTRACT:with the continuous increase of automobile ownership in China, the contradiction between market demand and energy and environmental constraints is becoming more and more prominent. Traditional fuel vehicles will develop towards efficient and low emission electric vehicles. Automobile lightweight is the general trend. The lightweight technology of automobile body mainly includes the use of lightweight materials and the lightweight design of structure. In practice, the two are closely connected, and lightweight materials are often used in combination with lightweight structural design. The most obvious feature of body lightweight is the choice of materials.

KEYWORDS:materials; Automobile; Body; Lightweight

I. INTRODUCTION

Under the premise of ensuring the strength and safety performance of the vehicle, the lightweight of the vehicle is to reduce the servicing quality of the vehicle as much as possible, so as to improve the power of the vehicle, reduce fuel consumption and reduce exhaust pollution [1]. In order to reduce the body weight, it is also necessary to ensure that it does not affect the overall performance of the vehicle, reduce the design trend of the body mass, and require the structural characteristics of the body strength, stiffness and mode. Therefore, the lightweight design of automobile is required to be fully combined with many different disciplines, such as materialanalysis, structural mechanics, production technology, ergonomics, industrial design, transportation and economic benefits, so astocarry out comprehensive research and development.

With the continuous consumption and reduction of current energy, the development of automobile lightweight has become the only way for the sustainable development of the automobile industry [2]. The design of new structures, the use of new materials and the development of new processes are closely related to each other and are limited to each other. Comprehensive and balanced development can promote the development of the whole lightweight. In this paper, the electric vehicle body with multi material structure is taken as the research object. Based on the idea of suitable materials for parts, and considering the structural performance of the body, its quality and cost are compared. This paper studies the current vehicle lightweight technology concept, gives a reasonable lightweight method and optimization scheme, and studies the lightweight of electric vehicle body.

In order to further improve the driving range of automobile, the research on Lightweight Technology of automobile body is of great significance to the healthy and sustainable development of automobile industry and China's social development and energy strategy. Although the development of automobile lightweight in China is relatively late, with the popularization of electric vehicles and the support of government policies, the lightweight technology in China has developed rapidly. At present, in the research of electric vehicle body lightweight [3], the vehicle lightweight has changed fromdecentralized and high-end to popular and diversified. Thedevelopment of lightweight devices is driven by a variety of demands, such as intelligent network connection, energy conservation, emission reduction and performance improvement. The development of automobile lightweight technology will become the future development direction of automobile technology, and also the main direction of automobile research in the future.

MAINWAYS OF AUTOMOBILE BODY LIGHT WEIGHT

In order to complete the lightweight of automobile, the use of lightweight materials and lightweight design of structure can be adopted. The use of lightweight materials is the main research direction of lightweight body. Light metal and non-metal materials are mainly used, including high-strength steel, aluminum magnesium alloy,

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engineering plastics, carbon fiber, new glass ceramics and various composite materials [4]. Using finite element method and optimization design can effectively realize the lightweight of the structure. In practice, under the premise of not reducing the performance, light materials are often used to closely combine, summarize the lightweight technology of electric vehicles, and combine the lightweight structure design to obtain the lightweight of the body.

Lightweight materials shall be designed for lightweight structures through an excellent manufacturing process. While lightening the automobile, other performances of the automobile shall also be ensured. Considering the technical conditions and costs of new materials currently used, high-strength steel, aluminum alloy and engineering plastics have been widely used. Although magnesium alloy, carbon fiber and other composite materials have better effects. However, its material application is still in the research and development stage. In the design and development, through optimizing the force transmission path and improving the channel interface to achieve the lightweight of the automobile body. It can also realize the lightweight of the automobile through the optimization of weight reduction holes and decorative lines. In the application of manufacturing technology, the current hot stamping and hydraulic forming continue to innovate and gradually mature, and continue to achieve mass production and application.

At present, lightweight materials are becoming more and more popular, and the proportion of high-strength steel in the market demand is rising. As shown in the figure above, blue represents the world, and red represents China. Magnesium alloy is one of the lightest metal structural materials in the automotive industry [6], and most of magnesium alloys are used in the automotive industry. Compared with aluminum alloy, magnesium alloy can reduce 15%-20%. Magnesium is only 22% of iron and 66% of aluminum by weight. Magnesium is easy to process, can well absorb impact and has high recovery rate. However, it has the disadvantages of high price, high temperature resistance and easy corrosion. When the resin, carbon, metal and ceramic are used as the matrix materials of plastics, they are carbon fiber composites [7]. It can be divided into matrix composites, ceramic matrix composites (CMC) and metal matrix composites (MMC) according to their uses [8]. Carbon fiber composites have good fatigue resistance, so they are widely used.

