Research and application of hot stamping and forming process of high-performance laser spliced plate and patch plate B-pillar

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The modern automotive industry is facing challenges in the pursuit of sustainable development, especially in reducing carbon dioxide (CO2) emissions and improving energy efficiency. In order to achieve this goal, the automobile manufacturing industry is increasingly adopting the hot stamping and forming process of high-performance laser welded panels and patch panels for B-pillars. This paper investigates the application of this process in body structures, discussing key aspects such as material selection, forming process and mold design, and cooling system design. By optimizing the design of the patch blank and the layout of the cooling system, a highly efficient and stable production process was achieved. Finally, the quality and reliability of the hot stamped formed parts were verified by mechanical property testing.

Keywords: High-strength hot stamping; Laser spliced plate; Patch plate; Cooling system design; Double-layer water circuit.

1. Introduction

The modern automotive industry is facing major challenges in terms of sustainable development, and automotive manufacturing is mainly concerned with how to reduce CO2 emissions, which is directly related to energy saving and efficient use of natural resources [1]. These activities should have a direct impact on reducing emissions from vehicles with conventional drive systems and stimulate the rapid development of electric vehicles [2]. Therefore, the goal is to reduce the weight of passenger car bodies while meeting all safety standards.

An increasing number of new body parts are being produced by hot stamping, which enables the production of high-strength stamped parts with relatively low weight [3]. In addition, this technology enables the production of drawn parts with different thickness zones and thus different mechanical properties in these zones, which is extremely difficult in the cold stamping process [4]. The research and application of hot stamping forming process for high performance laser spliced welded plate and patch plate B-pillar is an important research in the field of automobile manufacturing. As an advanced metal welding method, laser splicing technology is able to weld metal plates of different materials, thicknesses and strengths together to form a high-performance body structure. In automobile manufacturing, B-pillar, as an important part of the body structure, its strength and safety are crucial to the performance of the vehicle [5].

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2. Materials and structure of high-performance B-pillar

2.1. *Material and part structure*

The B-pillar material is 1500HS-AS, the composition of which is shown in Table 1. the master plate consists of 2 pieces of material with different plate thicknesses, which are combined by laser splicing and welding, and the thicknesses of the plates are 2.2mm and 1.5mm respectively. in the part of the mother material with a plate thickness of 2.2mm, the resistance spot weld is applied to weld 1 patch plate with a plate thickness of 1.8mm, and the parameters of the plate combination are shown in Table 2, which make up the part-forming component structure, see Fig. 1. the thickest of the B-pillar blanks is 4.0mm. The thickest position of the B-pillar blank is 4.0mm, and the thinnest place of the part is 1.5mm, and the fall of the blank is large.

Table 1 Composition of Hot Stamped High Strength Steel B1500HS-AS (w%)

C	Mn	P	S	Si	Al	Ti	B
0.2-0.25	1.1-1.4	<0.25	<0.008	0.15-0.35	>0.015	0.02-0.05	0.002-0.005

Table 2 B-pillar material and combination of welded and patched panels

Structure and Forming Plan	Board thickness	Material
Main plate: Laser tailord blank	2.2 - 1.5mm	1500HS-AS
Patch board	1.8 mm	1500HS-AS

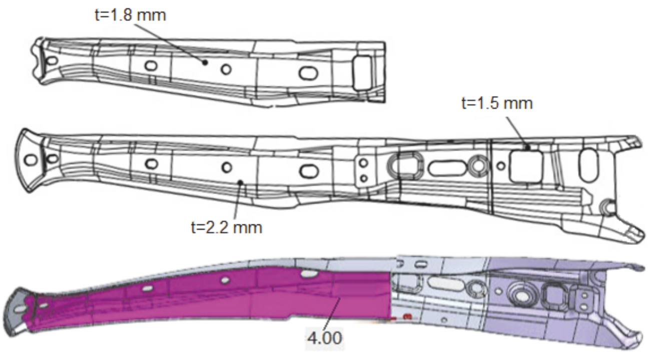


Fig. 1 Schematic structure of B-pillar reinforcing plate splicing weld plate + patch plate

3. Hot stamping process and mold

Hot stamping and forming process is a metal forming process carried out at high temperature, by which the precise forming of high performance laser welded plate and patch plate B-pillar can be realized. Subsequent to using a typical hot stamping process, heat is applied for 120 seconds, the temperature is raised to 930°C and then held for 210 seconds, and then removed from the machine. After 7 seconds of transport (cooling down), the press is formed at 780-870°C.

