Research and application of key mold technology for hot stamping integral door ring of high strength steel

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This paper aims at the research and application of key mold technology for hot stamping integral door ring with high-strength steel. With the development of automobile industry, lightweight body has become an important trend in the manufacturing industry, and high-strength steel materials and hot stamping technology are widely used in automobile manufacturing. The research focuses on the use of anti-convex mold technology and nitrogen springs and other technologies to overcome the wrinkling problem of the inner ring flange and patch plate area of the door ring. The door ring is fabricated by using non-spliced weld blanks and local patch plate reinforcement method, and realized by hot stamping forming. Simulation results show that wrinkling and thinning problems exist in the door ring forming, and the mold crimping and forming forces need to be adjusted. The improved mold design adopts a counter-convex die structure, which effectively reduces the appearance of wrinkling. The test results show that the mechanical properties of the hot stamped parts perform well, with a pass rate of more than 98.3%. The study shows that the use of anti-convex die technology and in-die cylinder countertop technology can improve the production quality of the door ring and reduce the cost, which provides an important reference for the technological progress of the automobile manufacturing industry.

Keywords: High-strength steel; Hot stamping; Counter-bumping die technology; Nitrogen spring; In-die hydraulic cylinder.

1. Introduction

With the booming development of automobile industry, body lightweight has become an important trend in the current automobile manufacturing field. High-strength steel materials are widely used in automobile manufacturing due to their excellent strength and lightweight characteristics, and hot stamping technology is regarded as one of the key processes to realize the manufacturing of high-strength steel bodies [1]. High-strength hot stamping direct forming is the mainstream method at present, but for large and complex parts, there are many forming processes that need to be improved, and it is of great value to overcome these key technologies. In this context, the hot stamped integral door ring, as an important component in the design of automotive structures, has many advantages in terms of improving productivity, shortening assembly time and reducing cost [2]. The manufacturing of this integral door ring is characterized by the use of non-spliced billets to produce the body integral door ring using equal strength, equal thickness plates and local patch plate reinforcement [3]. In order to overcome possible wrinkles and transition thinning problems, advanced technologies such as anti-convex mold technology, nitrogen gas springs, and in-mold hydraulic cylinder counter-roofing were introduced to enhance

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the production quality and processing efficiency of the integral door ring. Through in-depth research and careful application of these key mold technologies, it will be helpful to promote the technological progress and product quality improvement in the automobile manufacturing industry.

2. Analysis of hot stamping molding of overall door ring

The structural characteristics of the high-strength steel door ring are shown in Figure 1. The overall door ring is obtained by direct undercutting of equal-thickness plate, and in the B-pillar part, a patch plate is added. The type of hot formed steel plate used is CR950/1300HS-AS75/75, Thickness: 1.4mm and 1.8 (patch). Its chemical composition is shown in Table 1.

Table 1 High-strength steel materials for hot-stamped door rings

C	Si	Mn	P	S	Al	Cr	B	Ti	Mo	N
0.20-0.25	0.15-0.40	1.10-1.40	≤0.030	≤0.010	0.01-0.06	≤0.05	0.001-0.005	0.020-0.050	≤0.35	≤0.010

The 1.4mm sheet is cut to obtain the base plate of the door ring, and the 1.8mm sheet of the same grade is used as the patch plate. The cut sheet is welded to the patch plate and then used as the blank for hot stamping. After hot stamping and molding of the parts shown in Figure 1.

