Development of forming process and mold for hot stamping integrated door ring

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With the rapid development of the automotive industry, body lightweighting has become a key way to improve the energy efficiency and safety of automobiles. The application of high-strength materials can effectively reduce the weight of automobiles, thus reducing fuel consumption and emissions. This study revolves around hot stamping integral door ring forming molds and processes, and explores the advantages of multi-part integrated (MPI) hot stamping technology, especially in the application of Laser weld blanks. By integrally cutting blanks and laser splicing welding technology, hot stamping of door rings not only improves the production efficiency, but also enhances the strength and stiffness of the body structure. The study shows that with the optimized mold design and process, the weight of the integral door ring is reduced by about 20% and the safety performance is guaranteed, which provides an effective solution for the lightweighting of future automobiles.

Keywords: Body lightweighting; High-strength steel; Laser weld blanks; Integral door ring forming; Hot stamping molds.

1. Background

Energy saving, emission reduction and safety improvement in automobiles have become inevitable development trends. With the rapid increase of automobile production and sales, the automobile industry brings convenience to people and at the same time, it also brings problems such as fuel consumption, pollution, safety and so on. In order to cope with these problems, the automotive industry needs to seek effective solutions, and automotive lightweighting is an effective way to achieve energy saving and emission reduction [1]. The use of high-strength materials in the car body can ensure the performance of the car while reducing the thickness and amount of steel plate, to achieve the reduction of mass, thereby reducing fuel consumption and emissions. The application of high strength steel hot stamping and forming technology in automotive manufacturing is gradually increasing. Ultra-high-strength steel has become a favored lightweight material in the market due to its cost-effectiveness and relatively simple manufacturing cost and process. Under the condition of ensuring the safety performance of automobiles, optimizing the design to thin body parts can effectively reduce the weight of the body [2]. Multi component integration (MPI) hot stamping technology is an advanced metal stamping process, which achieves automotive lightweighting by integrating multiple components into an overall structure [3]. This technology is mainly applied to the manufacturing of automotive body structures by hot stamping and forming different materials and components into an integrated body structure. This structure can meet the requirements of automotive safety performance and

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also effectively reduce vehicle weight, thus improving fuel economy and reducing CO2 emissions. Components such as door rings of passenger car frames are beginning to make extensive use of this integral hot stamping and forming technology.

2. Application study of integral door rings

2.1. *Integral cut blank and hot stamping forming*

Integral cut blank is a kind of blank that cuts the metal plate into the desired shape by CNC cutting equipment [4]. In the process of hot stamping and forming of integral door rings, the use of integral cut blanks can improve production efficiency and reduce the generation of scrap. Hot stamping is the process of punching sheet metal under high temperature and pressure to make the required parts. However, this kind of forming of integral equal-thickness plate cannot meet the requirements of strength and elongation of different structural parts, and cannot reduce the weight of the body structure under the condition of collision safety anymore.

2.2. *Laser weld blanks and hot stamping*

Laser welding blanks are two or more metal plates welded into one by laser welding technology [5]. Laser welding blanks can be used in the hot stamping of integral door rings to achieve the composite forming of different materials and improve the strength and stiffness of the body. At the same time, the hot stamping process of Laser weld blanks can also meet the demand of lightweight body.

3. Process and mold design

3.1. *Process design*

In the design of the integral door ring forming mold, it can be divided into three steps: 1) the design of the 3D model of the product (see Fig. 1(a)); 2) the forming simulation of the selected material of the splicing plate (see Fig. 1(b)); and 3) the design of the process combined with the results of CAE (see Fig. 1(c)). The design of the mold is shown in Fig. 2, and its key technologies include: punch design, concave die design, guide device design, etc. Among them, the punch design should consider the strength and stiffness in the stamping process; the concave die design should fully consider the stress distribution and material flow in the forming process; and the guide device design should ensure the precision and flatness in the stamping process.

