Research and Application of Variable Strength Hot Stamping Process and Die

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Abstract. With the promotion and application of high strength steel and hot stamping forming technology in automobile engineering, researchers gradually realize that in addition to improving the strength of automobile structural parts, the problem of matching the mechanical properties of parts and body safety requirements is also worthy of attention, that is, the same Different areas of the part actually have different mechanical properties requirements, that is, high-strength steel variable-strength hot stamping technology. For the B-pillar parts of the car, the upper part needs sufficient strength to ensure the integrity of the car body when the car is impacted, and the lower part needs good ductility to absorb energy, prevent collision and intrusion, and cause occupant harm. The realization of high-strength steel variable-strength hot-stamping process through special hot-stamping process has become a research hotspot. The main methods are differentiated initial temperature, different thermophysical mold materials, mold block heating, differentiated surface contact conditions and tempering processing.

Keywords: High strength steel · Hot stamping · Variable strength forming · Die heating system

1 Introduction

With the popularization and application of high-strength steel and hot stamping forming technology in automotive engineering, researchers have gradually realized that in addition to improving the strength of automotive structural parts, the issue of matching the mechanical properties of parts and body safety requirements is also worthy of attention, that is, the same part In fact, different areas of the high-strength steel have different mechanical properties requirements, that is, the high-strength steel variable-strength hot stamping technology. As shown in Fig. 1, the upper part of the B-pillar part of the car needs sufficient strength to ensure the integrity of the car body when the car is impacted, and the lower part needs good ductility to absorb energy, prevent collision and intrusion, and cause occupant harm.

The realization of high-strength steel variable-strength hot-stamping process through special hot-stamping process has become a research hotspot. The main methods are differentiated initial temperature, different thermophysical mold materials, mold block heating, differentiated surface contact conditions and tempering processing, etc. [1].

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Hot stamping parts have high strength but low elongation, which makes it difficult to meet specific collision requirements, such as different areas of the same part requiring different mechanical properties. Typical parts such as B-pillars require better plasticity at the lower end to absorb collision energy, and higher hardness at the upper end to protect passengers from collision and intrusion. Higher safety requirements bring new challenges to the hot stamping process. In the process of vehicle collision, if the main structural parts of the car have high elongation in some specific areas, the non-critical areas of the vehicle can be deformed to a large extent and absorb energy without serious deformation of the key parts, thereby Reduce the damage to personnel caused by impact [2]. Softening the solder joint area and changing the work hardening properties here can avoid cracking defects in the solder joint area during crash testing [3]. Therefore, variable-strength hot stamping parts have high research and practical value in soft areas, and have been widely used in A-pillars, B-pillars and front and rear longitudinal beams of passenger cars.

Through the partition design of the mold (heating area and cooling area), cooling water is provided to the area that requires high strength to ensure sufficient cooling rate to achieve complete martensitic transformation; heating the mold in the area requiring high plasticity will reduce this area. The cooling rate is high, resulting in a mixed structure of martensite, bainite, ferrite and pearlite, which realizes the function of the soft and hard zone of the product.

The advantage of adopting this technical solution is that the strength, hardness and performance of the parts can be realized on demand, and the configuration of the collision performance of the whole vehicle can be improved. Compared with the TWB variable strength forming scheme, its disadvantages are: 1) The soft and hard areas have a certain length of strength transition area (30~50 mm); 2) The soft area of the mold is expensive to manufacture and debug, and the debugging cycle is high. longer. However, its customized strength zoning, which can achieve the optimized mechanical properties required by body designers in a single heat stamping, is still widely accepted.

2 Process of Variable Strength Hot Stamping

2.1 Design of Variable Strength Thermoformed Parts

Two kinds of variable strength hot stamping parts were developed and put into mass production, and their performance distribution and requirements are shown in Fig. 1.

In order to further enhance the strength and anti-intrusion performance of the upper end area of the B-pillar parts, a patch area is designed to improve the side impact performance. According to the front longitudinal beam parts and the numerical simulation results of the frontal collision of the whole vehicle, a two-stage soft zone is designed to achieve the optimal crash performance.