3.1. *Influence of forming molds of splice-welded plate and patch plate on quality*

Since the hot stamping forming process and molds for B-pillar are more mature, its focus shifts to the cooling problem after the complex plate combination. In addition to weld contamination, localized quenching rates may also lead to a decrease in weld hardness. Misalignment (Δx in Fig. 2) may reduce the hardening rate when weld blanks are made from sub-blanks of different thicknesses. Misalignments greater than 2 mm may result in more than 30% hardness degradation [6].

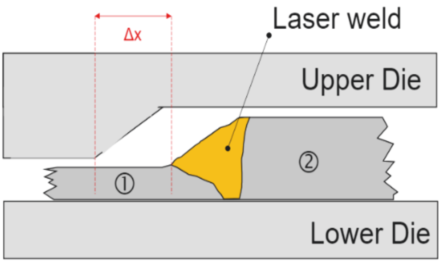


Fig. 2 Misalignment of blanks in the mold may lead to a reduction in the cooling rate of the weld seam

Patch blanks are combined blanks in which one or more "patch blanks" (reinforcements) are overlapped and spot-welded to the "main blank". The spot-welded blanks are then heated in a furnace and hot-stamped as a one-piece form in a single stroke. Patch blanks allow the possibility of reducing the number of forming tools and associated fixed costs. Stamping and post-processing joining costs can also be reduced, leading to a reduction in variable costs. Depending on how the part is designed, weight savings can be realized. These benefits come at the cost of additional punching operations and pretreatment welding stations that generate the patch blank [7].

Optimizing the initial geometry of the patch blank can help reduce these costs. One approach is to use one-step inverse simulation in the early planning/feasibility phase. In this approach, the initial profile is estimated based on plastic deformation theory and only a relatively short simulation calculation is required to obtain initial accuracy patch plate geometry. Then, at the design stage of the initial patch plate blank geometry profile, trimming optimization methods are used to improve the accuracy of the patch plate geometry and the forming simulation is performed once again. These iterations continue until the deviation is less than the set tolerance (±0.25 mm) [8].

3.2. *Cooling System Design*

3.2.1. *Cooling system design principle*

In order to ensure the mold temperature control during the forming process, the cooling system should be efficient, uniform and controllable. In the design, the following principles should be followed: 1) Arrangement of cooling channels, cooling channels should be reasonably arranged in the key parts of the mold, such as forming parts, transition parts and rebound parts, etc., in order to ensure that the mold temperature distribution is uniform throughout the molding process. 2) Selection of cooling medium, the conventional method is to select the appropriate cooling medium, such as water, glycol solution, etc., in order to meet the requirements of the cooling effect and cost. 3) Control of cooling system, Advanced water temperature monitoring and control system is adopted to realize precise control of cooling temperature to ensure the quality of forming.

According to the estimation method of the cooling process, the holding time is calculated according to the empirical coated plate production formula as T=t*3+2=4*3+2=14S. Therefore, at least 14S holding time is required to ensure the qualified performance of the part. In order to accelerate the cooling, in the thickest position of the part (4mm part) designed a double water circuit to ensure that there is sufficient water flow to take away the heat of the part, as shown in Figure 3.

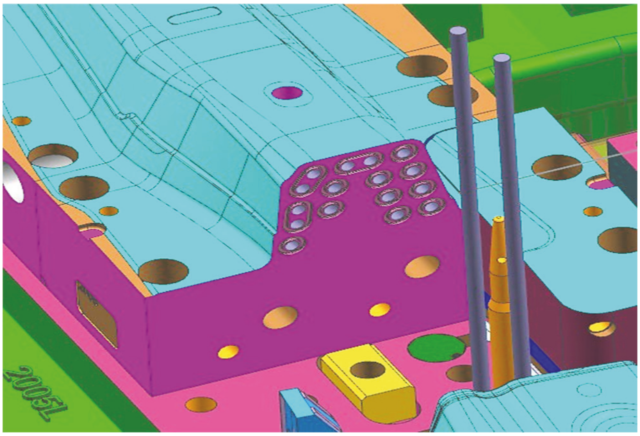
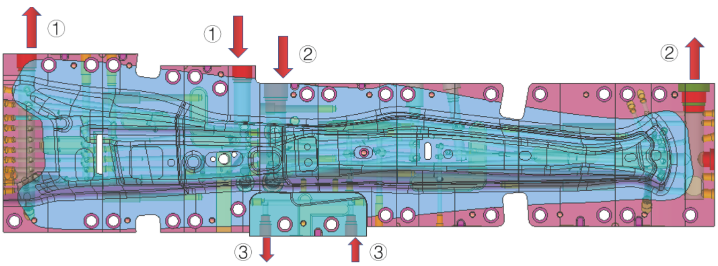
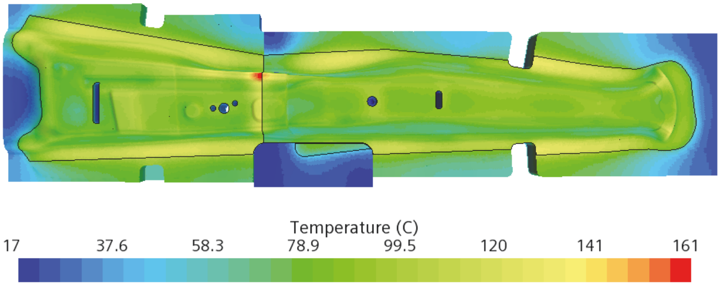


