Process and application of hot stamping double door rings for vehicle body with multi part integrated laser tailored blank

Qiang Wang[1,a,†], Jianlin Deng[2], Yisheng Zhang[3,b], Yilin Wang[3], Bin Zhu[3], Liang Wang[4] and Fang Zhang[4]

[1]*Anhui HST Automotive Parts Co., Ltd., Hefei, 237005, China*
[2]*Jiangxi HST Automotive Parts Co., Ltd., Jiujiang, 332499, China*
[3]*State Key Laboratory of Material Forming and Die Technology, Huazhong University of Science and Technology, Wuhan, 430074, China.*
[4]*Wuhan Zhongyu Dingli Intelligent Technology Co., Ltd., Wuhan, 430061, China*
E-mail: [a,]huakewq@126.com, [b]zhangys189@189.cn*

With the development of the automobile manufacturing industry and the increase of the demand for lightweight, the hot stamping of body double door rings with multi-component integrated laser splicing welded plate has become a widely used process technology. This thesis investigates the process and application of hot stamping body double door rings with multi-component integrated laser spliced welded plate, as well as the related mold design and production. Firstly, the background and significance of the process are introduced in the introduction part, and the purpose of the study is pointed out. The functional characteristics of laser spliced plates are discussed in detail, including the advantages and application areas of filler wire welding technology. The focus is on the design and forming process of the material sheet of the double door ring, considering the requirements of multi-component integration and process optimization. The design features and production conditions of hot stamping molds are discussed to meet the requirements of hot stamping body double door rings with laser spliced welded plates for multi-component integration. Finally, the results of the research work are summarized and the prospect of the process and mold design for the hot stamped body double door rings with multi-component integrated laser spliced welded plates for future applications is envisioned.

Keywords: Automotive lightweighting; Multi part integrated hot stamping; Car body double door rings; Laser tailored blank ; Process and molds.

1. Introduction

In the current development trend of automobile industry, lightweighting has become an important research direction. Lightweighting can not only improve fuel economy and reduce exhaust emissions, but also enhance the performance and safety of automobiles [1]. Therefore, research and development of new lightweighting technologies are of great significance to the automotive industry. Hot stamping and forming, on the other hand, is a process that utilizes the thermoplastic of the material in its heated state to change the shape of the material by heating the sheet metal followed by forming and cooling phase change [2]. This forming method can realize the forming of parts with complex shapes, and at the same time reduce the forming force and minimize the springback of stamping forming of high-strength steel, which is conducive to the improvement of the strength and quality of the parts. The hot stamping and forming technology of high-tensile steel is to reduce the weight of the body structure under the condition of improving safety. The maturity of high

Y. Zhang and M. Ma (eds.), *Proceedings of the 7th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2024)*, Atlantis Highlights in Materials Science and Technology 3,
https://doi.org/10.2991/978-94-6463-581-2_4

strength steel and laser welding plate technology lays the foundation for the integrated manufacturing of body structure parts. Laser splicing welding is the use of laser beams to weld two or more metal plates of different strength grades together to form a monolithic billet for hot stamping forming [3]. It meets the body structure design of plate forming parts "variable strength forming" functional requirements, but also simplifies the forming process, and reduces the body structure assembly welding and mold costs, and improve the material utilization rate [4]. The technology from the initial B-pillar welding plate hot stamping molding, and gradually developed to multi-part laser welding plate hot stamping molding, such as the body door ring of the laser welding plate multi-component integrated hot stamping molding [5].

Based on the existing research results and applications of single door rings, it is necessary to study a new manufacturing process for double door rings, which will use larger-scale integrated hot stamping molding of one-piece spliced plate components. This research will provide effective solutions and research results for the integration of multiple components in the body.

2. Technical and functional characteristics of laser-welded panels

2.1. *Body Structure and Crash Safety Analysis*

For exactly any structure to carry any load, it needs something called a "load path". Think of a lever that needs a "fulcrum" to counteract and generate force at the end [6]. A lever without a fulcrum cannot resist the applied force. The same applies to vehicles. Impact loads are expressed in terms of strength and angle, all of which are transmitted through the frame. The only real "resistance" in a collision is the deceleration of the inertia of the vehicle's mass (changes in motion cause forces to act on and deform the vehicle) and the traction of the vehicle on the ground through the tire contact patch [7].

