

Research Status of Lightweight Materials and Manufacturing Processes in Automobiles

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Abstract: Since the beginning of the 21st century, China's automobile market has shown a rapid development trend. To meet the domestic demand for the development of the automobile industry and provide convenience for transportation, automobile manufacturers have made long-term innovations, explorations, theoretical verifications, and designed more advanced and reasonable automobile materials and manufacturing processes, gradually moving towards lightweighting and adopting more advanced manufacturing processes. This paper conducts a comprehensive and detailed analysis and discussion on the application status of lightweight materials in automobiles and assembly processes, fully understanding the advantages and characteristics of new materials such as aluminum alloys, high-strength steels, and composite materials. Predictive analysis of the development prospects of the automobile industry is of particular importance.

1. Introduction

Energy conservation and emissions reduction are inevitable trends in the development of the automotive industry. In the 20th century, the oil crisis accelerated the process of energy conservation and emissions reduction in the automotive industry, aiming to improve people's living environment and reduce vehicle emissions. The energy conservation and emissions reduction in the automotive industry are of significant importance to national energy supply and environmental protection. Therefore, the application of new materials is imperative and urgent.

Lightweight materials play a crucial role in automobile manufacturing. Common lightweight materials include high-strength steel, aluminum alloys, carbon fiber composites, and so on. Compared to traditional materials, lightweight materials have higher strength and stiffness while being lighter in weight, allowing for overall weight reduction while ensuring vehicle safety.

The application of lightweight materials brings various benefits. Firstly, reducing vehicle weight can decrease fuel consumption, improve fuel efficiency, lower operating costs, and reduce tailpipe emissions. Secondly, the use of lightweight materials can enhance vehicle handling and acceleration performance, making the vehicle more agile and responsive. Additionally, lightweight materials can improve vehicle safety performance by increasing body stiffness and crash resistance, enhancing occupant protection.

However, the application of lightweight materials also poses challenges and considerations. Firstly, lightweight materials often come with higher costs, which may increase manufacturing

expenses for automobiles. Secondly, the reliability and durability of lightweight materials need to be carefully considered to ensure long-term safety during vehicle use. Moreover, the production and recycling of lightweight materials should take into account environmental impacts and sustainability factors.

Since the reform and opening up, the continuous improvement of people's economic income in China has laid a solid foundation for the development of the automotive industry. Especially since the 21st century, China's automobile sales have shown continuous high-speed growth, making it the largest consumer market for automobiles globally. However, on the other hand, there is still a significant gap between domestically produced vehicles and foreign brands (such as Mercedes-Benz, BMW, and Audi) in terms of material design and processing technology. This has had a major negative impact on the further development of domestic enterprises. How to improve the innovation and research speed of automotive materials and promote the further development of automotive manufacturing technology has become an important issue that major automotive manufacturers need to consider [1].

2. Current Application Status of Lightweight Automotive Materials

As the energy crisis in China becomes increasingly severe, the government has proposed the strategic policy of "low carbon, environmental protection, and sustainable development." Lightweight design in automobiles can effectively reduce energy consumption and promote healthy and efficient socio-economic development. According to statistics, currently, the six main materials (steel, aluminum, cast iron, composite materials, ceramics, and glass) account for 90% of the weight of various vehicle types (conventional vehicles, electric vehicles, hybrid vehicles, etc.). The specific contents are as follows:

2.1 Aluminum Alloy Materials

It is well known that aluminum metal has a small density and good mechanical properties, making it widely used in production and daily life. Especially when combined with elements such as zinc, manganese, and cadmium, aluminum alloys can exhibit excellent mechanical properties. Compared to traditional steel materials, aluminum alloys have many advantages such as good corrosion resistance, high ductility, and high thermal conductivity. Therefore, aluminum alloys are used in various aspects of automotive engines, bodies, and wheels. Aluminum alloys can effectively absorb collision energy better than steel materials, making them contribute to improved vehicle safety. Aluminum alloys weigh only one-third of low-carbon steel, significantly reducing vehicle weight and improving fuel efficiency. From this perspective, aluminum alloys are an important direction for lightweight design in automobiles, aligning with China's low-carbon environmental policies. So far, some high-end vehicle models have adopted aluminum alloy bodies, significantly reducing vehicle weight and improving safety performance. Aluminum alloys have become synonymous with high-end vehicle models.

