Key Technologies of Lightweight Technology of New Energy Vehicles

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Abstract: New energy vehicles mainly use three electric systems: battery, motor and electronic control. Although this system can effectively increase the application ability of new energy vehicles and improve the technical level of new energy vehicles, it greatly increases the self-weight of new energy vehicles and seriously affects the power, braking, safety, endurance and battery consumption of new energy vehicles. Lightweight research and development of new energy vehicles is the development trend of new energy vehicle industry. This paper explores the lightweight of new energy vehicles from three aspects: structural design, research and development of new materials and selection of new manufacturing technology. New materials include high-performance automotive plastics, carbon fiber composites, aluminum alloys, high-strength steel and so on. The new manufacturing technology includes laser splicing, laser-arc hybrid welding technology, friction stir welding technology, internal high pressure forming, hot pressing forming and so on. The above lightweight technology of new energy vehicles can continuously reduce the self-weight of new energy vehicles and extend the endurance level of new energy vehicles, which will be the core of future market competition of new energy vehicle manufacturing industry. Domestic and foreign automobile enterprises will continue to study the lightweight technology, and the lightweight new energy vehicles will bring greater benefits to mankind.

1. Introduction

In recent years, China's new energy automobile industry has developed rapidly. According to the latest statistics released by China Automobile Industry Association, in 2022, China's new energy vehicles continued to grow explosively, with production and sales reaching 7.058 million and 6.887 million respectively, up by 96.9% and 93.4% respectively, ranking first in the world for eight consecutive years. The market share increased to 25.6%, higher than the previous year's 12.1%, and the global sales accounted for more than 60%.

In the development of new energy automobile industry, green manufacturing is one of its main characteristics, and energy saving, consumption reduction, emission reduction and safety improvement have become the development direction of automobile industry. As we all know, new energy vehicles mainly use three electric systems: battery, motor and electronic control. Although this system can effectively increase the application ability of new energy vehicles and improve the technical level of new energy vehicles, it greatly increases the self-weight of new energy vehicles and seriously affects the power, braking, safety, endurance and battery consumption of new energy vehicles. Data research shows that reducing the weight of new energy vehicles by 20% can effectively increase the endurance by about 5% ~ 10%, save the battery cost by about 15% ~ 120%, and effectively reduce the loss of new energy vehicles in daily use [1]. Therefore, the lightweight research and development of new energy vehicles is the development trend of new energy vehicle industry. The lightweight of new energy vehicles can be studied from three aspects: structural design, research and development of new materials and selection of new manufacturing technology.

2. Lightweight Structure

Optimizing the vehicle structure design is one of the important ways to realize the lightweight of

new energy vehicles, that is, by optimizing the vehicle structure design, the weight of the vehicle body can be reduced. Generally, the design can be optimized from three aspects. First of all, without changing the strength parameters of the automobile itself, through the simplified design of the whole automobile structure, the number of new energy automobile parts is reduced, so as to achieve the purpose of lightweight automobile.

Secondly, on the premise of not changing the overall performance of new energy vehicles, the volume of automobile parts is reduced by reducing the size of automobile parts, so as to achieve the purpose of lightweight automobile. Advanced CAE software technology is used to analyze and optimize the corresponding parts, so that they can meet the performance requirements of strength, stiffness, collision safety, fatigue life, cost and so on [2]. Structural analysis mainly improves the utilization rate of materials by optimizing structural parameters. This can not only remove redundant components, but also realize the thinning, hollowing, miniaturization and compounding of parts, thus realizing the lightweight of the structure [3].

Finally, in the process of production and layout of new energy vehicles, the overall volume of the vehicle is reduced through the compact structural layout of parts, so as to achieve the purpose of lightweight. Among structural optimization techniques, topology optimization is an innovative optimization technique, which can find the best layout path of materials in a fixed optimization space under given performance conditions. After deciding which areas need to be reserved for important parts, topology optimization method can be used to optimize the overall structure of the car body. Topology optimization methods include variable density method, level set method, homogenization method, evolutionary structure optimization method, independent continuous mapping method, etc. [4].

3. Lightweight Materials

3.1 High-Performance Automotive Plastics

As one of the main automobile materials, plastic is widely used in all aspects of automobile interior and exterior decoration because of its advantages of weight reduction, energy saving, economy, comfort and durability. In recent years, with the increasing output of new energy vehicles, higher requirements are put forward for automotive plastics.