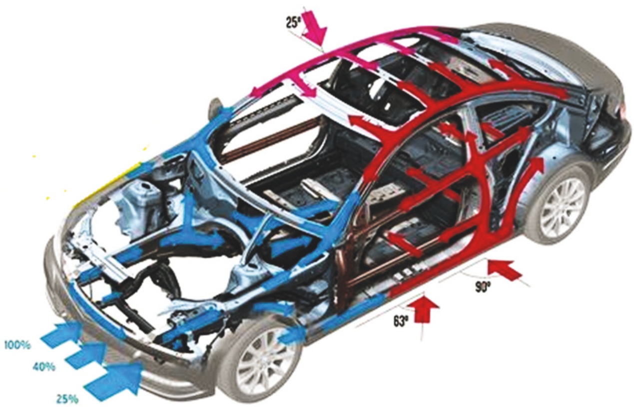

Figure 1 Body crash load transfer path and function of body structural components [6]

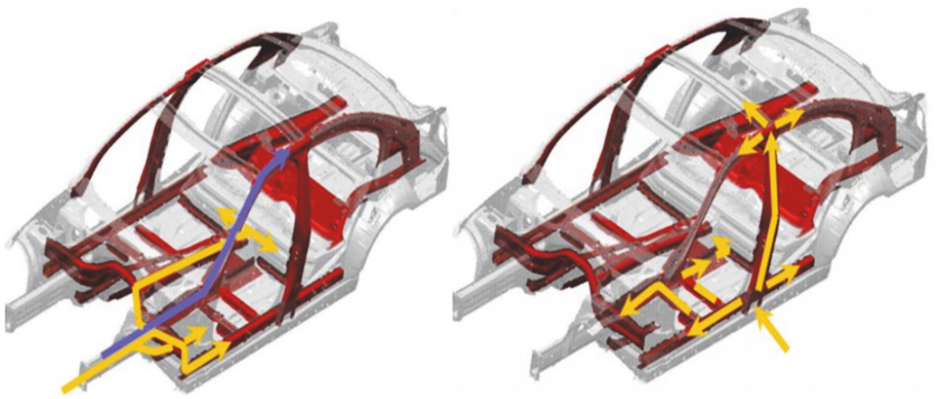

Figure 2. Load Path for Frontal and Side Impacts (Pfestorf, 2016) [7]

Transitions in crash load cases result in different characteristic curves, and characteristic load curves for typical crash scenarios indicate that adapting the local variation characteristics of component-specific load profiles is critical for passenger safety (Maikranz-Valentin et al., 2008; Steinhoff et al., 2009).

2.2. *Laser welded blanks and their characteristics*

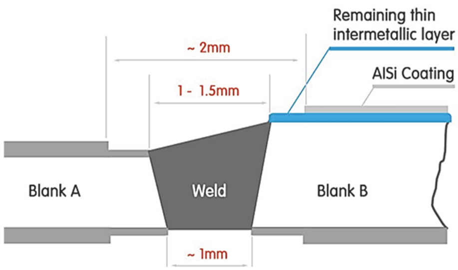

Fig. 3 Laser ablation-welding technology at ArcelorMittal

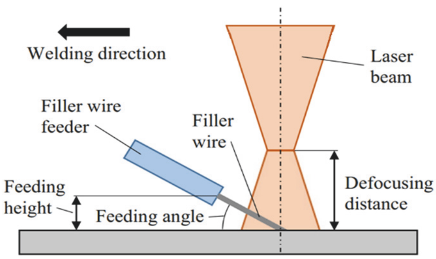

Fig. 4 Laser filler wire laser tailored blank technology at Baosteel, China

Laser welded blanks utilizes a high energy density laser beam to heat the filler material to a molten state while welding it to the surface of the workpiece. The energy of the laser beam is focused on the weld area, causing the filler material and the surface of the workpiece to instantly melt and form a weld seam. The filler material forms a strong bond with the workpiece surface through the surface tension and capillary effect in the molten state. In this study, the laser filler welding technology was used to successfully realize the precision welding of the material pieces of double door rings.

3. Research on the design and molding process of the material sheet of double-gate ring

3.1. *Structural characteristics of the outer ring of the double door ring*

According to the body design and the requirements of lightweight and safety, the structure of double door ring is divided into double door inner ring and double door outer ring. This study is only carried out with the objective of forming the welded plate of the outer ring of the double door outer ring, in the following discussion, the double door ring refers to the outer ring of the double door, see Fig. 5a is the three-dimensional structural design of the double door ring, which has been taken into account in the design of the mechanical properties of the part needs. Figure 5b shows the laser spliced plate configuration based on the 3D design and different strength configurations and plate thicknesses selected.

