Application and Lightweight Research of QP1180 High Strength Steel in Autobody Reinforcement Part

B. Liu[1](✉), J. Yang[1], X. Y. Zhang[2], Q. Yang[2], Z. Y. Li[2], G. Feng[2], Z. B. Wang[2], J. S. Zhang[2], and X. Q. Li[2]

[1] School of Mechanical Engineering, University of Science and Technology Beijing, Beijing 100083, China
liubo1@ustb.edu.cn

[2] Global R&D Center, Chongqing Changan Automobile Co., Ltd., Chongqing 401120, China

Abstract. In response to the severe cracking and wrinkling of the reinforcement part of front side rail, this research designs a replacement solution of high-strength plastic accumulation material (QP1180) and verifies its feasibility through structural optimization, process analysis, mold debugging, and extensive experiments. First, the material thickness is thinned and validated with new data for crash simulations. Subsequently, a process plan is developed based on structural characteristics and high-strength steel material properties, accompanied by a simulation analysis of the initial structure. The simulation results, such as local cracking, wrinkling, and material stacking, optimize the structure in multiple rounds to obtain data and process solutions that meet the formability. Thereafter, CAE simulation of the stamping process is carried out to improve the efficiency of the tool manufacturing. The simulation results demonstrate that the process performance meets the requirements and the rebound control effect is achieved by adopting 1:1 ratio for pre-deformation compensation. Ultimately, the sample development is completed on the basis of three rounds of mold debugging. The size deviation is assessed to be within 1.0 mm by blue light scanning, which meets the design requirements. The study accentuates that the maximum thinning rate of QP1180 material should not exceed 15%, providing insights into its application on vehicles.

Keywords: QP1180 · High strength steel · Structural optimization · Body lightweight

1 Introduction

People's demands and expectations for lighter weight vehicles are becoming a reality [1]. Compared with ordinary mild steel, high-strength steel sheets are widely used in auto body lightweighting technology due to their high tensile strength [2]. However, the increase in tensile strength can lead to a large amount of springback of the material after forming and unloading, and the accompanying dimensional accuracy is difficult to control [3]. The poor ductility leads to easy cracking and failure during the stamping and forming process [4].

Y. Zhang and M. Ma (Eds.): ICHSU 2022, AHMST 2, pp. 311–316, 2023.
https://doi.org/10.2991/978-94-6463-114-2_43

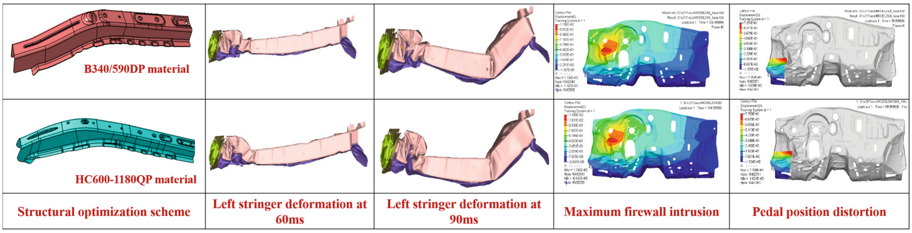

Fig. 1. Collision simulation analysis results of front rail, front panel, and driver left pedal position.

Quenching and Partitioning produce a high strength and plasticity martensitic steel, also known as QP steel [5]. QP1180 has a larger fracture strain and excellent fracture plasticity than QP980 and has great advantages for body safety structural parts [6]. Therefore, for the reinforcement part of front side rail (RPFSR) to crack, wrinkle, and spring back during the stamping and forming process, an alternative solution of high strength plasticity stacking material is designed. The feasibility is verified through structure optimization, process analysis, and mold debugging.

2 Structural Optimization Design and Verification

RPFSR is a t = 1.4/2.0 tailor weld blank with an initial material solution of B340/590DP. Based on the experience of thinning of high strength steel material thickness, as in Eq. (1), the design structure is QP1180, t = 1.6 mm equal thickness plate scheme, which can achieve weight reduction of 0.258 kg for single piece and 0.516 kg for the whole vehicle.

$$\frac{t_1}{t_2} = \sqrt{\frac{\sigma_2}{\sigma_1}} \tag{1}$$

where t_2, σ_2 and t_1, σ_1 denote the thickness and yield strength corresponding to the two materials before and after weight reduction, respectively.

It is necessary to perform crash performance verification using the new data since RPFSR is a crash safe structural component. In order to visualize the deformation effect, crash simulations of the front longitudinal beam, firewall, and driver's left pedal position were conducted, as shown in Fig. 1. The simulation results show that the longitudinal beam deformation, maximum firewall intrusion, and maximum pedal intrusion variation are all within the target values and meet the design requirements.

