Hot Stamping of a TRB Part in an Electric MPV Vehicle

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Abstract. Automobile lightening is a direct and effective measure to realize energy saving and emission reduction. TRB of boron steel has greater application value in automotive lightweight. In this work, the TRB scheme of a down plate of rear stringer with thickness of 1.8 mm, 2.0 mm, 1.6 mm and 1.4 mm was designed, and the weight of the vehicle was reduced by 3 kg. Then the numerical simulation of hot stamping process of this TRB part was carried out, and finally the TRB part was hot stamped. The simulation results indicated that there were no major defects after the forming of the part and the strength and hardness reached the expected values. All the tested hardness values of the hot stamped TRB part were above 480 HV, and all the tested yield strength and tensile strength of the TRB part were above 950 MPa and 1300 MPa, respectively.

Keywords: High strength steel · Hot stamping · TRB · Electric vehicle · Numerical simulation

1 Introduction

Studies show that 10% reduction in automobile weight can save 6–8% on fuel and reduce emissions by 4% [1]. Therefore, automobile lightweight is the most direct and effective measure for energy-saving and emission reduction. Benefiting its ultra high strength of about 1500 MPa after hot stamping, boron steels, for example, 22MnB5, are widely used in automobiles for lightweight because the thickness of the steel can be reduced [2]. Tailor rolled blank (TRB) has the advantages of continuous thickness change and the length of transition zone can be controlled artificially, and therefore, TRB of boron steel has greater application value in automotive lightweight [3]. Compared with tailor-welded blank (TWB) structure, TRB structure allows continuous thickness variation for thin and thick zones which results in a better formability and surface quality [4].

For an electric vehicle, its range is more sensitive to the weight of the vehicle [5], and thus lightweight is especially urgent for electric vehicles [6]. Furthermore, multi-purpose vehicle (MPV) has long and big body, its lightweight demand is more urgent. VOYAH Automobile has developed the world's first electric MPV and plug-in hybrid electric MPV which is named VOYAH DREAM. VOYAH Automobile has made many efforts on lightweight of the car body of VOYAH DREAM MPV, such as the application of the integrated laser tailor-welding hot-forming door ring [7], 2000 MPa Al-Si coating

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hot forming steels [8], TRB parts, the aluminium alloy chassis, composites and so on. Among them, hot stamping of a TRB part is introduced in this paper. In this work, the TRB scheme of a down plate of rear stringer was designed, then the numerical simulation of hot stamping process of this TRB part was carried out, and finally the TRB part was hot stamped.

2 Materials and Schemes

2.1 Materials

Al-Si coated Usibor1500 was used in this work and its chemical compositions are shown in Table 1.

2.2 Schemes

As shown in Fig. 1, the down plate of rear stringer has a uniform thickness of 1.6 mm in the original scheme, and a front section of stringer is joined with the down plate of rear stringer by spot welding. Besides, a reinforced plate is welded to the front section of stringer and the down plate of rear stringer. In order to reduce the parts' weight, the reinforced plate is abandoned, and a locally thickened and thinned down plate of rear stringer is designed. As shown in Fig. 1, the TRB down plate of rear stringer has 1.25 times thickness of the original at the position where the reinforced plate is. The thinner thickness is used at both ends of the down plate of rear stringer, and it is mainly convenient for spot welding to other parts. As result, a down plate of rear stringer with different thickness in different region was designed, and the thickness were 1.8 mm, 2.0 mm, 1.6 mm and 1.4 mm. Compared with the original scheme, the weight of a single part was reduced by 1.5kg and the weight of the vehicle was reduced by 3kg.

Table 1. The chemical compositions of Usibor1500 (mass fraction, wt.%).

Element	C	Si	Mn	P	S	Cr	Al	Mo	Ti	Nb	B	N
Mass fraction	0.2333	0.2578	1.1664	0.0127	0.0018	0.1989	0.0410	0.0010	0.0406	0.0011	0.0033	0.0060

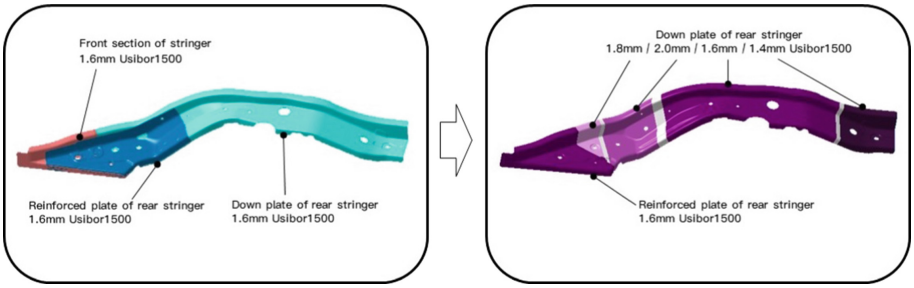

Fig. 1. The original scheme (left) and TRB scheme (right) of the down plate of rear stringer.