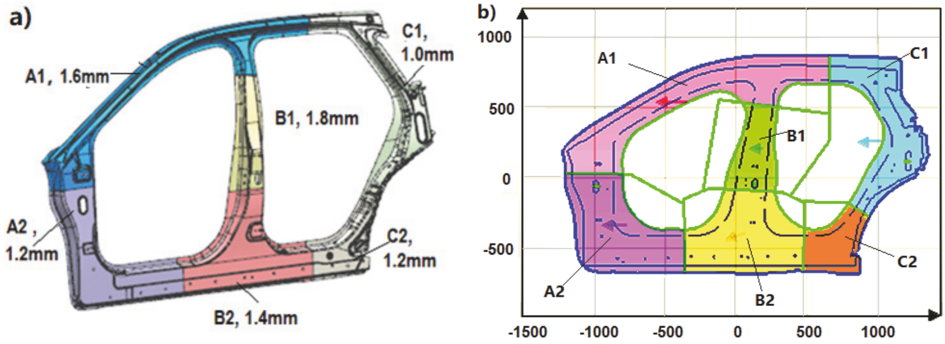

Fig. 5 Double door ring of a car body: a) design of the integrated part; b) laser spliced plate arrangement.

3.2. *Optimization of the material sheet design for the double door ring*

The outer ring of the double door ring (see Fig. 5b) consists of six pieces of material sheets of different strength classes and thicknesses, realized by laser fillet welding. The combination of material strength grade and sheet thickness, in addition to the requirement to meet the mechanical properties and weight reduction targets, should also consider as few sheet specifications as possible in order to optimize the dropout to improve the material utilization and further reduce the cost. The treated strengths and plate thicknesses of their different regions of the sheet are shown in Table 1.

Table 1. Strength grade, thickness, and weight of the door ring laser tailored blank

Welded Plate Area	Material	Thickness (mm)	Weight (kg)
A1, A-pillar upper reinforcement plate	B1500HS+AS	1.6mm	5.53Kg
A2, A-pillar lower reinforcement plate	B1500HS+AS	1.2mm	3.21Kg
B1, B-pillar reinforcement plate	B1500HS+AS	1.8mm	5.87Kg
B2, B-pillar bottom plate	HC370/550+AS	1.4mm	
C1, C-pillar reinforcement plate	B1500HS+AS	1.0mm	2.15Kg
C2, C-pillar lower reinforcement plate	B1500HS+AS	1.2mm	1.23Kg
Total	-	-	**17.99Kg**

Laser dropout technology can be better used "common edge" cutting program to reduce the generation of cutting waste. The combination of a double door ring dropout is shown in Figure 6. The weight of the laser welded plate solution is reduced from 21.94Kg to 17.99Kg compared to the traditional independent parts forming-welding solution, which is more than 17.0% weight reduction of the product. In the traditional way, several parts are independently formed by hot stamping and welded together to form a "double door ring", with a utilization rate of only 67.4%. Laser welding plate integrated door ring solution, no overlap lap spot welding, material thickness according to the needs of the distribution, the product weight reduction effect is obvious, the material utilization rate increased to 71.3%. Reducing the number of structural body parts reduces the cost of the whole vehicle assembly process. Customized optimization of material properties and effective load transfer. Lighter body, lower steel consumption, integrated material optimization reduces the number of molds and welding joints, meets the 2025 Chinese side impact regulations, and improves the vehicle's impact performance.

