Characteristics and manufacturing process of automotive plastic tailgate products

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Abstract: Lightweighting of automobiles is an inevitable trend towards environmental protection, energy conservation, and low-carbon development. Replacing steel with plastic in automotive components is one of the important technical routes to achieve lightweighting. As a typical product replacing steel with plastic, the plastic tailgate can reduce the weight of the component module by 25~30%, while leveraging the advantages of plastic molding to achieve shapes that cannot be achieved through sheet metal stamping. Additionally, the advantage of integral molding of plastic parts reduces the number of sub-parts of the sheet metal tailgate and avoids appearance defects that may occur during welding of different sub-parts. The special production process of plastic tailgate can also enhance the production capacity of the host machine's production line to a certain extent. This article specifically conducts an in-depth analysis of the development history, product types and characteristics, and key manufacturing processes of automotive plastic tailgates, and introduces the technological outlook and development trends of plastic tailgates.

Key words: lightweight; plastic tailgate; composite materials; high degree of design freedom; bonding process

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0 Preface

Replacing steel with plastic in automotive components is one of the important technical routes to achieve lightweight vehicles. As a typical product replacing steel with plastic, the plastic tailgate has a significant weight reduction effect, and it also has advantages in styling and functional integration that metal tailgates cannot achieve. This article specifically focuses on the development history, product types and characteristics, and key manufacturing processes of automotive plastic tailgates, and introduces the technological development trends of plastic tailgate products.

1 Types of plastic tailgate products

Plastic tailgate products are divided into three types according to the different constituent materials.

The first type is known as the Full Thermoset plastic tailgate, which emerged as early as the 1990s. Various Volvo models have adopted this type of plastic tailgate, which also represents the concept of the first generation of plastic tailgate. Both the inner and outer panels are made of thermosetting SMC material. This solution is suitable for the design of large tailgates, with good dimensional stability. Additionally, since it can be spray-painted online, it can be assembled in the body shop of the host factory, causing minimal changes to the production line and thus gaining high acceptance from the host factory. Compared to sheet metal tailgates of the same size, the weight reduction effect of Full Thermoset plastic tailgates is generally 20-25%. However, due to the low fluidity of thermosetting materials during manufacturing, Full Thermoset plastic tailgates have many limitations in terms of A-surface styling and component functional integration.

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The second type is the hybrid tailgate, which is a thermoset-thermoplastic composite plastic tailgate. This solution is suitable for small SUVs and hatchbacks. It is produced through a process of spraying before bonding. Since the outer panel is sprayed after injection molding, the paint surface quality is better than that of the first type of fully thermoset plastic tailgate. The low modulus of thermoplastic materials enables such plastic tailgates to automatically recover after low-speed collisions, reducing the probability and cost of repairs. However, due to the offline assembly method, it is necessary to add installation stations for plastic tailgates in the final assembly workshop of the host factory, requiring changes to the existing layout of the final assembly workshop. Compared to metal tailgates of similar size, its weight reduction ratio reaches 25-30%. At the same time, due to the application of thermoplastic materials for the outer panel, the freedom of design for the A-side styling of the hybrid tailgate is greatly enhanced. In the design of the plastic tailgate module, component function integration can be achieved through structural design, reducing the number of sub-components in the tailgate system and improving the assembly efficiency of the host factory's final assembly line.

The third type is the full thermoplastic plastic tailgate. Its inner panel is injection molded from composite-reinforced thermoplastic material, while the outer panel is made of ordinary thermoplastic material, also using the injection molding and subsequent spray painting manufacturing process. In addition to the technical characteristics of the thermoset-thermoplastic composite plastic tailgate, it has a more pronounced advantage in weight reduction. Compared to metal tailgates of similar size, its weight reduction ratio reaches 30-35%. The full thermoplastic plastic tailgate also features high freedom of A-surface styling and component functional integration, while avoiding the environmental issue of non-recyclability that arises from the use of thermoset materials after disposal.