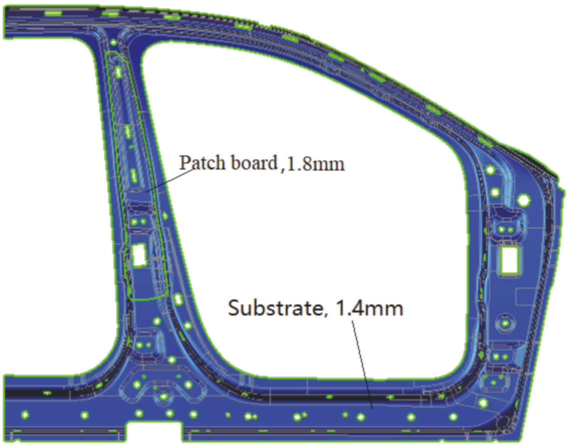

Fig. 1 Part drawing of hot stamping formed door ring

According to the hot stamping process, the overall blank is heated (930°C for 120 seconds and held for 210 seconds) to achieve austenitization, then transferred to the press mold for stamping and forming-pressure holding and cooling. In order to consider the design and manufacture of the forming die, after the hot stamping forming simulation, we now take some of the states in the forming process and analyze them, as shown in Figure 2.

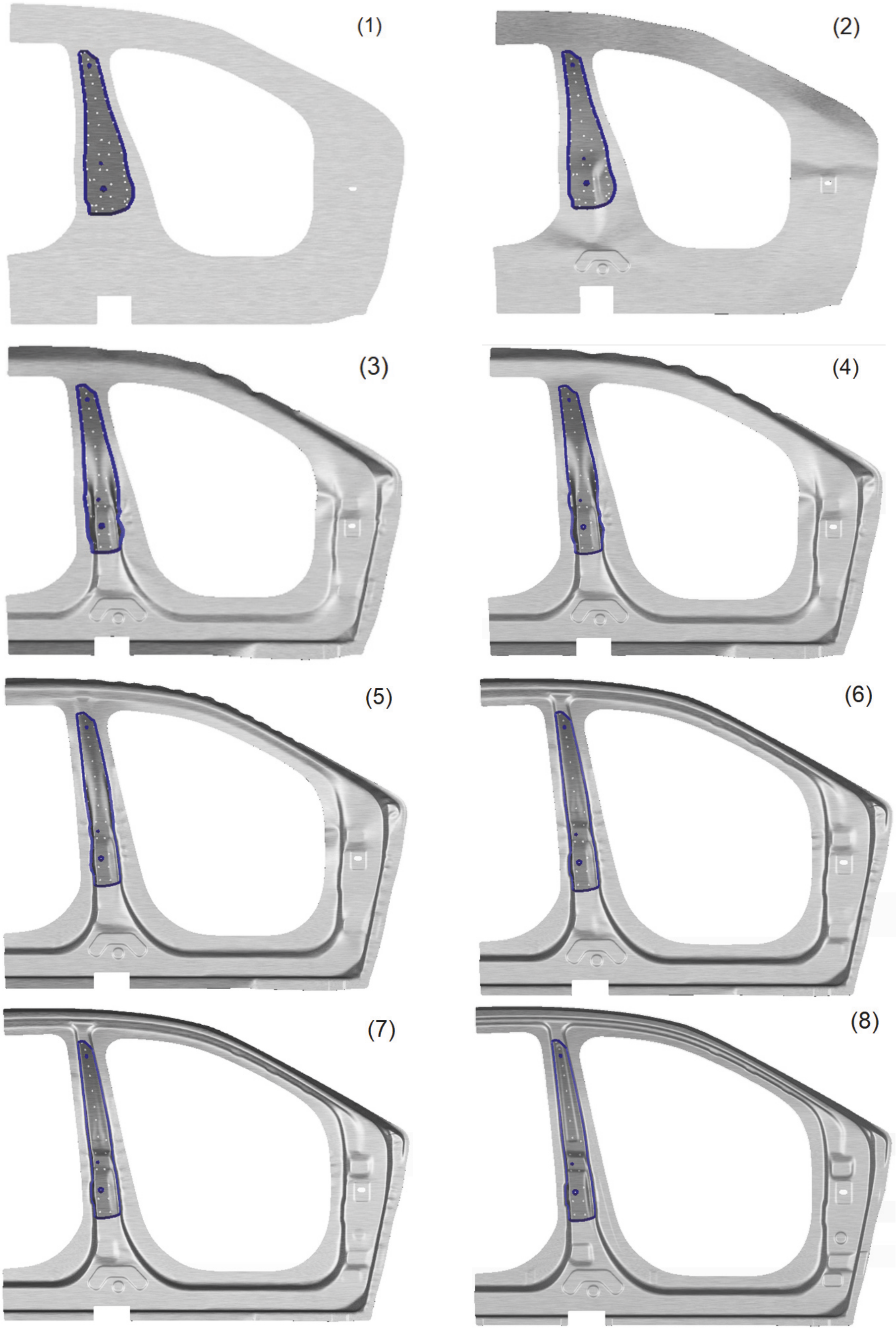

Fig. 2 Forming process of door ring with patch board (1-Blank and Patch board; 2- Lower pad closing (or 90mm from bottom; 3- upper pad closing (or 40mm from bottom); 4- 30mm before Bottom; 5- 15mm before Bottom; 6-5mm before Bottom; 7- 3mm before Bottom; 8-Bottom)

From the simulation results, it can be seen that the inner ring and outer flange of the door ring are wrinkled, and there are more obvious wrinkles on both sides of the B-pillar patch panel. In addition, through the formability analysis (formability/thinning), it can be seen that the max. thinning rate Max. thinning: -15.7 % and the max. thickening rate Max. thickening: 9.6 %. According to the criterion of cracking, a thinning rate of 15% or more exceeds the forming limit, as shown in Fig. 3.

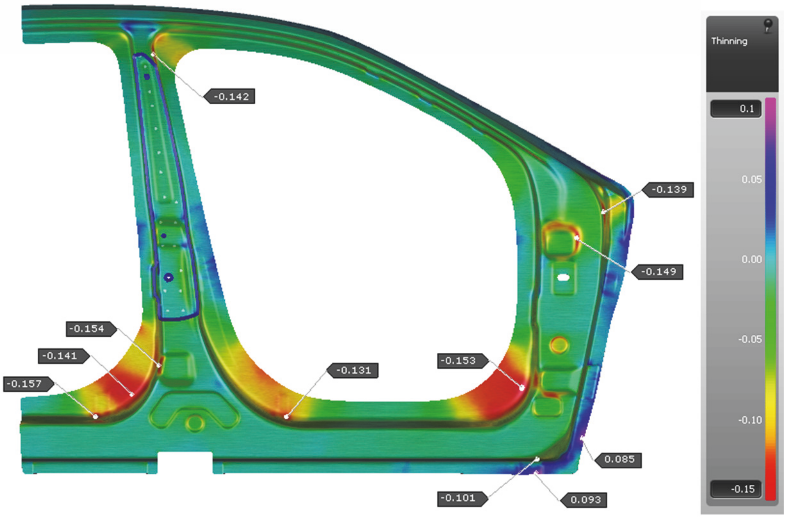

Fig. 3 Forming limit analysis (thinning rate)

According to the results of the forming simulation, to overcome the forming wrinkles and the localized thinning rate, it is necessary to take the die crimping and the localized forming force adjustment.

3. Mold structure design and characteristics

Since the rate of temperature change of the sheet is related to the contact thermal resistance, and the gap between the formed part and the mold affects the size of the contact thermal resistance, in order to speed up the production beat, it is necessary to improve the contact condition, so this paper investigates the design of the forming mold with the suppression of sheet wrinkling. The traditional mold is a typical convex mold, concave mold structure, not set up to prevent wrinkles, through the pressure, the gap as much as possible to reduce the appearance of wrinkles; while the improved mold draws on the principle of the anti-convex mold, the concave mold wrinkle prone to the position of a separate module, set up as an independent module, in the molding of wrinkle prone to the position of the molding first [4].

The mold takes the convex mold and crimping ring on the top, and the concave mold is on the bottom, see Figure4. The advantage of this is that when the patch plate sheet is heated in the furnace chamber, the patch plate is facing upward, which can effectively control the heat warping of the sheet and the stability of the position out of the furnace, and also reduce the adhesive contamination of the rollers by the aluminum-silicon coating of the rollers in the furnace chamber.

