Study on the Cold Stamping of Oil Sump Tank for the Thickness and Springback

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Abstract. In recent years, the high strength steel has been used widely to prove the advantage of lightweight used in automotive industry. The drawbacks occurred in the stamping procedure are thinning, springback and so on. And many process parameters affect the forming quality significantly, such as friction coefficient and blank holder force (BHF). In this paper, the effect of process parameters on the forming defects is investigated. The design of test was utilized and the finite element model was established and applied. The aim of this study is to get a further understanding on the stamping of high strength steel.

1. Introduction

Recently, the high strength steel was used widely to improve the environment [1]. And much effort was devoted to the analysis of high strength steel. G. Ingarao et al. [2] conducted the finite element analysis on stamping of an S-shape channel part. The dual phase steel is used in this study. They considered the relationship between the formability and other factors. F Ajersch et al. [3] discussed the application of high strength steel, and some effect of forming factors. The microstructure was also analyzed. Wang et al. [4] studied the material performance of high strength steel in a hot-finished process. And many kinds of material with different compositions were analyzed. Finite element simulation was also used to analyze the formability. Ghaei et al. [5] studied the springback behavior of the advanced high strength steel using experiment and simulation. Some kinds of materials were used, such as DP980, DP600 and Trip 780. Chongthairungruang et al. [6] researched the springback of dual phase steel in a S-shaped U channel. Many material models in FE simulation software were used and the predicted accuracy was compared. In this study, the springback and thinning behavior of high strength steel were analyzed using design of experiments, finite element simulation and response surface method.

2. FE model establishment

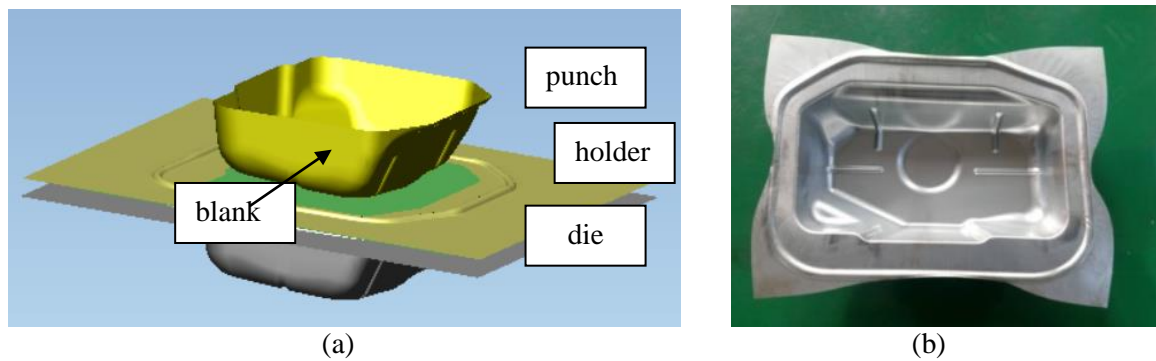(a)   (b)

Figure 1. The FE model (a) and experimental part (b)

The part is not symmetry. The Figure 1(a) is a FE model with punch, die, blank and holder. The Figure 1(b) is a finished one after stamping, which shows some details. The width of the oil sump tank is about 316 mm and the length is about 582 mm. And the depth of this part is about 134 mm. The material used in this analysis is DP780. The corresponding stress-strain curves are given as follows in Figure 2.
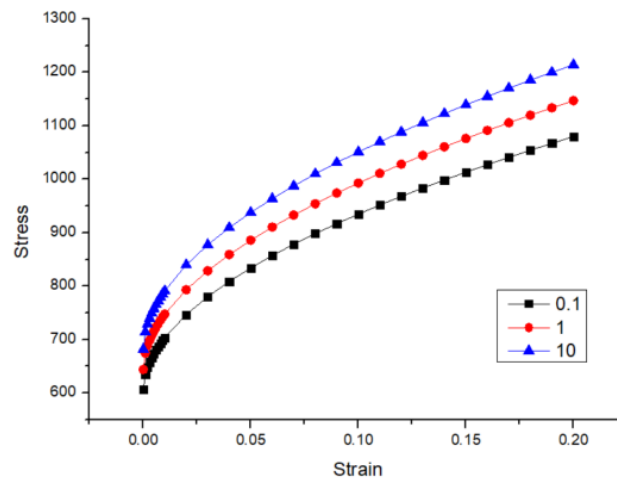

Figure 2. True stress-true strain curves for variant strain rates of 0.1 s^{-1}, 1 s^{-1} and 10 s^{-1} of DP780

3. Design of tests
The process parameters are blank holder force and friction coefficient with several levels, shown in the following table. This Central Composite Design is efficient and effective for the test. The range of friction coefficient is from 0.08 to 0.13. And the range of BHF is from 282 kN to 338 kN. Table 1 is shows the variables and different levels. Table 2 is the test design and the corresponding results.