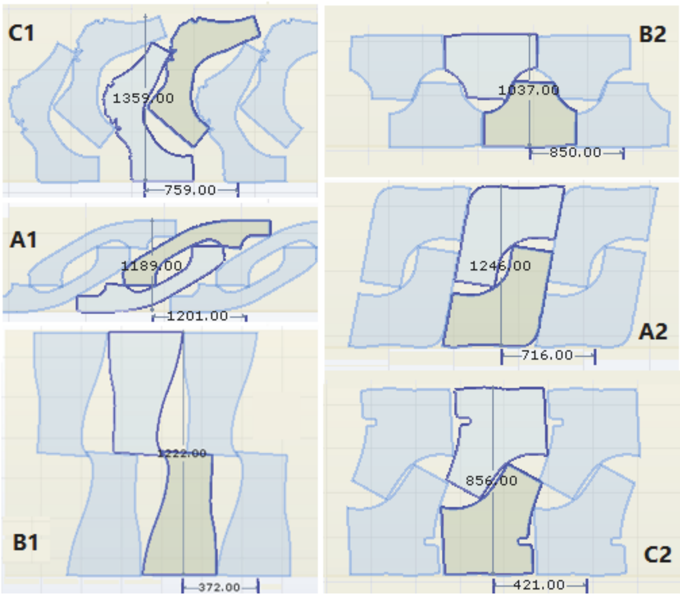

Fig. 6 Scheme of material sheet drop fitting of spliced welded plate

3.3. *Forming process research and process optimization of double door ring*

According to the simulation method of 3D sheet hot stamping, we successfully established a model for hot stamping forming simulation, and the specific model structure is shown in Figure 7. On the basis of the forming simulation, through the analysis and optimization of the simulation results, the following improvement measures were implemented: 1) carry out the optimization of the structural design of the part, modify the local structure of the original design, including changing the rounding angle and slope, and adjusting the depth of the local stretching. 2) adjust the design structure of the die, optimize the crimping structure of the die and the crimping force, and select a more suitable die structural element. 3) for the die The cooling system of the mold has been fully considered to ensure that the structural design of the part is guaranteed while meeting the feasibility of the design and processing of the insert structure and cooling water channel of the mold. These optimization measures will provide strong support for the stability and efficiency of the hot stamping forming process, and lay a solid foundation for the quality and performance improvement of the final product.

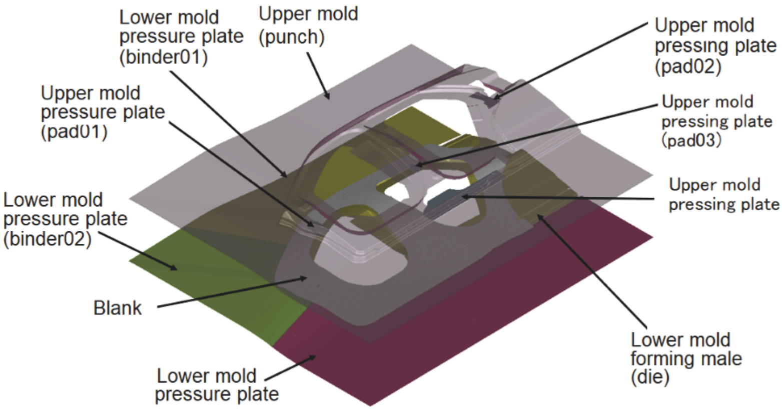

Fig. 7 Model design for hot press forming simulation

The most common defects in sheet forming are transition thinning and localized wrinkles. These defects occur when the assembled sheet undergoes different forming volumes and asynchronous contact cooling. The temperature difference between the blanks contacted first by the molds and the blanks contacted later leads to uneven strength distribution in the sheet. This deviation from the ideal temperature-contact-cooling process considered during the initial design results in lower localized deformation elongation in the contact-cooled region compared to the deformation-stretching region in the high-temperature zone, leading to localized moments of thinning. To address these issues, an optimal design should consider both the satisfaction of the structural shape and dimensions of the part, as well as the feasibility of mold realization. The following examples illustrate optimized solutions to actual forming defect problems.

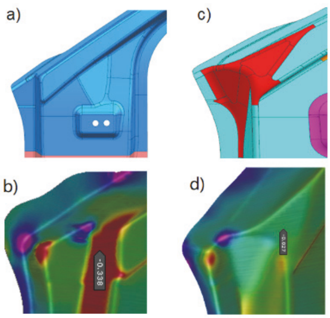

Fig. 8 Thinning rate after optimization of profile structure design

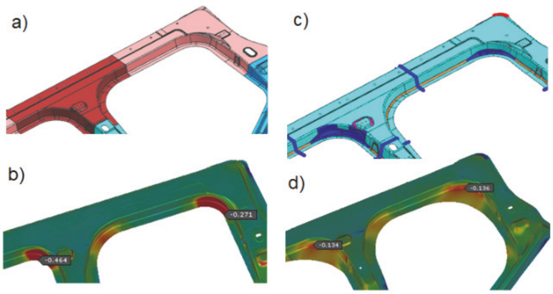

Fig. 9 Structural optimization of door ring hollow corner part

After simulation analysis, it was found that the thinning rate exceeded -33.8% in the original face model (Fig. 8b). In order to solve this problem, we targeted to add the triangular facade structure (red part, Fig. 8c) and performed simulation optimization. The modified simulation results showed that the thinning rate decreased to -2.7% (Fig. 8d), and the profile was optimized to have a thinning rate within a fully controllable range.