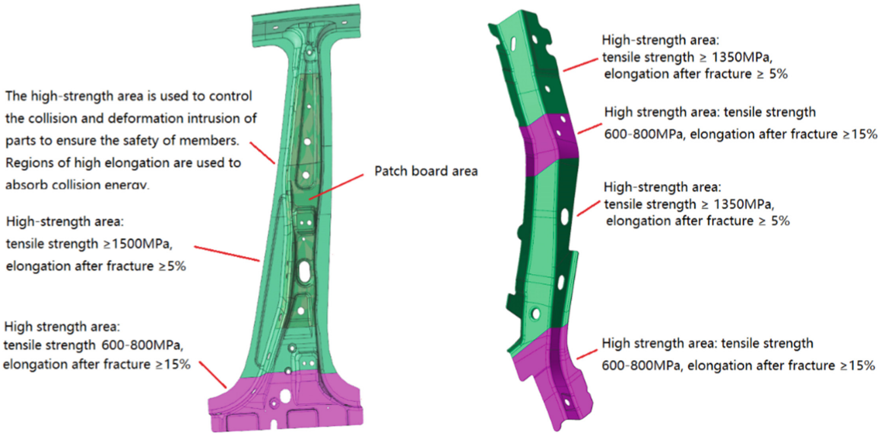

Fig. 1. Variable strength design of two BIW parts.

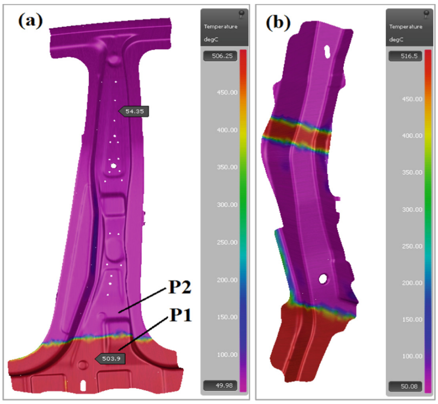

Fig. 2. Through the variable strength design and process analysis, the cloud diagram of the temperature distribution of the part after forming and pressure-holding is predicted: (a) B-pillar; (b) longitudinal beam.

2.2 Analysis of Variable Strength Process

Figure 2 shows the cloud diagram of the temperature distribution of the parts at the end of the forming and holding pressure (20 s). It can be seen that the temperature of the parts in the high-strength area after the forming and holding pressure is 50 °C, while the temperature of the parts in the high elongation area is kept with the set mold temperature. Consistent, at 500 °C. Take a point in the hard zone and the soft zone to extract the temperature history curve during the forming and holding process as shown in Fig. 3. The hard zone P1 point has a higher cooling rate and completely crosses the martensite region of the CCT curve, and the soft zone P2 point the cooling rate is low, mainly through the ferrite and bainite regions.

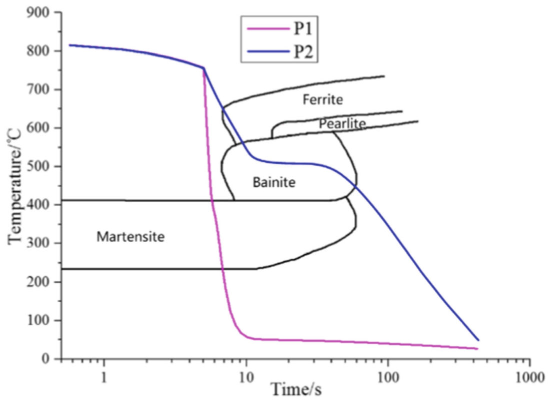

Fig. 3. Temperature history and cross-CCT curve of forming-pressure-holding-air cooling process at P1 and P2.