Figure 3 Patch plate and welding plate laminated parts of the double water circuit design

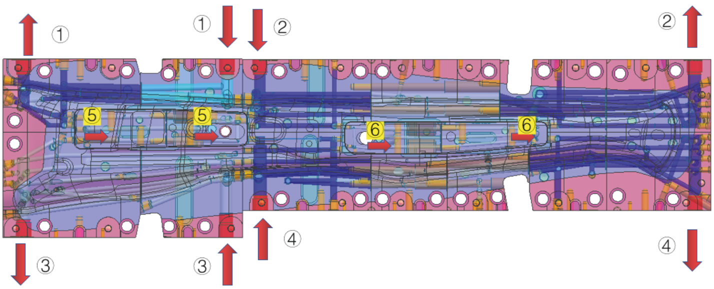
Cooling simulation using the following parameters: Inlet: water temperature 17 ℃, flow rate of 2m / s; parts temperature: 800 ℃ ambient temperature: 25 ℃. The results of cooling simulation are shown in Figure 4



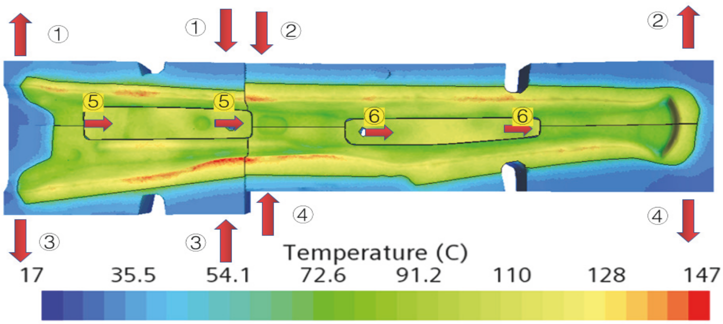
(a) Layout of Lower mold cooling system



(b) Simulation results of lower mold cooling



(c) Layout of upper mold cooling system



(d) Simulation results of uper mold cooling

Fig. 4 Cooling temperature field analysis of hot stamped part

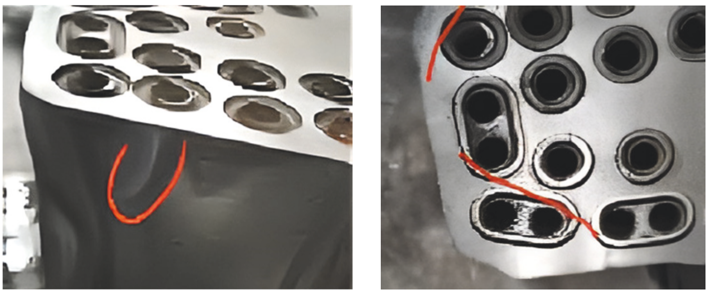


Fig. 5 Cracking and optimization of insert

3.2.2. *Mold material and waterway processing*

ASSAB QRO 90, a mold steel with high thermal conductivity, was used as the insert material with good thermal yield strength and thermal conductivity. Mechanical drilling is used to produce the water channel, and the first layer of cooling channels is processed based on optimization of strength and cooling efficiency. A second layer of waterways was then designed and machined on the inside of the cooling channel layer to increase the cooling rate. Although the production process has been found in the inlay cracking (see Figure 4), after analyzing the decision to reduce the overall hardness of the inlay 4HRC, the inlay normal production of the final mass production stabilization, the holding time is reduced to 10S, which is 4S lower than expected, and achieved a more efficient production beat.

4. Mechanical properties of hot stamping molded parts

4.1. *Sampling and testing*

After hot stamping and forming, the sampling and mechanical property testing of the B-pillar reinforcing plate, the sampling part is shown in Figure 5. In the parts that can not be sampled according to the A-50 test specification, the Vickers hardness test method is used, and the test results, as shown in Table 3. In the case of sufficient sampling space, the samples were taken according to the size of the test specification, and the tensile test was carried out, as shown in Table 4 and Table 5.