Lightweight Body Structure Optimization

The structural optimization design and finite element analysis method of "changing the structural strength" can be used to reduce the body frame,

LIGHTWEIGHT MATERIALS

At present, high-strength steel, aluminum alloy, magnesium alloy and carbon fiber composite are the main materials used for automobile lightweight. In terms of weight reduction effect, high-strength steel is smaller than aluminum alloy, magnesium alloy and carbon fiber [5]. In terms of cost, high-strength steel is less than aluminum alloy, and magnesium alloy is less than carbon fiber automobile lightweight.

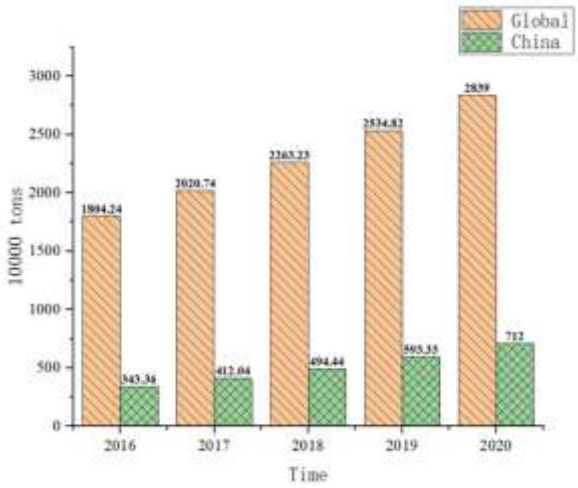

Fig.1 Trend of demand for high strength steel

reduce the body frame, reduce the thickness of parts, hollow, miniaturized, modular and composite automobile structure, improve the mass of automobile structure body parts and other components, and reduce the weight. In the aspect of structural optimization, the reasonable design of the parts' structure also requires the calculation of strength and stiffness, and the analysis of the shape, configuration and plate thickness of each part. The wall thickness of parts is reduced, the quantity is simplified, and the structure is integrated and reasonable. Figure 3-1 shows the upper beam assembly of a finite element model radiator of an automobile. Through structural optimization design, streamlined parts reduce the weight of 2.2 kg on the premise of ensuring safety.

When it is necessary to specify the distribution of materials in the design space, it can be analyzed by topology optimization, and the optimal power transmission path can be automatically obtained through the topology algorithm, so as to save materials as much as possible. The optimal distribution of materials in the space can be realized by topology optimization, which can combine the weight reduction design of automobile parts with the optimization design of automobile structure. So that it can obtain a lighter structure under the condition of

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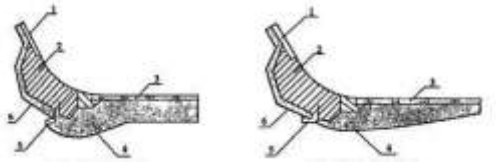
meeting the performance conditions of the parts.

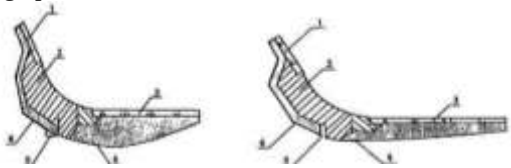
The optimal layout of the whole or partof thebody structure is achieved by considering the actual working conditions through layout optimization. For example, the front driver device can be used to reduce many transmission system components to reduce weight. In addition, the use of the load-bearing body can eliminate the frame and reduce the weight of the vehicle body.

In the process of size optimization, it is necessary to optimize the plate thickness, beam section and section moment of inertia according to the optimization objectives of mass and strength, so as to make the stress distribution uniform. At the same time, in order to meet the stiffness, strength, vibration and other limitations of energy absorption under different working conditions, the size of automotive parts (such as the wall thickness of stamping parts, the cross-sectional size of beams, the size of weight reduction holes, etc.) is often taken as design variables, and the linear static problems and linear vibration problems in lightweight design are solved by using traditional numerical optimization algorithms. The linear elastic dimension optimization design method can optimize the components used in the automobile and reduce the volume and weight of the automobile.

As shown in Figure 2, the shape of the structure can be changed, and the overall or local shape of the structure can be changed to make the structure subject to more uniform stress, so as to make full use of materials. Use the finite element method to avoid stress peaks and make the stress distribution as uniform as possible. The specific method is to store or reinforce the materials on the parts bearing high load, and thin or remove the materials on the parts bearing low load.



Design change process 1Design change process 2



Design change process 3Design change process 4

Fig.2 shape optimization design

Some structures have geometric shapes, and we can parameterize the geometric shapes of those structures, so that shape optimization can be transformed into size optimization. The problem we are facing now is that the automobile structure is more irregular geometry, so it will be difficult for us to use parameters to describe the geometry. Then it can not be transformed into a size optimization problem. In order to better solve this problem, we can only widely use the nonparametric shape optimization method without size parameters.