2.2 High-Strength Steel

Steel materials are the most commonly used materials in automotive bodies. Steel materials can withstand significant lateral and longitudinal pressures, ensuring vehicle structural stability. Under the same strength pressure, high-strength steel minimizes the use of steel materials while ensuring vehicle safety, thereby reducing the weight of the vehicle itself. Many automotive manufacturers have recognized the advantages of high-strength steel and have used it in various parts of the vehicle body, such as bumpers, body crossbars, and door reinforcements. The use of high-strength

steel is an important measure to reduce vehicle weight. In future lightweight design of vehicle bodies, high-strength steel will continue to play an indispensable role. However, on the other hand, high-strength steel also presents challenges during use. It has poor plasticity and formability, exhibits high rebound, low elongation, and difficulty in controlling dimensional accuracy. Moreover, China's current steel production technology is relatively poor, and most high-strength steel is imported from abroad. This, to a certain extent, restricts the further development of China's automotive industry.

2.3 Composite Materials

Composite materials, specifically carbon fiber materials, offer advantages such as low density, high corrosion resistance, and good toughness. They have been widely used in high-end vehicle models. Applying composite materials to large structural components of vehicles, such as the body and chassis, not only improves the strength and rigidity of the vehicle body but also significantly reduces the weight of the vehicle. Plastics are also a type of composite material. With the increasing number of low-end vehicle models in the market, the use of plastics in the automotive industry has greatly increased, providing significant development potential. Composite plastics such as polypropylene, ABS, and polyethylene have various advantages such as light weight, good ductility, and low cost. They play important functional roles in automobile interiors, dashboards, and door panels. However, carbon fiber and other composite materials have high production costs, making them limited to high-end vehicle models. Reducing the cost of carbon fiber materials, promoting their widespread use in mid- to low-end vehicle models, and further advancing the development of lightweight design in automobiles are important issues that automotive manufacturers should consider [2].

3. Analysis of Automobile Manufacturing Processes

3.1 Stamping Technology Manufacturing Process

Stamping technology is an important means of automobile manufacturing and the most basic and commonly used method for processing metal parts. Stamping technology uses molds and stamping equipment to apply pressure to metal materials, causing them to undergo deformation and bending to achieve the desired shape. Stamping technology has been widely applied in the automotive manufacturing industry due to its various advantages. Firstly, stamping manufacturing processes can effectively improve the dimensional accuracy of metal components. During the actual processing, stamping equipment generally does not cause damage to the metal surface or internal structure, ensuring the stability of the stamped parts' quality. Secondly, stamping manufacturing processes have a wide range of applications. Whether it is the U-shaped groove for door anti-collision or the engine hood, stamping technology can be used for processing. Thirdly, stamping technology does not generate metal chips and does not result in material waste, making it a low-cost production method with high efficiency.

Automotive metal components have significant differences in size and shape. Therefore, there are significant differences in the stamping processes used for different automotive parts. Generally, the stamping processes for automotive components can be divided into three types. The first type is the basic stamping processes, including blanking, bending, stretching, and forming. The second type is the separation process, which refers to the phenomenon where the raw material breaks or falls off after reaching the strength limit of the metal material under the action of the stamping equipment. The third type is the forming process, where the metal blank undergoes plastic deformation under the stamping force, without exceeding the strength limit of the metal material, to achieve the desired shape and model [3].

3.2 Welding Technology Manufacturing Process

Welding technology is primarily used to join two metal pieces together and plays an essential role in the welding production line. In the process of automotive manufacturing, there are four main welding methods commonly used. The first method is spot welding, which involves placing two metal pieces together and using resistance heating to melt the base metal, forming a weld point that fuses the two materials together. The second method is projection welding, which is an extension of spot welding. Projection welding can simultaneously form multiple fusion zones at the welding position, allowing two pieces of equipment to be joined together and creating one or more weld points under the action of resistance heating. Projection welding has high welding efficiency and does not cause diversion effects. The current flow concentrates at the projection point, resulting in a high current density that allows even small currents to complete the welding task, making it a cost-effective welding method. The third method is laser welding, which is the most widely used welding technology in automotive production. According to available information, half of the welding tasks in current steel structure car bodies are completed using laser welding. Laser welding technology can meet the design and functional requirements of automotive parts by combining components with different strengths, thicknesses, and materials. Laser welding can effectively fuse different materials, reduce the weight of the vehicle body, aligning with the requirements of lightweight design in automobiles. Compared to other welding processes like spot welding and projection welding, laser welding can be applied to the welding of materials with different strengths and thicknesses. Importantly, it can reduce the weight of the vehicle body and improve the safety factor of the vehicle. Laser welding technology does not cause significant material consumption, effectively reduces production costs, and improves production efficiency. Additionally, laser welding uses butt joints, eliminating the need for overlap joints and reinforcing plates, significantly improving the mechanical performance of the weld points.