2 Characteristics of plastic tailgate products

2.1 Obvious weight loss effect

Research indicates that for every 100 kg reduction in vehicle weight, fuel consumption per 100 kilometers can be reduced by an average of 0.3 to 0.6 liters, and vehicle exhaust emissions can be reduced by 9 grams. Therefore, whether from an economic or environmental perspective, lightweighting of vehicles is an inevitable trend in automotive technology development. Compared to tailgates made of sheet metal structures, plastic has a lower density. Currently, the main technical solutions, namely thermoset-thermoplastic composite plastic tailgates and fully thermoplastic plastic tailgates, can achieve a weight reduction of 25 to 35% compared to sheet metal tailgates of the same size and grade.

2.2 High degree of modeling freedom

The outer panel of the plastic tailgate is manufactured through injection molding and paint spraying using thermoplastic materials. The good ductility of thermoplastic materials makes it possible to form structures such as undercut structures and excessively small R corners, which have significant technical limitations in sheet metal stamping processes. Currently, some vehicle models that have adopted plastic tailgates leverage this advantage to design special shapes to match uniquely shaped taillights (see Figure 1 below), or use separate painting of the plastic tailgate and the body to create a color separation between the rear of the body and the body (see Figure 2 below). The development of plastic tailgates provides multiple possibilities for automotive styling design, and with the continuous research and development of plastic tailgate products, this choice of possibilities is becoming increasingly greater.

Figure 1 The plastic tailgate can be designed with uniquely shaped taillights

2.3 High integration of component functions

Due to the advantages of thermoplastic molding, plastic

Figure 2 Different color schemes can be designed for different areas of the vehicle body on the plastic tailgate

tailgates can integrate various functional components of tailgate units through the design of inner and outer panels. For many tailgates using sheet metal structures, it is often necessary to develop a spoiler that is mounted onto the sheet metal tailgate. However, if the same design is used for a plastic tailgate solution, the spoiler can be directly integrated onto the plastic tailgate, forming a single unit (as shown in Figure 3 above). Similarly, in the area where the glass is installed and lowered on the tailgate, the plastic tailgate can directly mold the license plate, while the sheet metal tailgate often requires a separate license plate to be developed and welded onto the sheet metal tailgate (as shown in Figure 4 above). In addition, the plastic tailgate can also integrate door handles, antenna mounting brackets, and some interior trims and other structures (as shown in Figure 5 below).

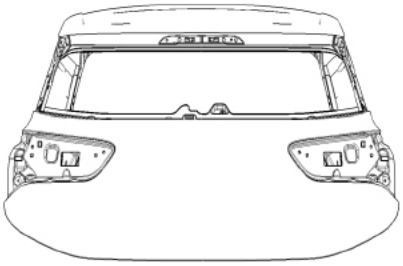

Figure 3 Plastic tailgate can be integrated with a spoiler

Figure 4 The plastic tailgate can be integrated with a license plate

Figure 5 From left to right, they are respectively the cases of plastic tailgate integrated door handle, integrated antenna bracket, and integrated interior trim

2.4 Improvement of final assembly efficiency of the host machine factory

Under normal circumstances, the host machine assembles the sheet metal tailgate onto the vehicle body in the body shop. As a part of the vehicle body, the sheet metal tailgate undergoes processes such as electrophoresis and painting, and the installation of parts on the tailgate is carried out in the final assembly shop. Since thermoplastic cannot withstand a baking temperature of nearly 200°C, it cannot undergo electrophoresis and painting processes online together with the sheet metal body. Therefore, the plastic tailgate is assembled onto the vehicle body in the final assembly shop in an off-line manner (see Figure 6 for the schematic diagram of the assembly position). Leveraging this characteristic, the entire production line of the host machine will experience a capacity increase due to the use of plastic tailgate products. In the body shop, the production line without plastic tailgate installation at the front of the painting shop and final assembly shop, each vehicle to be operated does not include an opened tailgate, and the length of the vehicle occupying the production line will be shortened by about one-third, which to some extent means an increase in the Job per Hour (JPH) of the entire production line. The off-line assembly mode of the plastic tailgate makes it possible to install parts on the tailgate offline. When the plastic tailgate is assembled with tail lights, wiring harnesses, wiper motors, and even glass at the supplier's site, the pre-assembled plastic tailgate assembly is fixed to the vehicle body side through hinges and air supports on the host machine's final assembly line, completing the full assembly of the tailgate unit. The modular supply characteristics of the plastic tailgate enable the integration and timely supply of multiple configurations, reducing the logistics and on-site layout costs of the host machine, reducing the number of assembly stations required in the final assembly shop, shortening the length of the assembly

line in the final assembly shop, and reducing the likelihood of line downtime. The industrialization solution for plastic tailgates provides more assembly options for different host machines.