II. MANUFACTURING PROCESS OF MULTI MATERIAL BODY

At present, with the application of materials and optimized body structure, some new manufacturing processes can also meet the changes of materials and structure, so as to realize the lightweight of automobile body. For the current common body design, processes such as laser cutting, hot stamping and hydraulic forming have been widely used.

The technology of laser processing has been mature and applied. The blanks processed by laser are made of different materials, so that the slabs with different surface coatings and strengths are pressed together as a whole. It is also used in the manufacture of door inner panels, reinforcement panels, struts, base plates and wheel housings. According to the material and thickness of the part, it can be welded into a complete part by laser welding technology. According to the material and thickness of the part, it can be welded into a complete part by laser welding technology, and then stamping the required part shape, which can reduce the consumption of resources. For example, the total length of laser welds on a certain vehicle body is 70mm. If the laser tailor welded blanks can be used to reduce the number of parts, make local steel plates thinner and even remove the spot welded flanges, then the weight of the vehicle body can be reduced. The edge of the inner plate of the door needs to be hinged, so a 2mm thick cutting plate needs to be applied on the 0.8mm main plate to strengthen it. Since no additional stiffeners are required, the total weight of the door is reduced by 1.4kg.

When the yield strength and tensile strength of high-strength steel plate increase, the drawback is that it will reduce the stamping formability, so many forming defects will exist, and a large forming force and serious springback will occur, which will lead to the deterioration of the size and accuracy of parts. If the degree exceeds 1000MPa, the hot stamping process of high-strength steel can occur, which is zero for those with complex geometry. Because it can not be formed by ordinary cold stamping process. The hot stamping process first needs to heat the high-strength steel plate to austenite state, and then quickly transfer

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it to the die for stamping. The workpiece in the die body is cooled at a temperature greater than 27 ° C / s, and it must be ensured that it is under certain pressure conditions. In order to make ultra-high strength steel parts have uniform martensite structure, it is necessary to carry out quenching treatment and pressure maintaining quenching for some time.

Hydroforming process usually has three processes: pre forming, forming and calibration, which can be used for plate and pipe forming [9]. The sheet metal hydroforming technology is especially applicable to the hydroforming process of the outer panel. Due to the pre forming, the material will produce the required prestress, so that the wall thickness of the door and other outer panel components can be reduced, while maintaining the same impact resistance, so as to achieve the lightweight effect.

The processing methods of aluminum alloy include casting, die casting, rolling, extrusion and stamping [10]. Aluminum alloy is more and more widely used in automobile body because of the use of non hole die casting, stamping die casting and pinhole die casting in automobile design and manufacturing. The most popular method is the non hole die casting method, because it enables high-quality die-casting parts without holes and heat treatment. For the anti-collision beam, although the manufacturing cost of aluminum alloy anti-collision beam is higher than that of steel [11], its safety factor is higher and it is safer for passengers and drivers.

The most obvious feature of light vehicle weight is the selection of materials. Nowadays, new materials such as high-strength steel, aluminum alloy, magnesium alloy and carbon fiber have been widely used in the body of electric vehicles. Tesla, the global pioneer of electric vehicles, has already begun to study the lightweight of electric vehicles.

III. BODY MATERIAL STRUCTURE COMBINATION AND OPTIMIZATION

The BIW Welding of Buick b823 adopts advanced CMT welding technology, which can ensure the welding quality between aluminum parts [12]. In addition, by riveting and bonding aluminum parts to high-strength steel parts, b823 model has perfectly verified the lightweight manufacturing process. Therefore, the lightweight design of vehicle body should also consider the combination of vehicle body materials and structure, and further optimize the design reasonably.

PUNCHING AND HOLLOWING OF METAL MATERIALS

We can reduce the weight of the car body through reasonable hole design for some car body parts or plates. Of course, we need to ensure the safety of the car body and whether the strength of the structure meets the requirements. This can be achieved by optimizing the structure of the frame and BIW through finite element analysis software. At the same time, the use of ultra-high strength steel and aluminum alloy materials will have a more prominent weight reduction effect.

Fig.3 Hollowing out treatment of metal parts

As shown in Figure 3.1, these holes are not randomly marked. The accurate computer simulation is used to obtain the drilling plan, so as to avoid the occurrence of resonance. If it is a place with air circulation, the impact of noise must be considered and sound insulation materials must be added to fill the noise. Punching and hollowing out metal parts and stamping metal materials into special-shaped protruding structures not only have light weight, but also improve structural strength and ensure safety.