The lower die uses a cylinder to press the edge ring of the top die, at the end of forming, before the mold is opened, the cylinder continues to press the edge ring of the top die to achieve the function of delayed nitrogen spring, see Figure 5. the actual application of the mold put into use on the mold is shown in Figure 6.

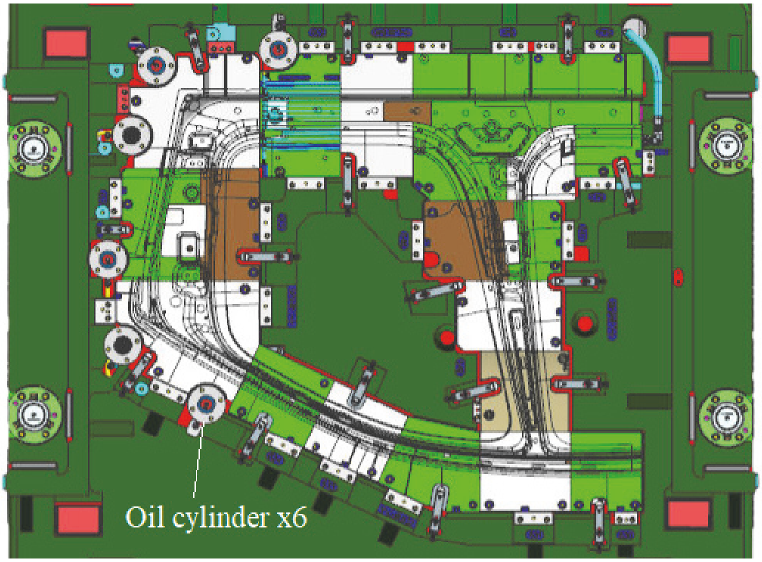

Figure 4 The lower mold uses 6 sets of in-mold cylinders to PAD the top mold.

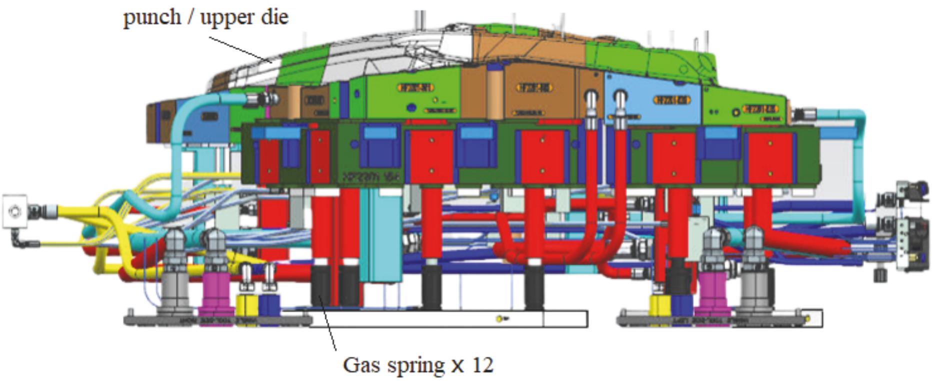

Fig. 5 The upper mold uses 12 sets of nitrogen springs.