Most of the plastics are made of plants, which solves the problem of non-degradation of traditional automotive engineering plastics, and has trans-generational significance. Because it uses renewable raw materials with low toxicity and harm, it can greatly reduce the volatile amount of VOC in the car as an automobile interior decoration. In addition, it can be decomposed and subsequently recycled, so it will not cause ecological burden and be more environmentally friendly. As early as 2010, Toyota Motor Corporation announced the use of a new bio-plastic. 30% of the raw material of this plastic is extracted from sucrose, which is mainly used for interior decoration such as doors, cushions and wear plates. Up to now, the application of bioplastics has extended beyond the automobile decoration parts. At present, many bioplastics are used in automobile manufacturing, such as polylactic acid (PLA), polybutylene succinate (PBS), bio-based polyamide (PA), natural fiber composites, polyhydroxyalkanoate (PHA), etc [5].

3.2 Carbon Fiber Composites

Carbon fiber technology means that organic fibers, such as flaky or broken stone ink crystals, are laid in the axial direction according to a certain organizational structure by artificial synthesis technology to achieve strong mechanical properties, and finally meet the needs of the mechanical combination of materials and the application of new profiles such as magnesium and aluminum alloys. The application of composite materials based on resin and metal in automobile body is mature, and it has many advantages in manufacturing technology. Compared with similar steel parts, the parts made of carbon fiber composite materials have a mass of only 50%. Compared with aluminum parts, its mass is only 30% [6].

At the same time, the corrosion resistance of carbon fiber material and the shielding function of

battery structure far exceed those of similar steel materials with the same size. Therefore, the use of carbon fiber technology in new energy vehicles can ensure that the original performance indicators of the vehicle remain unchanged and achieve the goal of lightweight of the vehicle. As far as the manufacturers of new energy vehicles around the world are concerned, the use of carbon fiber technology is still in the initial research and exploration stage. For example, BMW is at an advanced level in the technical use of carbon fiber. In the BMW i3 series, carbon fiber materials have been widely used, and compared with steel materials, it has made a contribution of about 300kg in reducing the weight of automobiles. In other automobile manufacturers, the application of carbon fiber technology has not achieved the purpose of mass production, but the precedent of successful application of carbon fiber technology in mass production of BMW automobile can provide solid support for the use of carbon fiber technology in new energy vehicles to reduce the dead weight of the whole vehicle, and can also promote the further development of carbon fiber technology. At present, the application of carbon fiber technology in new energy vehicles in China has achieved good results. Many automobile manufacturers have applied carbon fiber materials to mass production of automobiles through their technology research and development and market practice, which has reduced the actual total weight of automobiles by about 50% and helped to improve the endurance of new energy vehicles. Relevant data show that through the application of carbon fiber technology, the actual endurance of new energy vehicles can be as high as 440km [1].

3.3 Aluminum Alloy

The density of aluminum alloy is relatively small, which is only about 30% of that of steel material. This material is extremely plastic and easy to be extruded. But also has good corrosion resistance, high strength and good toughness. Compared with the car body made of steel, aluminum alloy can reduce its weight by 30 ~ 40% for the same car body structure. Under the same structure, the mass of aluminum hub will be reduced by 10% ~ 15% compared with steel hub [7]. In modern automobile production technology, the application scope of aluminum alloy is expanding and becoming more and more common. At present, aluminum alloy materials are mainly used in new energy vehicles.

With the continuous maturity of the research and development technology of BMW New Seven Series and BMW Group's new energy vehicles, the proportion of BMW series vehicles in the application of composite materials has reached a new height. As an important representative of this automobile manufacturing enterprise, BMW 3 Series is a typical model widely welcomed in the market. With the help of mass production of composite materials, BMW 3 Series has made the carbon fiber and polymer composite technology manifest in the lightweight process. It can also maximize the application efficiency of carbon fiber composite materials in the upper part of the car body through the strong combination of its carbon fiber composite body structure and aluminum alloy body structure. While combining the aluminum alloy lower frame structure with the battery structure, it ensures the strong combination of the upper new materials and the optimized lower frame design, and ensures that the weight of the whole car is reduced by more than 300kg [1].