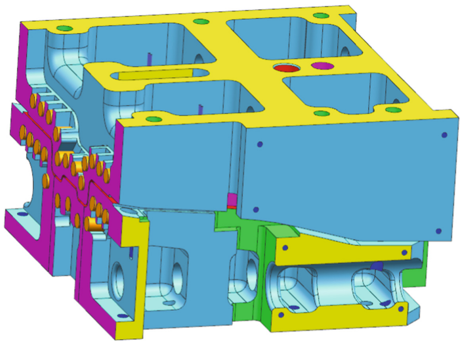

Fig. 4. The design of the mold structure and the hollow design of the heating zone.

3 Design and Application of Variable Strength Forming Die

In the hard zone, the cooling water circuit is designed according to the traditional hot stamping die. In the soft zone, the die has built-in heating rods and thermocouples to control the die to maintain the set temperature. In order to make the temperature heating of the whole soft area more uniform, the mold in this area is divided into multiple areas, each area has an independent thermocouple to control the heating rod in this area, and the heating temperature can be set independently for each area. The heating rod, thermocouple and PID control box together constitute the soft zone area mold temperature control system.

The heating zone design is hollowed out without affecting the rigidity and strength of the mold, as shown in Fig. 4. The mass of the module is reduced as much as possible to achieve the purpose of rapid heating and temperature control; the upper and lower molds are controlled by a total of 10 areas. Mold surface temperature, see Fig. 5.

Figure 6 is the actual picture of the multi-distribution area variable strength forming mold, and the hardness test results of the transition zone of the formed part. Take tensile

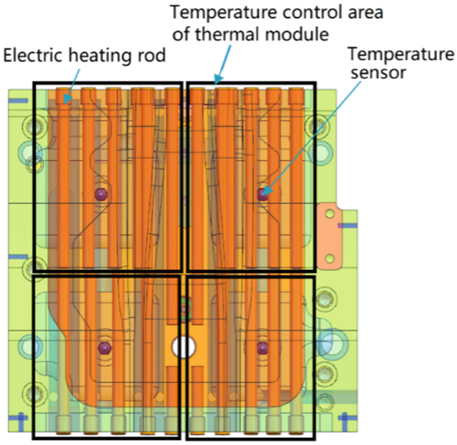

Fig. 5. The arrangement of the heating zone divided into 4 pieces and the heating device.

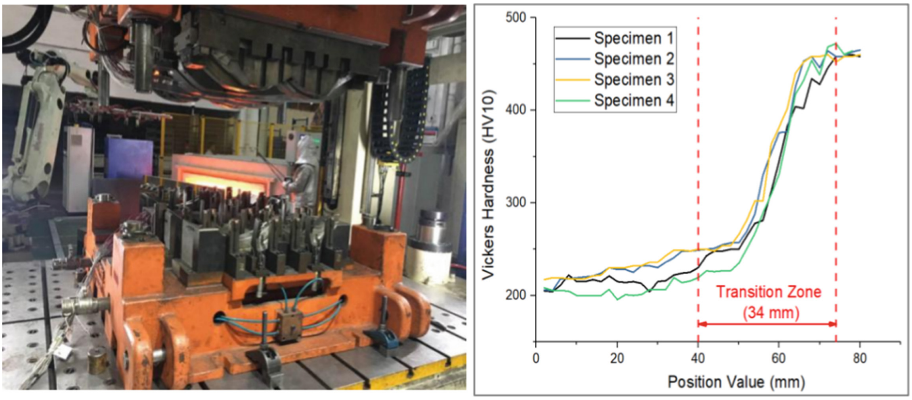

Fig. 6. Multi-distribution area variable strength forming mold and hardness results of transition zone.

specimens in the heating zone and cooling zone, and take hardness test specimens in the transition zone. The tensile strength of the hard zone is about 1500 MPa, and the elongation is greater than 5.9%; the tensile strength of the soft zone is about 760 MPa, and the elongation is greater than 13.9%.

4 Conclusion

Through the reasonable design of the heater system of the soft zone module of the mold, the cooling rate of the soft zone of the part can be controlled with high response, so as to achieve customized mechanical properties, and achieve low strength and high strength while ensuring local high strength of intrusion resistance. The local function of elongation satisfies the excellent comprehensive anti-collision performance of body design.

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