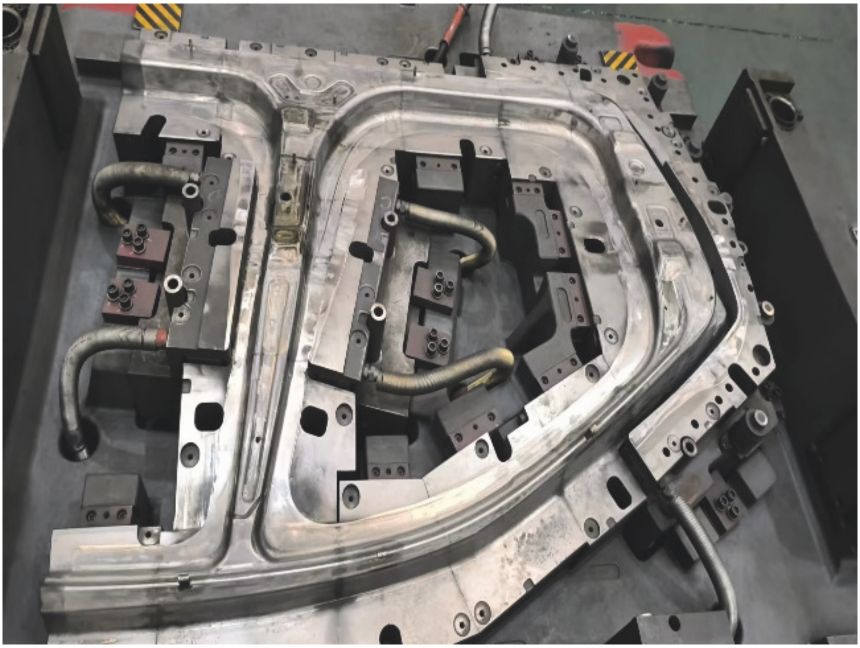

Fig. 6 Photo of the actual mold (upper mold)

4. Analysis of test and application results

Each different inspection point (Point) does 3 times sampling to test the tensile strength and elongation. The sampling of the testing part of the critical part (Point) of the hot stamped part, the test results are shown in Table 2. The average tensile strength is 1485MPa, productivity is 5.71%.

Table 2 Mechanical properties of hot stamped parts testing

Regional performance		Tensile strength RM（MPa）	Yield strength RP0.2（MPa）	Elongation after fracture A50（%）
Point-1	1	1492.06	1083.99	6.40
	2	1438.72	1028.42	6.68
	3	1489.88	1083.61	5.24
Point-2	1	1511.94	1098.00	5.58
	2	1464.12	1060.79	5.50
	3	1504.86	1098.43	5.22
Point-3	1	1500.64	1087.66	5.62
	2	1477.82	1071.64	5.42
	3	1487.91	1083.95	5.80

After the test results of small batch production, the parts qualification rate is summarized in Table 3. The comprehensive quality inspection pass rate is more than 98.3%.

Table 3 Summary Table of Parts Qualification Rate

Item	Classify	Date	2023.10.27	2023.10.27	2023.10.27
		Part No	No.1	No.2	No.3
1	Surface	Qualified	316	317	313
		Total	321	321	321
		Pass rate	98.4%	98.8%	97.5%
2	TRIM	Qualified	66	66	66
		Total	66	66	66
		Pass rate	100%	100%	100%
3	HOLE	Qualified	84	84	84
		Total	84	84	84
		Pass rate	100%	100%	100%
4	CPT	Qualified	116	116	115
		Total	117	117	117
		Pass rate	99.1%	99.1%	99.3%
5	Pass rate	Qualified	466	467	463
		Total	471	471	471
		Pass rate	98.9%	99.2%	98.3%

5. Conclusion

The objective of this research is to study the key technology of hot stamping and forming of door rings and the feasibility of mass production. Whole piece drop and patch plate welding are used, and the influence of forming and heating process of the patch welded plate is strictly examined. In order to meet the specification requirements of formability, especially the wrinkling and transition thinning of the inner ring flange edge and outer ring flange edge of the patch plate part and the door ring, the control strategies of nitrogen spring and in-die hydraulic cylinder's crimping force and stroke are commonly used to realize the overall forming of the parts, and the qualification rate of the parts is more than 98.3%.

The hot stamping die with anti-convex die significantly reduces wrinkles and improves the contact conditions between the material and the die, which is conducive to improving the consistency of the phase transition of the material, thus obtaining a uniform microstructure and mechanical properties play an important role. Due to delayed nitrogen, there is often unreliable spool closure, often resulting in product scrap. The use of in-mold cylinder to the top of the way, greatly reducing the quality defects.

The use of this technology, due to the use of equal-thickness plate and patch plate combination of blanks, mold manufacturing is reduced, the original program requires 24 groups of delayed nitrogen cylinders for each set of molds, while the use of in-mold cylinder technology program to save money 420,000 yuan. Post-maintenance spare parts cost reduction, cost savings of more than RMB 400,000 yuan.

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