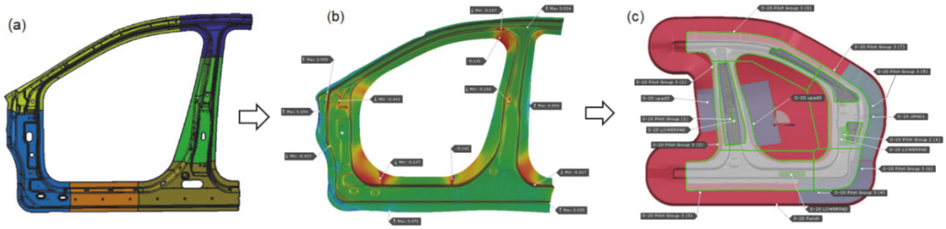

Fig. 1 Process design of the product: (a) product number mold design; (b) CAE analysis; (c) forming process design

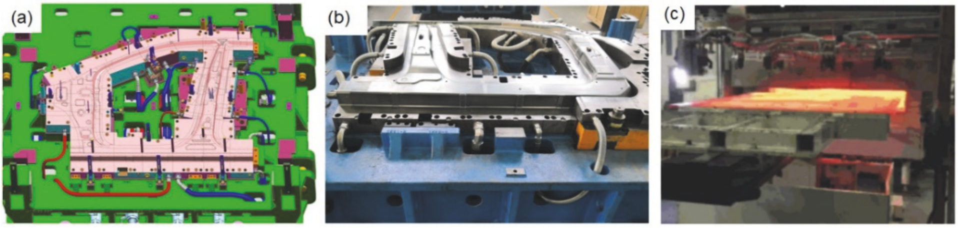

Fig. 2 Mold design and hot stamping forming test of the product

3.2. *Hot stamping simulation*

The part contour size of the door ring is relatively large, and the control of forming dimensional accuracy is difficult. High precision of mold is required, and debugging is difficult. Secondly, the material flow of the Laser weld blanks at the splicing seam may lead to weld displacement or even cracking, which requires adjusting the position of the weld at the early stage of design or adjusting the forming process to control the material flow of the weld blanks. In addition, when the part sheet is closed into a ring, the material flow during the forming process is restricted, and the forming difficulties increase, so it is necessary to analyses by adjusting the parameters several times until the optimal result is obtained.

For the corners of the door ring structure, there is a possibility of stacked material, thinning, and even cracking risk is high, the development is difficult. When the splicing material is of different thicknesses and strength levels, especially in the case of patch panels, the stresses after forming in local areas are uneven, and the parts are prone to warpage, all these difficulties increase the debugging difficulty of the test mold, see Fig. 3. The risk of cracking can be identified through test simulation. Based on the analysis of forming simulation, an optimization plan can be proposed to reduce or completely avoid the risk of failure in mold development as much as possible.

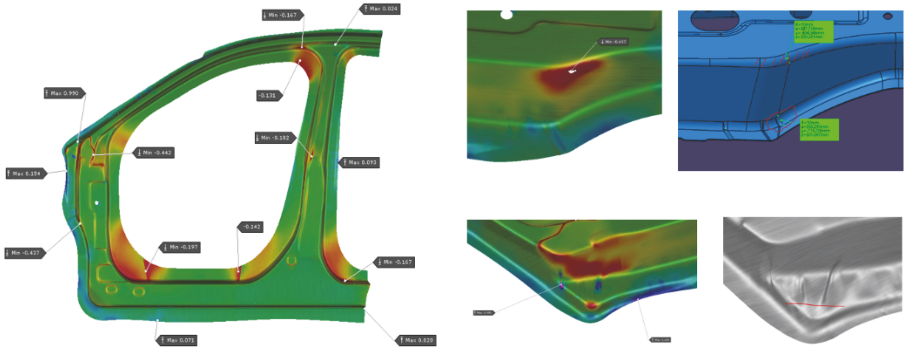

Fig. 3 Forming analysis and defect treatment

3.3. *Cooling waterway design*

Cooling waterway design is a key link in mold manufacturing. Reasonable cooling waterway design can effectively reduce the temperature of the mold, reduce the wear and tear of the mold, and extend the service life of the mold. In the design of cooling waterway, we should fully consider the water flow rate, cooling effect, water pipe layout and other factors. Due to the large size of the blank for the integral door ring, a certain heat transfer time is required. In order to accelerate the cooling to shorten the holding pressure cooling time, it is necessary to increase the temperature difference between the mold and the blank. For this purpose, a double-layer cooling waterway is designed, as shown in Fig. 4.