Table 1. The design variables and the corresponding levels

		Low	High	-alpha	+alpha	Mid
A	u	0.09	0.12	0.08	0.13	0.105
B	BHF	290	330	282	338	310

Table 2. The design tests and the corresponding results

No.	A	B	u	BHF	Min t	Max s
1	0	0	0.105	310	0.497	13.82
2	0	-a	0.105	282	0.499	34.73
3	0	a	0.105	338	0.498	27.16
4	1	-1	0.12	290	0.167	17.11
5	1	1	0.12	330	0.253	14.12
6	-1	-1	0.09	290	0.47	25.88
7	-1	1	0.09	330	0.503	13.195
8	a	0	0.13	310	0.592	23.762
9	-a	0	0.08	310	0.531	23.715

This is the result of case 8 with the friction coefficient of 0.13 and blank holder force of 310 kN. The thickness distribution in the stamping process is illustrated in the follows. And the springback value is also shown. Figure 3 is the thickness distribution in the middle of stamping process. Figure 4 is the thickness description at the end of stamping. Figure 5 is the springback distribution after the stress release.
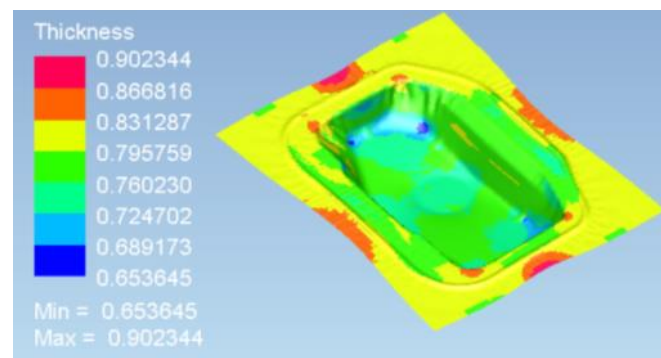
Figure 3. The thickness distribution of the part in the middle of stamping operation

The figure 3 shows the thickness distribution in the middle of stamping operation. The blank becomes thin at the corner and thick at the flange. The minimum thickness is about 0.654.
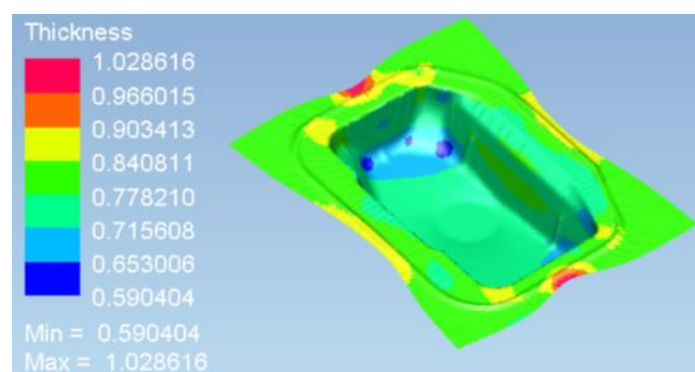
Figure 4. The thickness distribution of the part at the end of stamping operation

It can be seen from the figure 4 that the thinning area appears at the punch corner. And the flange shows the thickening with red colour. The minimum thickness is about 0.59.
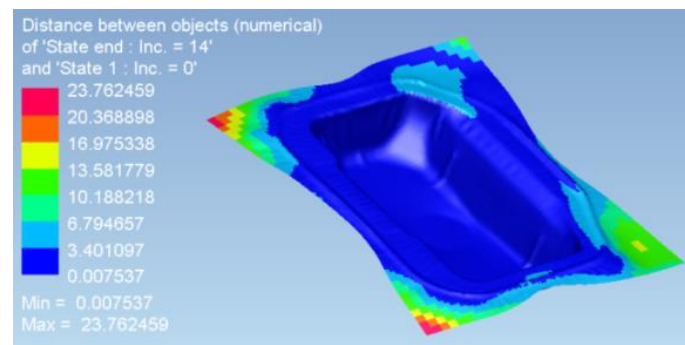
Figure 5. The springback of the part after the stress release

The figure 5 shows the springback result. The maximum springback appears at the corner of flange. And these areas with high springback value would be cut in the following procedure. And the area inside the rib reinforcement shows a relatively low and uniform springback value. After the release of the stress, the springback would occur, and the corner of flange would show a large value.