3 Numerical Simulation of Forming and Hot Stamping

3.1 Numerical Simulation of Forming

Figure 2 shows the blank of the down plate of rear stringer. The thickness of the blank corresponds to the thickness of the corresponding area on the part. Besides, two transition zones were used and the thickness were 1.8 mm and 1.5 mm. In the simulation, a binder and four pads were used (Fig. 3). The heating temperature was 950 ℃ and the friction coefficient was 0.45. During forming, the pad and die moved down to the punch, and the pad first contacted with the blank.

3.2 Hot Stamping

The part was hot stamped in an industrial production line. The sheet was heated in a continuous roller-hearth furnace at 950 ℃ for 300s, and then the hot sheet was transferred to the press quickly. After that, the sheet was stamped and quenched, following by a holding process of 8 s. The tools were cooled by the water. After stamping, samples were

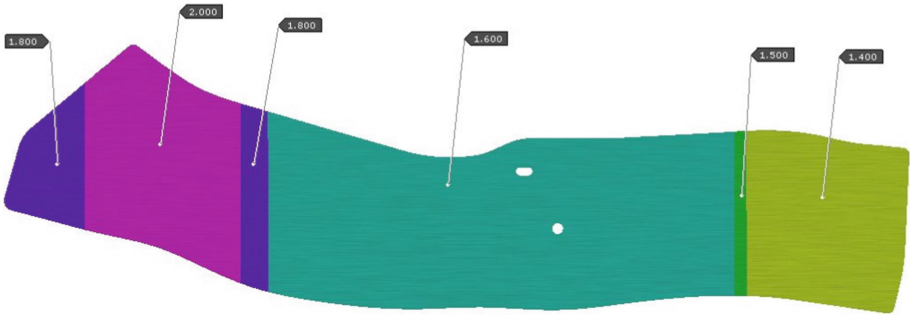

Fig. 2. The blank of the down plate of rear stringer (the numbers in the figure means thickness, mm).

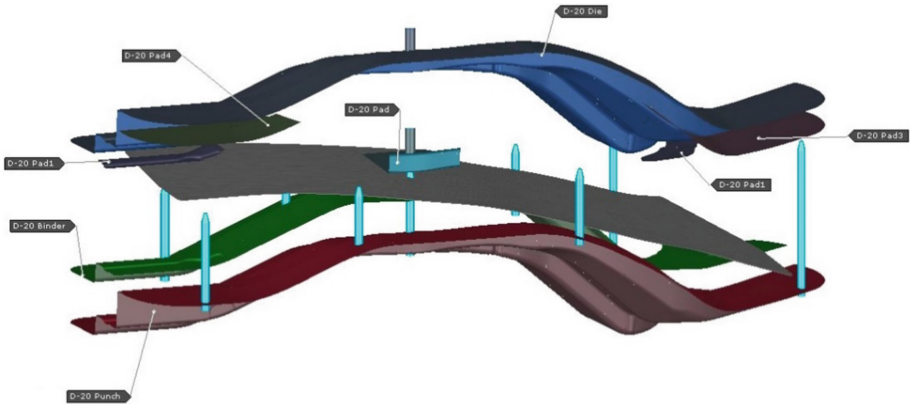

Fig. 3. The model of the simulation.

cut from both the left (L) and right (R) down plate of rear stringer to test the mechanical properties. The tensile test and hardness test were carried out according to GB/T 228.1 and GB/T 4340.

4 Results and Discussion

4.1 Numerical Simulation

Figure 4 shows the simulation results of thinning ratio of the part. The thinning rate in most areas of the part was less than 5% and the maximum thinning was less than 15%, meaning there was no risk of crack. The value of thinning rate in Fig. 4 corresponds to the value of thickness in Fig. 2, representing areas with different thicknesses. A small area of the part had a slight increase in thickness and the thickening rate was about 10%. In conclusion, from the simulation results, there were no major defects after the forming of the part. Figure 5 shows the simulation results of strength and hardness of the part. The hardness of most areas was above 450 HV and the tensile strength of most area was above 1400 MPa. Seen from the simulation results, the strength and hardness reached the expected values.

4.2 Hot Stamping

Figure 6 shows the hot stamped down plate of rear stringer and there were no cracks and wrinkles in the part. Figure 7 shows the locations of the samples for mechanical properties tests and Table 2 and Table 3 show the testing results. All the hardness values and strength values tested were in line with expectations and closed to the simulation results. However, the elongations of some samples were a little bit low, and it could be the size of the sample that caused the low elongation. In general, the quenching cooling rate of the side wall of the part decreases due to tools' clearance and thus the strength may be low. Fortunately, the strength at the side wall of the down plate of rear stringer met the requirements.