The cooling simulation was carried out according to the contact process and water temperature difference of the heat transfer from the blank to the mold, as well as the temperature distribution of the convex and concave molds during the holding pressure process. After the water channel arrangement and adjustment, the simulated temperature field of the concave mold is shown in Fig. 5(a), and the calculated temperature field of the convex mold (time-dependent) temperature field, is shown in Fig. 5(b). The results of the simulation can ensure that the part temperature out of the mold is below 199°C within the predetermined holding time.

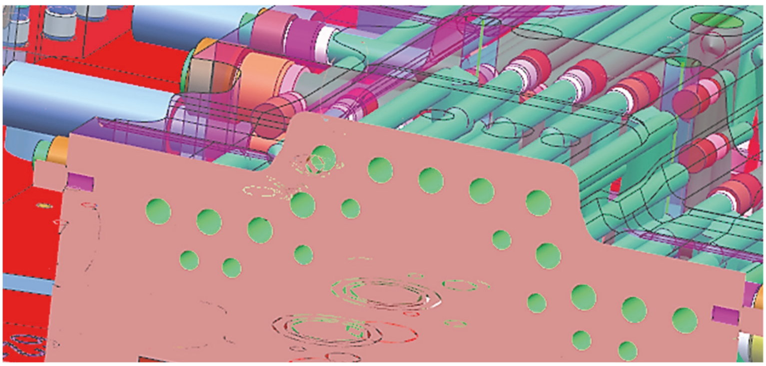

Fig. 4 Design of double layer cooling water channel

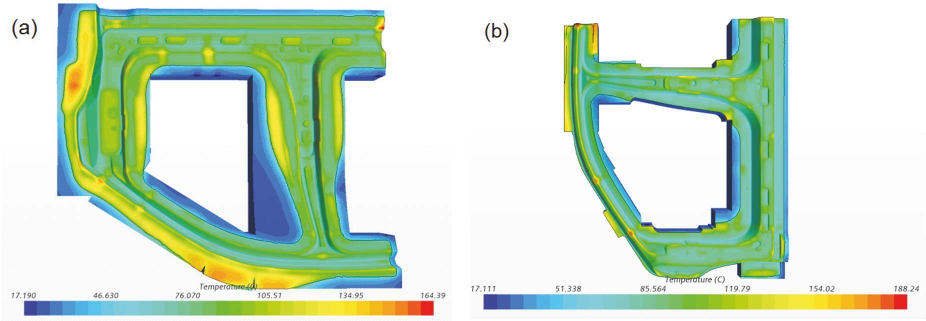

Fig. 5 Cooling simulation after designing the water channel and cooling system: (a) Temperature field analysis of a concave mold; (b) Temperature field analysis of a convex mold

3.4. *Test mold and forming defect control*

Forming defect control is an important part of mold manufacturing. In the hot stamping process of integral door ring (see Fig. 6), the common forming defects include: rupture, wrinkle, burr, and so on. In order to reduce the forming defects, it is necessary to control from the following aspects, i.e. optimizing the mold design, choosing the stamping parameters reasonably and modifying the shape of the blank.

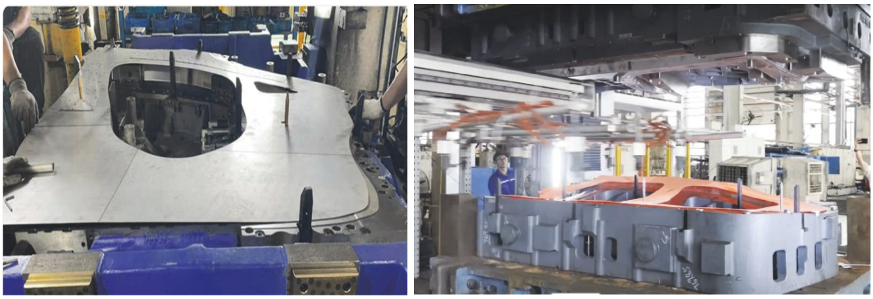
Fig. 6 Blank positioning inspection and hot stamping and forming tests in the test molds

4. Application development cases

In the hot stamping process of an integral door ring for a certain car model, the above process and mold design method were adopted to successfully achieve high-quality production of the integral door ring. Compared with the conventional process, the hot stamping process using integrally cut blanks and Laser weld blanks has resulted in a reduction in the weight of the door ring by approximately 20% and improved body performance. The configurations of plate thicknesses and strength levels of the laser-filled spliced plates are shown in Figure 7 and Table 1.