4. Results and discussion

The following response surface figures are drawn in terms of the second order function. Figure 6 is the response surface analysis for the relationship between minimum thickness and BHF and friction coefficient. Figure 7 is the relationship between springback and BHF and friction coefficient. It can be seen from the Figure 6 that with the increase of friction coefficient, the minimum thickness decreases. However, when the blank holder force increases, the minimum thickness value increases, especially at a large friction coefficient value, which is contrary to the conclusion in some papers. This should be due to the dimension of this part. The box-shaped part would wrinkle more obviously, as the blank holder force is low, so it is more difficult to draw the blank into the die hole, which leads to a more serious thinning rate.
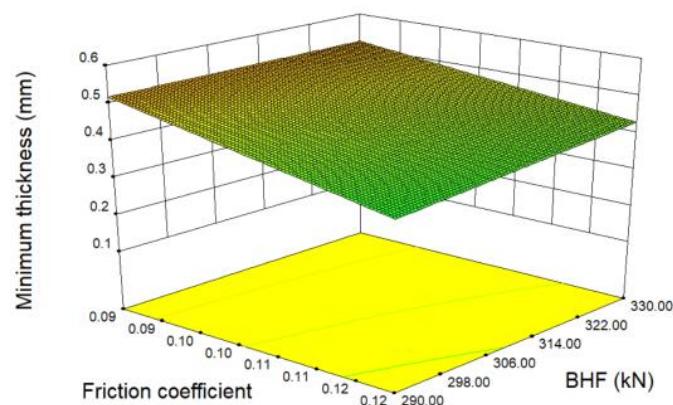

Figure 6. Response surface of the minimum thickness for DP steel

The fitting equation for minimum thickness is given as follows.

R1=2.07958-17.58111*A-3.9e-3*B+0.044167*A*B; where, R1 is the minimum thickness; A is friction thickness, and B is blank holder force.
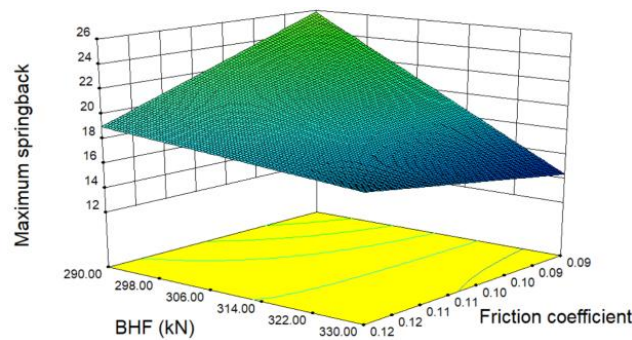
Figure 7. Response surface of the maximum springback for DP steel

The figure shows the relationship between the maximum springback value and design factors, i.e. the friction coefficient and the blank holder force. When the blank holder force and the friction coefficient are large, the springback is relatively low. When the blank holder force and friction coefficient are low, the springback value reaches a high value.

The equation for the relationship between springback and other two factors (BHF and friction coefficient) was established. R2=340.0318-2569.36277*A-1.01319*B+8.07917*A*B. Where, R2 is the maximum springback value; A is friction coefficient, and B is blank holder force.

5. Conclusion

The design of test, response surface and finite element simulation were combined to analyze the relationship between forming indexes (minimum thickness and springback) and forming factors (BHF and friction coefficient) in stamping oil sump tank process using high strength steel. Some conclusions were got.

1) In terms of the minimum thickness, with increasing the friction coefficient, the minimum thickness decreases. At the same time, with increasing the blank holder force, the minimum thickness value increases, especially at a large friction coefficient value.

2) In terms of the springback, the springback value shows a negative correlation with the forming factors. The springback decreases with the increase of BHF and friction coefficient.

6. Acknowledgement

7. References

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