3.4 High Strength Steel

There are two kinds of high-strength steel: ordinary high-strength steel and advanced high-strength steel. Ordinary high-strength steel mainly refers to bake-hardening steel, interstitial-free atomic steel and rigid-strength low-alloy steel. Advanced high-strength steel mainly includes dual-phase steel, multi-phase steel and transformation induced plasticity steel. The research shows that high-strength steel can not only reduce the total weight of automobile, but also greatly improve the safety performance of automobile collision [8]. Therefore, from the perspective of cost and performance, high-strength steel can meet the lightweight requirements of new energy vehicles, and at the same time ensure the safety of new energy vehicles to meet the requirements of automobile industry standards and laws and regulations [9].

4. Lightweight Process

4.1 New Welding Technology

4.1.1 Laser Splicing

Laser tailor-welded technology draws lessons from the relevant principles of cutting and garment making. Steel plates with different thickness, different materials and different coatings are welded by laser technology. A welding method that makes it into a complete tailor-welded blank, and then is integrally assembled with other parts through integral stamping. This technology can meet the different requirements of automobile parts for material properties, and realize the use efficiency of materials and the quality control of parts. The traditional connection method has a large joint area, which will increase the overall mass of the automobile, while this welding method basically has only one solder joint, which can greatly reduce the mass of the joint and is a feasible lightweight way. Laser splicing technology is mainly used in the manufacture of automobile parts, exhaust pipes and car bodies. In the mature workshop assembly line, laser splicing is widely used, and artificial intelligence is basically used. Laser tailor-welded blanks technology is applied to this process, which can reduce the number of parts, thin local steel plates and remove spot welding flanges, and finally achieve lightweight [10].

ThyssenKrupp's products were the first to use laser tailor-welded blanks, which were first applied to the body structure of Audi 100. The research shows that the application of laser tailor-welded blanks in automobile body structure can reduce the overall quality by 20% ~ 40%. Laser tailor welding is the key technology to promote the development of lightweight automobile structure, but it also has some limitations. Mainly reflected in the fact that the splicing weld will have a certain degree of influence on the mechanical properties and surface quality of stamping parts materials. In addition, it is difficult to achieve smooth connection between thin and thick plates because of the different thickness of laser tailor welded blanks. Therefore, it is not suitable for automobile body panels. With the continuous upgrading and development of China's automobile production technology, this technology is gradually improving and progressing in the splicing of high-strength steel plates for new energy vehicles, which also makes new energy vehicles achieve more prominent lightweight effects [11].

4.1.2 Laser-Arc Hybrid Welding Technology

As an advanced welding technology, laser-arc hybrid welding combines two different heat sources, laser and arc, and acts on the same position of the workpiece. Through the interaction of the two heat sources and the interaction between the composite heat source and the workpiece, the welding process is completed. This technology not only embodies the advantages of the two heat sources, but also makes up for their shortcomings, achieving the effect of $1+1 > 2$. Laser-arc hybrid welding technology combines the advantages of laser and arc, has the characteristics of wide heating range and high energy density, obtains high-density and high-energy heat input, and can effectively reduce welding cracks. Moreover, the welding effect is stable, and in the welding process, if the speed is too fast, the anode spot will be unstable, which will cause the arc to drift. Laser can create good conditions for arc to form corresponding anode spots, so the combination of laser and arc can maintain a relatively stable state under high-speed welding [3]. Audi A8 used laser-arc hybrid welding technology in the car body weld of about 4.6m on the transverse top frame of the car frame.

4.1.3 Friction Stir Welding Technology

Friction stir welding (FSW) is a relatively new technology invented by welding institute to produce aluminum alloy welded plates. The operation process is mainly to insert the stirring head into the parts to be welded, and use the rotary motion of the stirring head to make it rub against the parts to be welded, so as to raise the temperature of the metal material at the weld and soften it. As the stirring needle moves along the welding direction, the thermoplastic material will bond the

metal at the joint, thus realizing the solid state connection [12].

Friction stir welding is an economical, efficient and high-quality "green" welding technology, which is known as "a revolutionary welding technology after laser welding". Friction stir welding technology has been applied to the flat butt joint of Mercedes-Benz SL-class aluminum body and the butt joint of continuous curved parts with small curvature radius. Most aluminum parts of Mercedes-Benz SL-class car body adopt friction stir welding technology on the main board of the car body. The thickness of the plate is uniform, the distribution of fish scales is very uniform, and the welding marks on the back are very stable, that is, the parameters of the connection process are consistent.