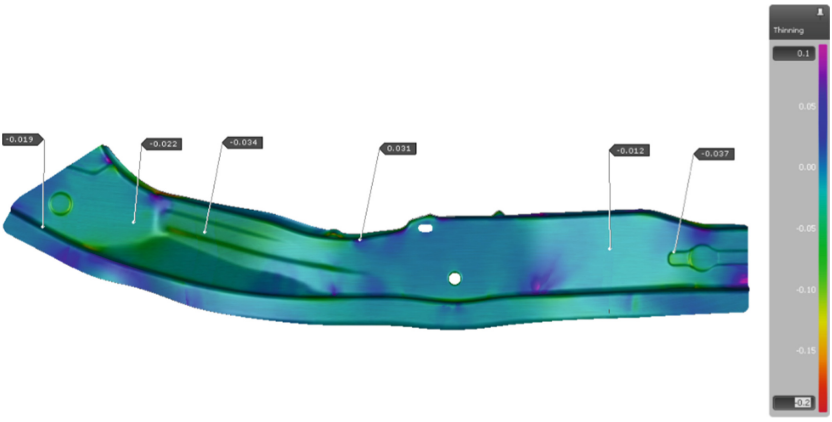

Fig. 4. The simulation results of thinning ratio of the part.

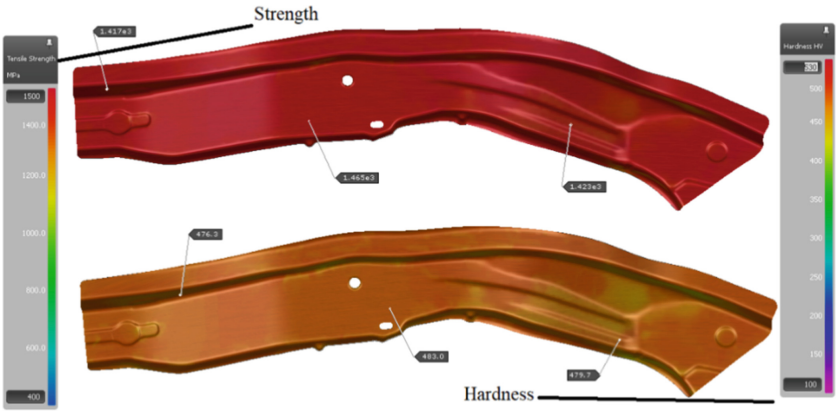

Fig. 5. The simulation results of strength and hardness of the part.

Fig. 6. The hot stamped down plate of rear stringer.

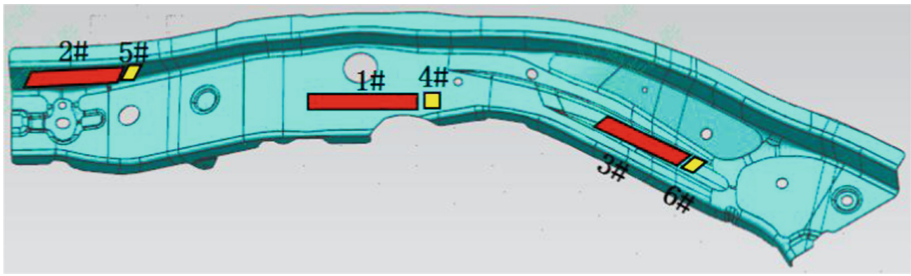

Fig. 7. The locations of the samples for mechanical properties tests.

Table 2. The hardness of the hot stamped part (HV1).

Location	L4#	L5#	L6#	R4#	R5#	R6#	Expected value
Hardness	480	510	463	523	512	517	≥400

Table 3. The strength and elongation of the hot stamped part.

Location	L1#	L2#	L3#	R1#	R2#	R3#	Expected value
Yield strength (MPa)	1104	958	1025	1111	1061	1119	950~1250
Tensile strength (MPa)	1505	1338	1439	1504	1458	1430	1300~1700
Elongation A_{50} (%)	7.0	6.0	5.5	7.5	5.0	5.5	≥5

5 Conclusions

(1) A TRB down plate of rear stringer with different thickness in different region was designed, and the thickness were 1.8 mm, 2.0 mm, 1.6 mm and 1.4 mm. Compared with the original scheme, the weight of a single part was reduced by 1.5 kg and the weight of the vehicle was reduced by 3 kg.
(2) The simulation results showed that the thinning rate in most areas of the part was less than 5% and the maximum thinning was less than 15%. The hardness of most areas was above 450 HV and the tensile strength of most area was above 1400 MPa. The results indicated that there were no major defects after the forming of the part and the strength and hardness reached the expected values.
(3) All the tested hardness values of the hot stamped TRB part were above 480 HV and were in line with expectations and closed to the simulation results. All the tested yield strength and tensile strength of the hot stamped part were above 950 MPa and 1300 MPa, respectively. Besides, the strength values were in line with expectations and closed to the simulation results.

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