A serious thinning problem was also found in the sidewalls of the R-corner region of the original design (Fig. 9b). In order to improve this problem, the triangular façade was increased and the R-angle was enlarged (blue section of the profile, Fig. 9c). After optimization, the results showed that by increasing the R angle and the sidewall draw angle, the thinning rate was reduced from -46.4% in the original design to -13.6% after optimization (Fig. 9d). Such optimization measures satisfy the necessary controllability requirement of product thinning in production.

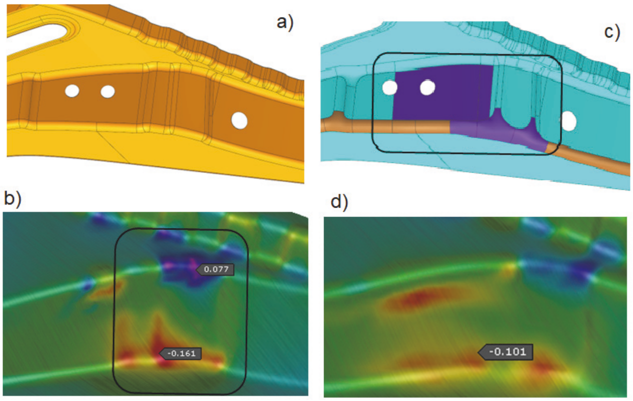

Fig. 10 Modification of wrinkling produced by drastic changes in the transition surface between the door ring projection and the flange

Fig. 10a The R angle of the original design is too drastic, the flow of sheet material in the molding process changes drastically, serious wrinkles appear, and the material sheet stacks up in the molding process, see Fig. 8b. Due to the stacking of the material is too serious, modification of the original design is shown in Fig. 10c), and the increase of the R angle here is shown on the purple part of the surface in the figure. The modified result is shown in Fig. 10d. After optimizing and increasing the R angle, the product thinning rate is optimized from -16.1% to -10.1%, the product thinning is controllable, and the stacking defects are eliminated. After repeated optimization and modification, the double door ring thinning rate is controlled within -13.3%, and the wrinkling rate is controlled within 5.0%, as shown in Figure 11.

According to the design-forming simulation-cooling simulation, the overall mold structure is determined as shown in Figure 12. The effective die surface of the forming mold is 2850x1728mm, the hot stamping forming force is 13500kN, and the actual production uses a 16000kN hot stamping hydraulic press. Due to the large size of the mold, the use of a wide table press, need to ensure that the mold and the press table machine slider has sufficient stiffness, the current generation of hot stamping presses have improved the stiffness to meet the hot stamping forming - holding pressure stability, reduce the probability of warping deformation and other defects.

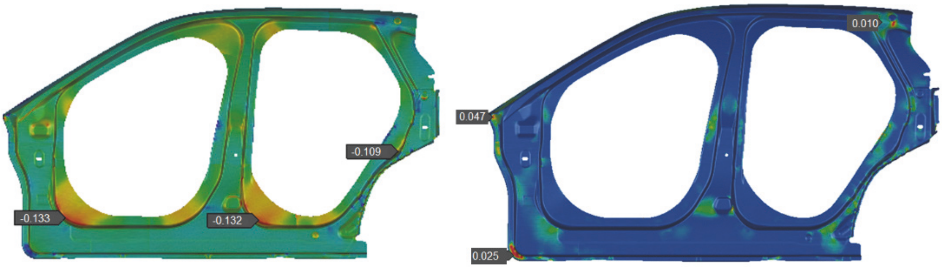

Fig. 11 Results of the final design optimization: a) the overall structure of the thinning state; b) the overall structure of the wrinkle level control state