Figure 6 Schematic diagram of assembly of sheet metal tailgate and plastic tailgate at the host machine factory

3 Key manufacturing processes for plastic tailgates

The manufacturing process of plastic tailgates primarily involves injection molding, painting, bonding, assembly, and other stages. Among these, injection molding, painting, and assembly are standard manufacturing processes for automotive exterior parts, and their manufacturing techniques and quality control methods are largely similar. The bonding process determines the dimensional stability, performance, and compatibility with surrounding parts of the plastic tailgate product, making it a core process in the manufacturing of plastic tailgates. This article will focus on introducing the characteristics of the bonding process in the manufacturing of plastic tailgates.

The adhesive used in the bonding process of plastic tailgates is a two-component polyurethane adhesive. When bonding parts, this two-component polyurethane adhesive not only ensures the sealing performance between the bonded components but also achieves a stable bonding effect. The bonding performance of the two-component polyurethane adhesive is reflected in its bonding strength and failure mode. The bonding strength is divided into tensile strength and shear strength. During testing, samples are prepared using standard 100×25mm plates and tested using a universal tensile machine. The failure mode of the adhesive refers to the state of the adhesive when it fails after the bonded components are damaged by external forces.

As shown in Figure 7, Cohesive Failure in Peeling (CFP) refers to the failure caused by a significant decrease in the cohesive strength of the glue due to an imbalance in the mixing ratio of the glue or changes in the properties of the polymer matrix. Adhesive Failure (AF) refers to the failure caused by the separation at the interface between the glue and the substrate when the part fails. The occurrence of CFP and AF in the same area indicates that the glue in that area has not reached the designed bonding state, indicating an area with unqualified bonding quality. Cohesive Failure (CF) refers to the failure where the failure area is within the internal structure of the glue when the part fails, with good bonding at the interface between the glue and the substrate. Surface Cohesive Failure (SCF) is a type of Cohesive Failure (CF), characterized by the failure area being near the edge of the substrate on one side of the glue layer. This failure mode is different from AF, which is the failure of the contact surface between the glue and the substrate. In addition, Substrate Failure (SF, DF) refers to the failure of the bonded part manifesting in the substrate rather than the glue, indicating that the bonding role of the glue in the bonded body is qualified.

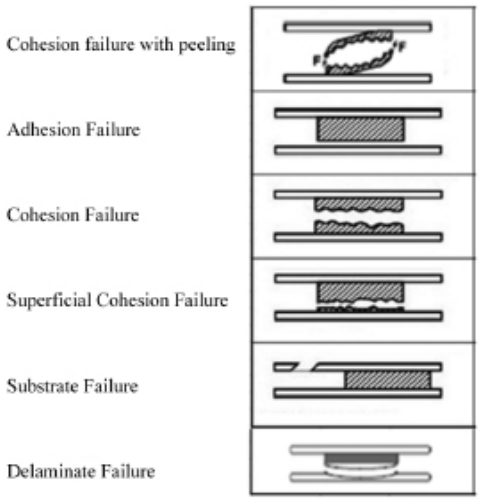

Figure 7 Schematic diagram of failure modes of adhesive parts

Two-component polyurethane glue begins to react and form bonding strength from the moment the components A and B are mixed. The freshly mixed glue is a viscous flow polymer with thixotropy. In this state, the surface and interior of the glue strip contain a large number of active groups. These active

groups combine with the active groups of the bonding substrate to form bonding strength. The period during which the glue strip surface contains active groups is called the open time. From the moment the two components of the glue are mixed, the surface of the glue strip reacts with moisture in the air and gradually solidifies, and the active groups on the surface and interior of the glue strip also gradually decrease. When the active groups on the surface of the glue strip lose their activity, the open time of the glue strip ends. When all the active groups inside the glue strip also lose their activity, the solidification time of the glue strip ends. Therefore, in the actual production process, it is necessary to control the bonding of different substrates before the open time to avoid the loss of activity of the glue. Therefore, the longer the open time and solidification time, the better.