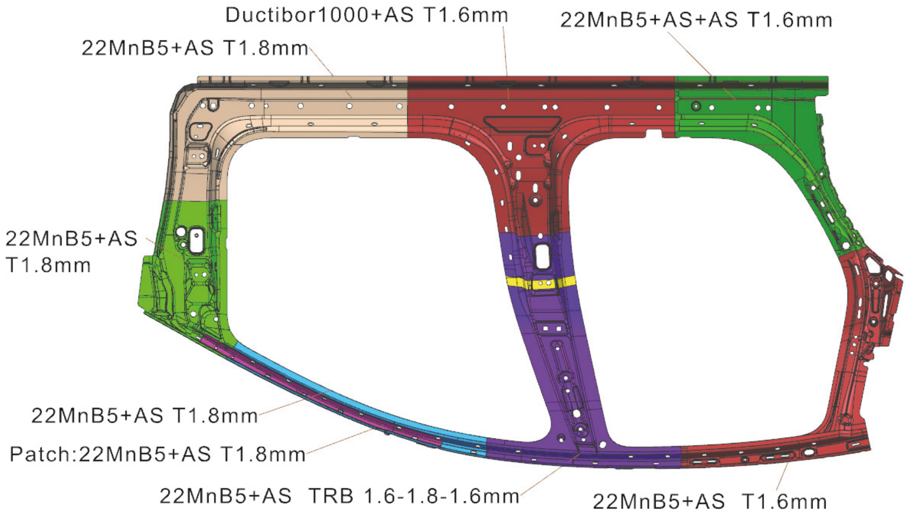

Fig. 7 Multi part integration design of a double door ring for a model of car

Table 1 Material and configuration options for a model of double door ring

Material	Weights (kg)	Size: (mm)	Splicing type TWB/TRB	Patch panels (piece)	Weld length (mm)
AlSi coated	21.42	2512*1318*258	TWB+Patch	1	1553

The door ring was designed using a combination configuration of a differential thick plate (TRB) and a laser spliced plate with patches. The comparison between the forming simulation and the actual formed part of the product is shown in Fig. 8. The design of the product and the manufacture of the mold meet the requirements of fine parameter control of the forming process.

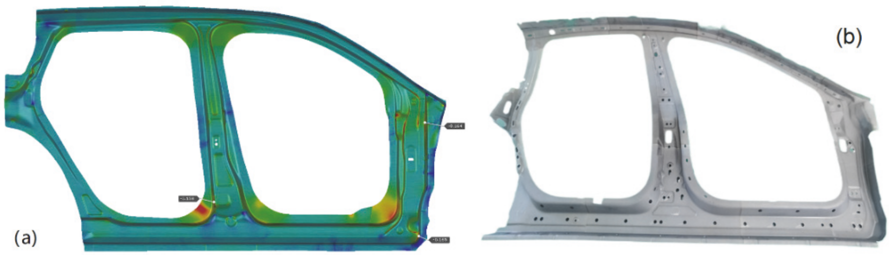

Fig. 8 Forming simulation results (a) and actual thermoformed parts (b).

5. Conclusion

This study conducted an in-depth discussion on the forming molds and processes for hot-stamped monolithic door rings, and the results showed that the hot-stamped forming process using laser welding blank and monolithic cut blanks can significantly improve the strength and stiffness of the body while effectively reducing the weight of the door rings.

Various challenges in the forming process, such as material flow, positional adjustment of the spliced weld seam and control of forming defects, were successfully overcome through rational mold design and process flow. The proposed cooling channel design and forming defect control measures further optimize the service life of the mold and the quality of the finished product, which provides a strong guarantee for the actual production. Successful application cases of integral door rings show that this new process significantly improves fuel economy and reduces carbon dioxide emissions while meeting the safety performance requirements of automobiles, which promotes the development of automobile lightweighting. Therefore, the hot stamping integral door ring molding technology provides a new idea and direction for future automobile manufacturing, and has a broad application prospect.

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