4. Hot stamping mold and production

4.1. *Hot stamping mold design and forming equipment*

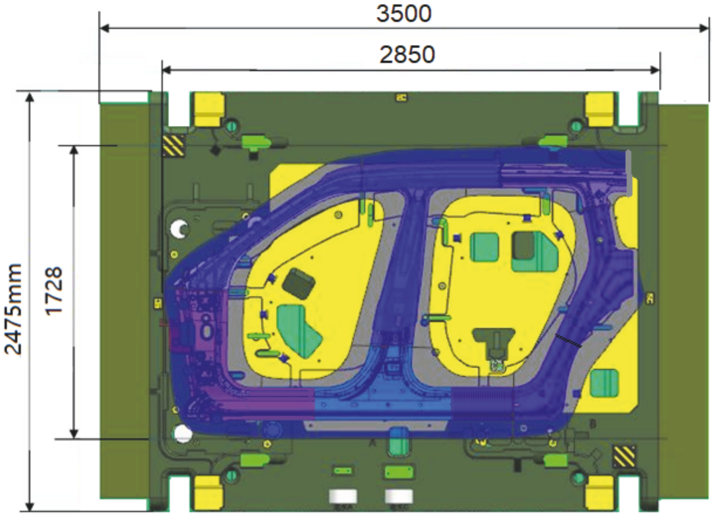

Fig. 12 Schematic diagram of the final mold design after trial mold modification

4.2. *Mechanical properties testing of double door ring hot stamping forming parts*

After the trial production on the 16000kN hot stamping production line, in addition to the dimensional accuracy test, the more important thing is the mechanical strength test of the weld and base material. Samples were taken from the key parts of the hot stamped double door ring, as shown in Figure 13. According to GBT 228.1-2021 National Standard for Tensile Testing of Metallic Materials, the samples were prepared according to A50 sampling, and the tensile test was carried out on Intron 3382 tensile testing machine, and the results are shown in Table 2.

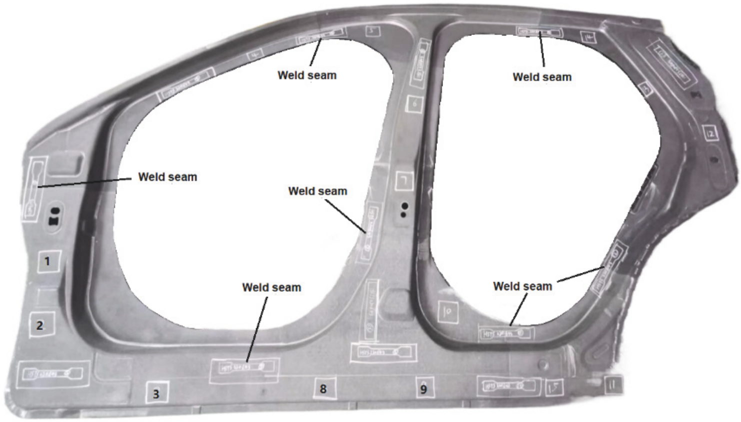

Fig. 13 Sampling part diagram of the hot stamping and forming of double door rings

Table 2 Sampling tensile test results of hot stamped parts of double door ring

	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Conclusion
Sample No.	1300-1700	950-1250	A50≥5	Specification
1.	1382	1109	6.0	pass
2.	1462	1016	6.5	pass
3.	1454	1067	7.0	pass
4.	1342	973	6.0	pass
5.	1416	1039	6.0	pass
6.	1424	1052	6.5	pass
7.	1373	1100	5.0	pass
8.	1302	983	6.0	pass
9.	1343	1021	5.0	pass
10.	1431	1096	6.5	pass
11.	1359	1007	5.0	pass
12.	1316	1062	5.5	pass
13.	1402	1043	6.5	pass
14.	1385	1017	8.0	pass

All fracture parts are fractured in the base material part of the spliced welded plate, which meets the specification requirement of 1300-1700MPa. No fracture occurred in the weld part of the laser spliced plate, which has proved that the splicing quality of the product is qualified, and the mechanical properties of the hot stamped double door ring are qualified.

4.3. *Production efficiency and cost*

The new laser welded plate integrated hot stamping process has the advantage of light weight, reduced mold manufacturing cost, reduced welding equipment, reduced plant area than the conventional manufacturing process of hot stamped parts + assembly welding of double door rings, so it has a very strong product competitiveness, see Table 3. The extended application of this technology, due to the reduction of material usage, the reduction of mold material usage, assembly space and labor Reduction of carbon emission will contribute to the development of automobile manufacturing industry in China and the world.