3 Stamping Process Design and Simulation

3.1 Stamping Process Analysis and Scheme Design

The original data of RPFSR is 758.5 × 136 × 241.2. The cross-section is U-shaped with flanged edges and the longitudinal section is a V-shaped structure at 165°. The left and right sides of the RPFSR front end need to be flanged, with a height of about 20.5 mm and 32.5 mm respectively. There is a localized 15.8° internal pinch angle at the front end, which requires side shaping to meet in dimensional requirements.

Based on the structure of RPFSR and the performance characteristics of QP1180, the drawing process is used to ensure good appearance and quality control performance. Since there are holes in different planes and the cut edges are not in the same stamping direction, two sub-trimming and punching processes are required. Simultaneously, the side shaping process is added to facilitate the control of rebound accuracy at a later stage.

3.2 Stamping Process Simulation Analysis

CAE analysis of stamping and forming can significantly reduce the problems during mold manufacturing and product commissioning. Therefore, the RPFSR was simulated for the whole stamping process, mainly analyzing the drawing process, the cutting edge punching process and the flap shaping process.

The results of the drawing process are expressed in Fig. 2(a), with no overall cracking and transition thinning areas and only some areas of material thickness increase. There is no risk of cracking during the trim process, as depicted in Fig. 2(b). No transitional thinning and cracking areas appeared in the turning and shaping process, as calculated in Fig. 2(c). The presence of high yield strength in high tensile steel causes a large amount of springback after cold stamping, leading to warpage and even scrap of RPFSR. Rebound compensation by CAE simulation is the most effective method to solve the late rebound. The simulation results of the drawing process and the flap shaping process are shown in Fig. 2(d), which indicates a large amount of spring back in the forming of UHSS, up to about 4.5 mm.

Pre-deformation compensation is taken in 1:1 ratio according to expert experience. After several times of rebound compensation, a comparison of the final state with that before rebound is obtained as demonstrated in Fig. 2(e). The rebound compensation has achieved better results, and the dimensional deviation has been effectively controlled.

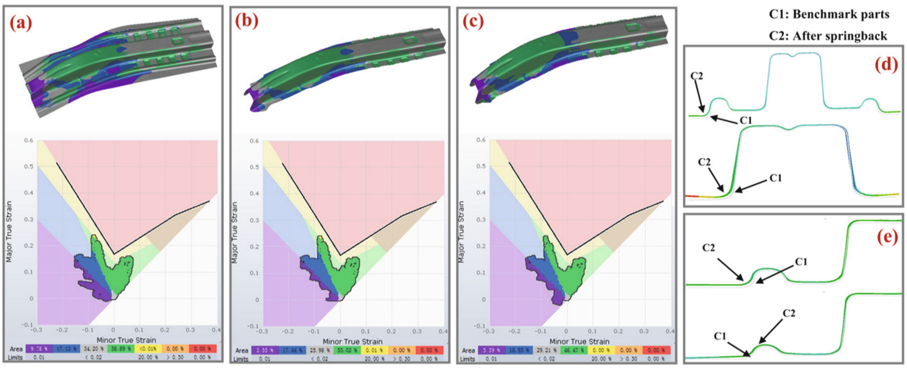

Fig. 2. Stamping process full process simulation: (a) Drawing process analysis results; (b) Trim process analysis results; (c) Flange and shaping process analysis results; (d) Springback section of drawing process and flanging process; (e) Section before and after rebound compensation.

4 Tooling Commissioning and Manufacturing

The material of RPFSR is replaced with QP1180 in the test without changing the process parameters (Fig. 3(a)). QP1180 belongs to the third generation of advanced high-strength steel and its material properties are shown in Table 1.

The test equipment is a 1500-ton hydraulic press, as presented in Figs. 3(b) and (c). The main cylinder pressure at the first die casting is 1200 tons and the top cylinder pressure is 100 tons. Cracking occurs before the mold is completely closed due to excessive pressure, as depicted in Fig. 3(d). Therefore, we need to reduce the friction and improve the flow ability of the material.

The second commissioning is mainly to coat the surface of the blank with lubricant and then wrap two layers of plastic film to keep the mold condition as well as the pressure value unchanged. It has been verified that the stacking phenomenon occurs due to too fast flow of the blanks, as expressed in Fig. 3(e). The results accentuate a significant lubrication effect and low resistance to the flow of the blank. Therefore, we need to control the feed rate. During the third debugging, the film on the billet surface was

Table 1. QP1180 material properties.