4.2 New Molding Process

4.2.1 Internal High Pressure Forming

Internal high-pressure forming technology is a process in which the tube is used as the main material, and the tube blank is pressed into the die cavity by applying ultra-high pressure oil to the tube and axial thrust to make it form. The internal high pressure forming process includes the following stages: first, the filling stage. Put the pipe into the mold cavity and close the film. Under the condition of flushing, the two ends of the pipe are pushed along the horizontal direction, while gradually forming a relatively sealed state, the pre-filling body plays a role to exhaust the air inside the pipe. The second is the forming stage. Apply pressure to the liquid in the pipe, so that the pipe is gradually formed. The third is the integer stage. Under the action of applied pressure, the die angle and the film cavity are gradually fitted to form the required workpiece. Compared with the traditional stamping process, the internal high-pressure forming technology can not only reduce the weight of parts, but also effectively improve the actual utilization of resources and reduce the loss of materials. In the manufacturing process of new energy vehicles, this technology is widely used in automobile dashboard beams, seat frames, and battery brackets.

4.2.2 Hot Pressing Forming

Hot pressing technology is a common and universal processing technology. By heating the mold, the sample is injected into the mold, the mold is fixed on the heating plate, and the finished product is taken out of the mold after the sample is cooled and hardened. The hot pressing process mainly includes three steps: first, the raw materials are placed in the mold. Secondly, the upper and lower dies are used to form a certain pressure on the material template, so that the workpiece in the die is pressed to form a preset shape. Thirdly, the cooled and formed mold is cut. Compared with the traditional manufacturing process, the strength of parts manufactured by hot pressing process is not low, and the thickness can be controlled reasonably, the number of parts used can be effectively controlled, and the quality of automobiles can be reduced. In the production process of new energy vehicles, this technology is mainly used for automobile floors, door anti-collision beams and front anti-collision beams.

4.2.3 Roll Forming

Roll forming technology is the technology that materials are formed into various complex parts under the rolling of the roller while following the continuous rotation of the roller. Matters needing attention when using this process are as follows. First of all, in the shear butt welding device, the disposal of materials should be reasonable. Secondly, we should give full play to the role of press and forming machine to determine the shape of roll forming. Finally, we should pay more attention to the punching, trimming and pressing of the finalized die. In the manufacturing technology of new energy vehicles, this technology is mainly used for car door sill beams, anti-collision beams and door window frames.

4.2.4 Hydroforming

In order to solve the problem that lightweight materials are difficult to form, hydraulic forming technology is adopted. Different from stamping, the working mechanism of hydroforming is to use

liquid as working medium, usually water or oil in liquid state. Compared with the parts manufactured by stamping, the parts processed by hydroforming have higher quality control ability, which can further expand the forming limit of parts. Parts are shaped by molds, and the use of hydraulic forming can reduce the development cost of a few molds, which also reduces the total cost of automobile manufacturing. At present,

For parts with complex surfaces and high precision requirements, such as automobile fenders, hydroforming will be adopted.

In order to further improve the performance of parts, researchers at home and abroad have conducted in-depth research. There are few grooves in the outer cover of the car body, and the hydroforming technology of sheet metal is suitable to reduce the thickness and achieve the effect of lightweight. For two or more control parts, tube hydroforming technology can also be used. This technology is mainly used to make transmission shaft parts, side door beams, roof brackets and so on. Pipe hydraulic technology can reduce parts manufacturing cost by 11%, equipment cost by 14% and parts quality by 7.3% [13].

5. Conclusion

With the further development of new energy vehicle industry, the total output of new energy vehicles is expected to exceed that of traditional fuel vehicles by 2035. Through the lightweight design of new energy vehicles, the application of manufacturing technology, structural optimization technology and new material research and development technology, it will be the core of future market competition of new energy vehicle manufacturing industry to continuously reduce the self-weight of new energy vehicles and extend the endurance level of new energy vehicles. Domestic and foreign automobile enterprises will continue to study the lightweight technology, and the lightweight new energy vehicles will bring greater benefits to mankind.

Although China's manufacturing capacity has been developed by leaps and bounds in decades, compared with the production technology of automobile powers, China's production technology still has great room for improvement. Therefore, all manufacturing enterprises should grasp the development route and trend of new energy lightweight technology and make due contributions to China's new energy vehicles in the international market.

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