Table 3 Comparison of two types of double door ring hot stamping technology

Structure and Forming Plan	Board thickness	Material	Product Weight (kg)	Tooling Cost	Dev.period (month)
Hot stamping+assembly welding	1.0-1.2-1.8-2.0	1500HS-AS	21.12kg	100%	4.0
Laser tailord blank MPI hot stamping	1.0-1.2-1.4-1.6-1.8	1500HS-AS	17.91kg -15.2%	93.9% -6.1%	4.0

5. Conclusion and Outlook

The process and mold design of hot stamped double door rings for multi component integration (MPI) laser tiled plate (LTW) body has a broad application prospect. Its application can realize the lightweighting of double door rings, reduce the weight of the body, improve fuel economy, and reduce exhaust emissions. With the increase in demand for environmentally friendly and energy saving and emission reduction, automotive lightweighting has become an important development direction for the automotive industry, which will provide a broad application prospect for the process and mold design

As a key component of the automobile body, the strength and rigidity of the double door ring is crucial for crash safety. Multi-component integrated laser welding plate hot stamping body double door ring process and mold design can provide higher manufacturing precision and material strength, increase the impact resistance and structural stability of the double door ring, and further enhance the safety of the car.

Traditional manufacturing methods often require multiple processes, increasing manufacturing costs and time. However, the multi-component integrated laser spliced welded plate hot stamping body double door ring process and mold design can seamlessly connect multiple components through laser spliced welded plate technology, while using hot stamping forming process to achieve precise molding of the double door ring, which simplifies the manufacturing process and improves production efficiency.

In addition, multi-component integration will face a variety of new materials welding integration, such as zinc-based plating plate, stainless steel plate and other plating plate welding, will be conducive to improve the corrosion resistance of the bottom structure of the body involved in water [10]. The continuous breakthrough of new material splicing and welding technology will give the multi-component integrated laser splicing and welding plate hot stamping body double door ring process and mold design with high flexibility and adaptability. According to different car models and design requirements, different shapes and sizes of double door rings can be manufactured by adjusting the laser splicing plate and mold structure to meet the demand for personalized customization.

References

1. H. Karbasian, A.E. Tekkaya. A review on hot stamping, journal of Materials Processing Technology, 210 (2010)2103-2118
2. Yisheng Zhang, Zijian Wang, Liang Wang. Progress in hot stamping process and equipment for high strength steel sheet. Journal of Plasticity Engineering, 2018, 25(5): 11-23.
3. Braun,M., Fritzsche, Ch., 2009. Joining of hot-formed steel. In: 2nd International Conference on Hot Sheet Metal Forming of High-Performance Steel, Luleå, Sweden,pp. 313–322
4. Marion Merkleina, Michael Wielanda, Michael Lechner, Stefania Bruschi,Andrea Ghiotti.Hot stamping of boron steel sheets with tailored properties: A review,Journal of Materials Processing Technology 228 (2016)11-24
5. Yisheng Zhang, Yilin Wang, Bin Zhu, et al. Research progress of hot stamping technology based on multi part integration. Journal of Plasticity Engineering, 2023, 30(8): 1-7.
6. https://www.cybertruckownersclub.com/forum/threads/cybertruck-live-night-driving-video-on-san-francisco-streets.8306/page-4
7. Nicolas Saba，Jihad Rishmany，Issam Tawk，Michel Daaboul. Optimization of the Production Process of an A-Pillar using a Differential Thickness Profile Approach via FEA. Athens Journal of Technology and Engineering, June 2017, Vol. 4, No. 2:109-123.
8. Steel safety net，By ArcelorMittal25 April 2019, https://www.automotive manufa - cturingsolutions.com/ materials/steel-safety-net/37988.article
9. H. Pan, K. Ding, Y. L. Gao, T. H. Wu. Performance Evaluation and Application of the Laser Welded Joint with Filler Wire for Al-Si Coated Press-Hardened Steels, Proceedings of the 6th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2022), Atlantis Press,2023:185-194. DOI 10.2991/978-94-6463-114-2_25
10. Q. Wang, X. Q. Zhang, B. Zhu, Y.L. Wang, Y. S. Zhang. Research and Application of Hot Stamping Process for High Strength Steel Zinc-Based Coated Sheet, Proceedings of the 6th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2022), Atlantis Press: 217-223