Material	Yield strength (MPa)	Tensile strength (≥MPa)	Elongation (≥%)
QP1180	850–1060	1180	14

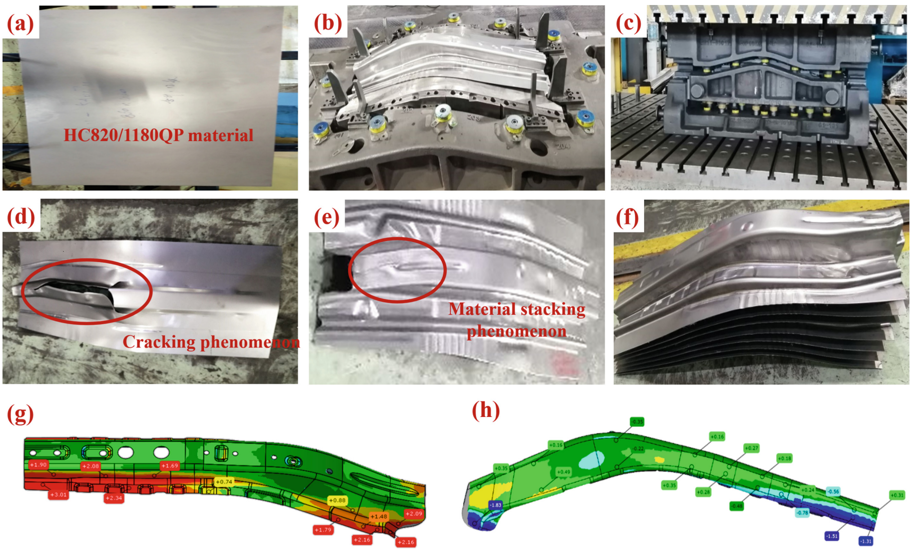

Fig. 3. RPFSR debugging and production: (a) RPFSR material; (b) Die casting surface structure; (c) Die casting model; (d) RPFSR cracking phenomenon; (e) RPFSR stacking phenomenon; (f) RPFSR samples; (g) RPFSR Rebound value before debugging; (h) RPFSR Rebound value after debugging.

cancelled and the balance blocks were increased by 0.5 mm, while the other process parameters remained unchanged. Figure 3 (f) demonstrated no cracking and wrinkling phenomenon in this scheme, and all ten products obtained good appearance quality.

The severe springback of RPFSR during stamping and forming needs to be solved. The rebound value is detected by blue light scanning, and the rebound compensation is set according to 1:1. Through four rebound compensations, the average rebound of RPFSR is now controlled within 1.0 mm, with an average value of 0.5 mm. However, negative rebound occurs locally and the corresponding position of the mold needs to be optimized.

5 Conclusion

To solve the problem of RPFSR severe cracking and wrinkling, this study designed an alternative to QP1180. First, the RPFSR structure thickness was changed and verified by new data from collision simulations. The simulation results show that the longitudinal beam deformation, the firewall maximum intrusion amount and the pedal maximum intrusion amount are all within the target range. Moreover, according to the structural characteristics and material properties of high-strength steel, the process plan was developed and simulated the initial structure. Drawing and flanging process have no cracking and thinning area, cutting and punching process have no cracking risk. There is a massive amount of spring back during the forming process, about 4.5 mm. According to the experience setting the rebound compensation ratio of 1:1, the compensation impact and dimensional deviation have been successfully improved. Ultimately, the sample development is completed based on three rounds of mold debugging. The size deviation is assessed to be within 1.0 mm by blue light scanning, which meets the design requirements.

The actual production verification shows that QP1180 material has good stamping forming performance and can be used to manufacture more complex parts. Meanwhile, the simulation results are in good agreement with the actual production. In addition, material flow resistance greatly influences the formability of ultrahigh strength steel, which can be improved by increasing the height of the counterweight or increasing the surface lubrication of the mold.

Acknowledgements. The work is supported by grant 06500203 of the Fundamental Research Funds for Central Universities.

References

1. X. Chen, C. Niu, C. Lian and J. Lin, The evaluation of formability of the 3rd generation advanced high strength steels QP980 based on digital image correlation method, *Procedia engineering* **207**, 556 (2017).
2. I. O. Yilmaz, A. Y. Bilici, H. Aydin and B. G. Inc, Microstructure and mechanical properties of dissimilar resistance spot welded DP1000–QP1180 steel sheets, *Journal of Central South University* **26**, 25 (2019).

3. Y. Li, Z. Liang, Z. Zhang, T. Zou and L. Shi, An analytical model for rapid prediction and compensation of springback for chain-die forming of an AHSS U-channel, *International Journal of Mechanical Sciences* **159**, 195 (2019).
4. R. Cai, X. Y. Nie and J. Z. Zhang, Surface Fatigue Cracking Behavior of a CrN-Coated Tool Steel Influenced by Sliding Cycles and Sliding Energy Density, *SAE International Journal of Engines* **10**, 239 (2017).
5. X. Wang, Y. Wu, H. Pan, C. Yao and J. Huang, Microstructure and softening of advanced high-strength steel QP1180 lap joints welded with CMT, *Materials Letters* **287**, 129282 (2020).
6. X. Wei, Y. Zhong, Z. Peng, Y. Y. Liu, C. W. Lian and X. L. Zhang, Plastic deformation and fracture behavior of QP980 and QP1180, *Journal of Plasticity Engineering* **28**, 103 (2021).