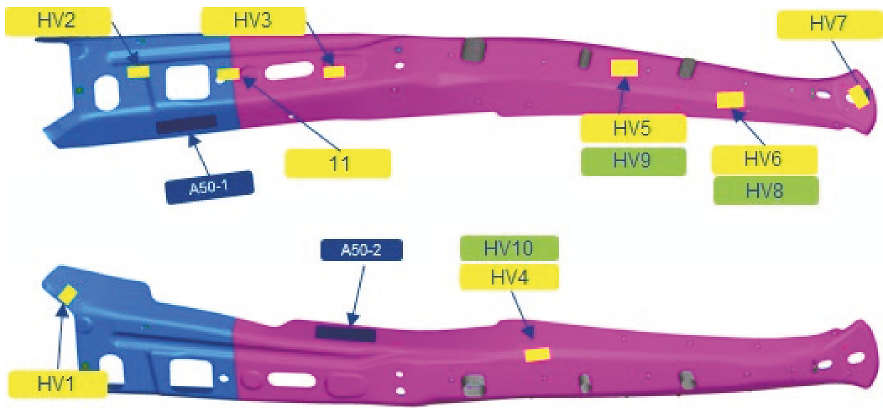


Figure 6 Mechanical properties of hot stamped parts testing and sampling location

The test results show that the Vickers hardness test results are between 440.5 and 501.3, which meets the specification requirements. The results of the tensile sampling test, with all parameters meeting the specification requirements, are shown in Tables 4 and 5.

Table 3 Vickers hardness test report

Sample No.	HV （400-520）	Sample No.	HV （400-520）
L1	453.9	R1	469.2
L2	498.7	R2	485.4
L3	497.6	R3	453.1
L4	461.8	R4	450.8
L5	440.5	R5	484.7
L6	447.9	R6	461.8
L7	480.0	R7	451.8
L8	494.6	R8	496.1
L9	497.6	R9	490.7
L10	501.3	R10	467.2

Table 4 Mechanical Performance Testing Performance Report

Item	Mechanical Property	L1	L2	Evaluate
1	Tensile strength 1300-1650Mpa	1470	1450	Ok
2	Yield strength（Rp0.2）950-1250Mpa	1010	1100	Ok
3	Elongation rate: A50≥5%	7.0	7.5	Ok

Table 5 Mechanical Performance Testing Performance Report

Item	Mechanical Property	R1	R2	Evaluate
1	Tensile strength 1300-1650Mpa	1490	1510	Ok
2	Yield strength（Rp0.2）950-1250Mpa	985	1080	Ok
3	Elongation rate， A50≥5%	7.0	7.0	Ok

5. Conclusion

This study shows that the hot stamping and forming process of high-performance laser spliced plate with patch plate B-pillar is of great significance in automobile manufacturing. Through the comprehensive optimization of material, structure, process and cooling system, the manufacturing of high strength and lightweight body structure is realized. Optimization of the design of the patch blank and the selection of the die material provides a guarantee for production efficiency and quality. The double-layer water circuit design of the cooling system ensures temperature control and molding quality during the molding process and reduces the holding time. Mechanical properties test results show that the hot stamped formed parts have good mechanical properties and meet the requirements of automotive structures. Therefore, the hot stamping forming process of high-performance laser spliced plate and patch plate B-pillar provides important technical support and innovative ideas for the development of automobile manufacturing industry.

References

1. Burton, I. Our common future. The world commission on environment and development. Environment **1987**, 29, 25–29.
2. European Union. Directive (EU) 2019/1161 of the European Parliament and of the council of 20 June 2019 amending directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles. Off. J. Eur. Union 2019, 88, 116–130.
3. H. Karbasian, A.E. Tekkaya. A review on hot stamping, journal of Materials Processing Technology, 210 (2010)2103-2118
4. 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.
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. B-47 A. Breuer, "Optimizing Parameters for Hot formed Tailored-Blank Applications ", Presented at 2015 Great Designs in Steel, Sponsored by American Iron and Steel Institute.
7. U-12. K. Uejima, C. Beku and T. Onoe, "The 2015 WRX STI", Presented at EuroCarBody 2014, October 21-23, Bad Nauheim, Germany, 2014.
8. S-108. M. Sonntag, "How to Determine the Initial Patch Outline in Hot Stamping? Three Different Approaches Compared ", February 25, 2021.