3.3 Automotive Body Assembly Process

Assembly process is the final stage of automotive production, where hundreds or thousands of qualified parts are assembled together according to established standards and specifications. Automobiles need to have good dynamic performance and a certain durability to function effectively in various complex environments. This places increasingly high demands on automotive assembly processes. So far, automotive assembly processes mainly fall into two categories. The first category is fixed assembly, which involves fixing the assembly body and installing other components onto it to form the final assembly process. Examples include the assembly of car seats and tires, which are typically achieved through fixed assembly. In the actual assembly process, the assembly parts can be processed, and most of the operations are performed manually. Although fixed assembly processes require low power, they demand high skills from workers. As a result, they are rarely used in mass production of automobiles and are mainly applicable to assembly processes with high-quality requirements. The second category is the assembly line, which involves the continuous movement of automotive components on a conveyor device in a multi-station assembly line. Each station completes a specific assembly process, and one operator only needs to ensure the proper operation of the equipment at each station. Assembly line production has high efficiency and quality and is the mainstream assembly mode in current automobile production.

4. Analysis of the Trends in Automobile Manufacturing

4.1 Shift towards Green and Environmentally Friendly Practices

With the increasing number of vehicles worldwide, there is a growing awareness of the significant pollution caused by automobiles, prompting many countries to implement environmental

protection measures to safeguard the ecological environment vital for human survival. In China, the government has implemented the most stringent emission standards for automobiles and introduced the "China VI" industry standard. Traditional gasoline-powered vehicles that meet the China V standard are prohibited from being sold, while the development of new energy vehicles (NEVs) and electric vehicles (EVs) is being strongly promoted. The coverage of clean energy is being expanded, fossil fuel utilization is being improved, and engine devices are being upgraded, with the application of innovative three-cylinder technology in passenger cars. Additionally, the Chinese government is encouraging major automotive manufacturers to innovate and develop electronic control fuel injection systems, secondary air injection, waste recycling technologies, and more. Importantly, Chinese automakers are also actively promoting the lightweight design of automobiles, utilizing high-strength steel, aluminum alloys, and other materials to reduce vehicle weight and enhance fuel economy. [4]

4.2 Move towards Intelligent Integration

Traditional automobile assembly tasks are complex and costly, coupled with the increasing labor costs in China, which have led to shrinking profit margins in the automotive industry. In such a context, automakers such as BYD and Geely have begun innovating and developing automated assembly technologies, incorporating functions such as artificial intelligence, radio frequency identification (RFID) technology, and remote control into the automotive assembly process. This not only significantly improves assembly efficiency but also reduces a substantial amount of labor costs. However, compared to countries like Germany and Japan, China's level of automation in automotive production lines is still relatively behind. This requires Chinese automakers to increase their research and development efforts in automated production lines, design and innovate more advanced robot welding technologies, automated stamping technologies, and keep pace with international trends, promoting the development of intelligent automotive assembly technologies.

5. Conclusion

The lightweight design of automobiles is not only an essential societal demand but also a future development trend for the automotive industry. Up to the present, significant progress has been made in the lightweight design and assembly processes of automobiles. Materials such as aluminum alloys, high-strength steel, and composite materials are widely used in vehicle bodies, reducing vehicle weight and enhancing safety. Stamping technology, laser welding technology, and assembly line processes have greatly improved assembly efficiency. In the future, the automotive industry will continue to evolve towards green and environmentally friendly practices, lightweight design, and intelligent integration.

References

- [1] Cao Jianlin. *Analysis of lightweight materials and manufacturing processes for automobiles [J]. Southern Agricultural Machinery*, 2019(10), 15.
- [2] Jia Minmeng. *Research status of lightweight materials and manufacturing processes for automobiles [J]. Equipment Maintenance Technology*, 2019(08), 22.
- [3] Wang Yinchao. *Research on lightweight materials and manufacturing processes for automobiles [J]. Times Automotive*, 2019 (04), 12.
- [4] Yang Mengxin, Sun Pengbo. *Research and implementation approaches to automotive lightweighting [J]. Times Automotive*, .2019(06), 16.