When different substrates are brought into contact through the glue, due to the viscous flow state of the glue, the spatial positions between the different substrates cannot be fixed immediately. Therefore, a special positioning fixture is needed for positioning and pressing. When the strength of the glue increases, the pressing time begins to be counted. After the pressing of the substrates is completed, the bonding strength of the glue reaches a certain range, and the spatial positions between the substrates have been fixed. At this point, the substrates can be removed from the fixture. When the substrates are removed from the fixture, the glue continues to cure and react, and the bonding strength of the glue continues to increase until it reaches its final strength. The relationship between the four key times in the above gluing process is shown in Figure 8 below. In the actual production process, due to the fact that the pressing of the fixture occupies equipment in key processes, the length of the pressing time directly determines the length of the production cycle. Therefore, for the characteristics of the glue, the shorter the pressing time and curing time, the better.

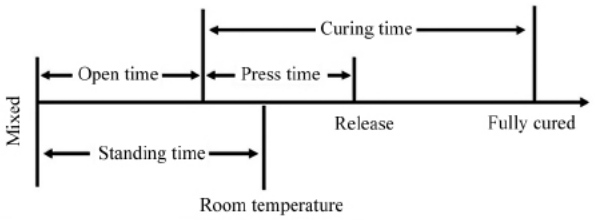

Figure 8 Four timings in the sizing process

4 Prospects for Plastic Tailgate Technology

With the successful launch of multiple plastic tailgate products, their advantages in weight reduction and styling are attracting increasing attention from host machine manufacturers. When considering the use of plastic tailgates in subsequent new products, more lightweight and intelligent technical solutions can be adopted.

4.1 Lightweight

The lightweighting of plastic tailgates is achieved through the application of high-performance composite materials and continuous optimization of structural design. The development of high-performance composite materials is crucial for the advancement of plastic tailgates. The newly developed composite materials should have lower density, simpler molding processes, thinner wall thickness of parts, but higher strength and other performance characteristics. In the development of plastic tailgates, composite materials such as PP-LGF30 have been gradually applied, and the material density has been further reduced.

With the increasing maturity of simulation technology, the wall thickness of products has gradually decreased while ensuring product performance. At the same time, some metal components in plastic tailgates have also been replaced by composite materials, all of which contribute to the lightweighting of plastic tailgates.

4.2 Intelligentization

With the vigorous development of China's automotive industry, OEMs (Original Equipment Manufacturers) are no longer limiting the positioning of plastic tailgates to their original function as opening and closing components. They require plastic tailgates to serve as carriers capable of integrating more functions, such as intelligent sensing, electric control, safety protection, remote connectivity, and more. For instance, integrating more electronic components can facilitate automatic opening of the tailgate and long-distance signal sensing, which in turn supports autonomous driving. The tailgate, once a mere opening and closing component, is gradually evolving into an information exchange center for transmitting information inside and outside the vehicle. The advantages of plastic tailgates, such as high design freedom and high integration, can be further leveraged in automotive

intelligence.

5 Conclusion

In recent years, both domestic and international host machine manufacturers have developed multiple models featuring plastic tailgate products, which occupy a high proportion especially in new energy vehicle models. Their advantages in weight reduction and styling are receiving increasing attention. Due to their significant weight reduction effect compared to metal tailgates, plastic tailgates offer unique advantages in new energy vehicles. Plastic tailgates, through methods such as integrated injection molding of outer panels, high degree of freedom in styling, and multi-part functional integration, provide various options for the development of intelligent and personalized automobiles. They are a product with mature technology and broad market prospects.