CONVERTING SPLIT MOLDED TAIL TO BLOW MOLDING

When the car is running at high speed, the rear spoiler can be added. The power and operational stability of high-speed vehicles can be improved by adding the rear spoiler, because it can reduce the lift at the rear of the vehicle, thereby increasing the ground adhesion of the wheels. Due to the light weight of the rear spoiler, the impact is small. The main factor affecting its performance is the shape. The weight of the FRP spoiler produced by compression molding is 2.68kg, and the ABS (acrylonitrile butadiene styrene copolymer) resin or PC + ABS (engineering plastic alloy) alloy resin plate produced by blow molding process is only 1.5kg. Compared with compression molding, blow molding can reduce weight by 44% and unit cost by 18%. Blow molding process can integrate complex parts with less manufacturing time, which is conducive to rapid industrial manufacturing. Therefore, the application of blow molding to some special parts of the car body is conducive to the

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lightweight of the car body. This shows that this can be said to be an effective way of processing and transformation.

Table 1 comparison of quality and cost between FRP rear spoiler and ABS, pc+abs spoiler

Part name	Material Science	weight	Cost (yuan)
Rear spoiler of a vehicle model	FRP	2.68	C1
	ABS,PC+ABS	1.50	C2
ABS,PC+ABS advantages	----------	Weight reduction 44%	Cost reduction by 18%

As shown in table 1, compared with the molded FRP spoiler, the blown ABS resin or PC + ABS alloy resin automobile rear spoiler can reduce the weight by 44% and the cost by 18%. Therefore, it is a good choice for automobile design.

Split Type Side Wall Replaces Integral Type

Figure 4 shows an exploded view of the split sidewall and the integrated sidewall (the sidewall of two SUVs of similar size) on the same platform. We can find from the figure that the split side parts are more, so it is easy to change the vehicle model, and the material utilization rate is higher than that of the integral type. For example, the windshield pillar reinforcement panel can allow separate side walls to replace many reinforcement panels. According to CAE analysis, compared with the integrated sidewall, the split sidewall with thinner thickness and lower material strength reinforcing plate can meet the impact performance requirements.

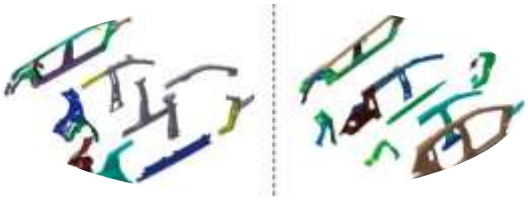

Fig.4Side wall explosion photos of split type (left) and integral type (right)

As shown in table 2, the weight and cost of split and integral side wall components are compared. It can be seen that the automobile frame is an important structural component of the automobile [12]. Compared with the overall structure, the split structure reduces the weight by 37% and the cost by 25%. From the point of view of light weight and cost reduction, the split side wall is a better structural design choice.

Table 2Comparison of split and integral side walls

Part name	Weight (kg)	Cost (yuan)
Split side wall assembly	14.40	C1
Integral side wall assembly	22.76	C2
Split advantage	Weight reduction 37%	Reduce costs by 25%

IV. CONCLUSION

In China, the application trend of automotive lightweight materials is obviously diversified. A single body material will no longer meet the strength and stiffness required by the current body. Therefore, in the future development of the car body, its lightweight materials will realize the combined manufacturing of a variety of materials. In the car body processing and manufacturing technology, it will mainly control the use of processing materials and develop recyclable materials, so that the car body can not only meet the requirements of lightweight, but also have the advantages of low energy consumption, effectively improve the utilization rate of materials, use various technologies to improve the safety factor of the human body, and improve the shortcomings of traditional processes, In this way, the lightweight requirements can be met in the production and manufacturing of car bodies.

When the prototype vehicle is trial produced, the overall test of the vehicle and the summarized design experience meet the requirements, it is meaningful to realize the lightweight application of the vehicle by optimizing and improving the body structure. Of course, the situation that cannot be ignored is that the overall vehicle structure should meet the national vehicle safety standards. Of course, the lightweight design and safety of the automobile should meet the requirements, and the automobile performance should meet or even exceed the requirements of the traditional steel body. In addition, it is necessary to increase the bending strength,

torsional strength, roll strength and collision energy absorption of the body structure to further ensure the safety of passengers when meeting the requirements of various regulations.

In short, lightweight helps to increase the lightweight and endurance of the whole vehicle. At the same time, it should also be considered that it meets the requirements of vehicle safety performance. It is more important to comprehensively consider the optimization of new materials and structures, and then better achieve the lightweight of vehicles by combining new production processes [13]. Therefore, only through the application of new materials, new structures and new processes, can we achieve lightweight while ensuring its safety, and obtain a low-cost, lightweight body.

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