

Influence of Process Parameters on Springback of S-Shaped U-Channel Stamping

Wenyu Ma*, Xuebin Zheng, Tao Li, Ye Yao, Shaobo Li and Hongya Zhu

Research Institute of Technology of Shougang Group Co., Ltd.

Beijing Key Laboratory of Green Recycling Process for Iron & Steel Production Technology

Beijing Engineering Research Center of Energy Steel

*Corresponding author

Abstract—This research was conducted to analyze the influence of process parameters on springback of S-shaped U-channel stamping for DP590. The test was designed using Taguchi test and results were analyzed according to analysis of variance (ANOVA). The process parameters analysed includes punch velocity, blank holder force, friction coefficient and blank thickness. The most influential parameter is blank holder force in this analysis, followed by friction coefficient and punch velocity. And blank thickness shows the least effect. The effect of these parameters can be quantified using this analysis method. The influence of friction coefficient, blank holder force, punch velocity and blank thickness were 56.21%, 33.06%, 7.98% and 2.75% respectively. The results can be used to get a deep understanding on the springback of DP590.

Keywords—deep drawing; springback; analysis

I. INTRODUCTION

The research on springback of high strength steel has gained a lot of attention in recent years. Chongthairungruang et al. [1] conducted the springback tests in consideration of pre-strain. The simulation was also employed to analyze the springback of high strength steel in terms of different material models. Marretta et al. [2] used a design tool to stamp the high stress steel into s shape. The relationship between thinning and springback was analyzed. The variables, such as blank holder force and friction coefficient were considered. Ma et al. [3] used design of test, finite element analysis and experiment validation to analyze the relationship between thinning and springback for an autobody panel made of aluminum alloy. The experiment was also conducted and a compromised result was got. In reference [4] the springback of TRIP steels was analyzed. The thickness of blank and other process parameters were under consideration. The change of Young's modulus affected the springback significantly. With the increase of prestrain value, the Young's modulus decreases. Wang et al. [5] studied the springback using a press brake bending. A lot of experiments were conducted and a proper way was studied to get a relatively accurate geometric shape. And the springback model was introduced. In this paper, the effect of process parameters on springback of high strength steel DP590 was analyzed. And the design of test and statistical analysis were employed to get the specific influence contribution of each parameter.

II. DESIGN OF TEST

Many parameters can affect the springback of stamping process. In order to get a deep understanding on the relationship between process parameters and springback value, the Taguchi test design was employed. There are four process parameters, namely punch velocity, blank holder force, friction coefficient and blank thickness. The target value is the springback value after stamping process. The material used in the test is DP590 produced by Shougang Group. High level, middle level and low level were chosen for each parameter. The specific value for each value is shown in Table 1. The level 1, 2 and 3 in this table were not all in an ascending or descendant trend to avoid the artificial system error. So these three values for the level 1, 2 and 3 are given by random.

TABLE I. PROCESS PARAMETERS AND THE CORRESPONDING LEVELS FOR STAMPING OF S-SHAPED U CHANNEL

| Process parameter | Level | | |
|--------------------------------|-------|------|------|
| | 1 | 2 | 3 |
| Punch velocity (V) (mm/s) | 240 | 200 | 220 |
| BHF (kN) | 300 | 500 | 700 |
| Friction coefficient (μ) | 0.11 | 0.07 | 0.15 |
| Blank thickness (t) (mm) | 0.9 | 0.8 | 0.7 |

The L9 of Taguchi orthogonal arrays is suitable for the four parameters and three levels for each parameter. This L9 is also traditional and given in many literatures.

TABLE II. L9 DESIGN FOR FOUR PARAMETERS AND THREE LEVELS FOR EACH PARAMETER

| Experiment | Parameter | | | |
|------------|-----------|-----|-------|---|
| | V | BHF | μ | t |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 |
| 3 | 1 | 3 | 3 | 3 |
| 4 | 2 | 1 | 2 | 3 |
| 5 | 2 | 2 | 3 | 1 |
| 6 | 2 | 3 | 1 | 2 |
| 7 | 3 | 1 | 3 | 2 |
| 8 | 3 | 2 | 1 | 3 |
| 9 | 3 | 3 | 2 | 1 |

III. FINITE ELEMENT MODEL

The finite element model used is a traditional S-shaped U-channel stamping model, including punch, die, blank holder and blank, which is shown in Fig. 1. The forming process has three steps, i.e. holding, stamping and springback. After the springback the springback value can be measured and recorded in the Table for further analysis. The figure for the model was shown as follows. The material used is DP590. The yield stress is 375MPa, n 0.16, rm 0.925,

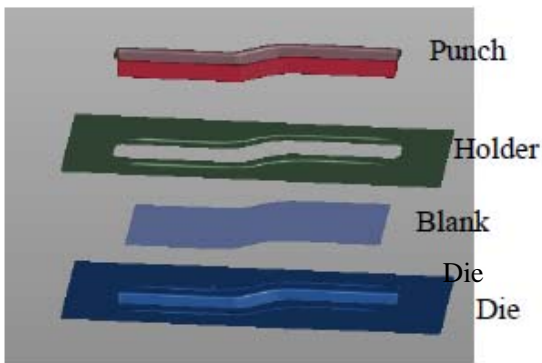


FIGURE I. FE MODEL FOR STAMPING AND SPRINGBACK

IV. RESULTS AND DISCUSSION

A. Stamping Process and Springback

The stress distribution of part affects the springback markedly. After the stamping process, the punch and die would be removed and then the stress would be released. Then the initial, middle and final stress distributions were captured. After the holding stage, the stress of the blank is low. In the middle of the stamping process, the stress concentrated in the corner. The concentrated stress is large and reached a high value of about 870.3 MPa. At the end of the stamping process, the concentrated stress located in corner of the wall is about 974.8 MPa. And the stress of flange is low. The stress value of flange is about 100 MPa. So it can be indicated that after the stamping process the released stress value would be very high, which leads to a high springback value. After the springback, the stress is released, and the max major stress is about 728.3 MPa. The major stress distributions in the middle of the stamping, at the end of stamping and after springback are

given in Fig. 2. And the maximum springback is at the end of the flange near the maximum stress. The springback distribution is given in Fig. 3.

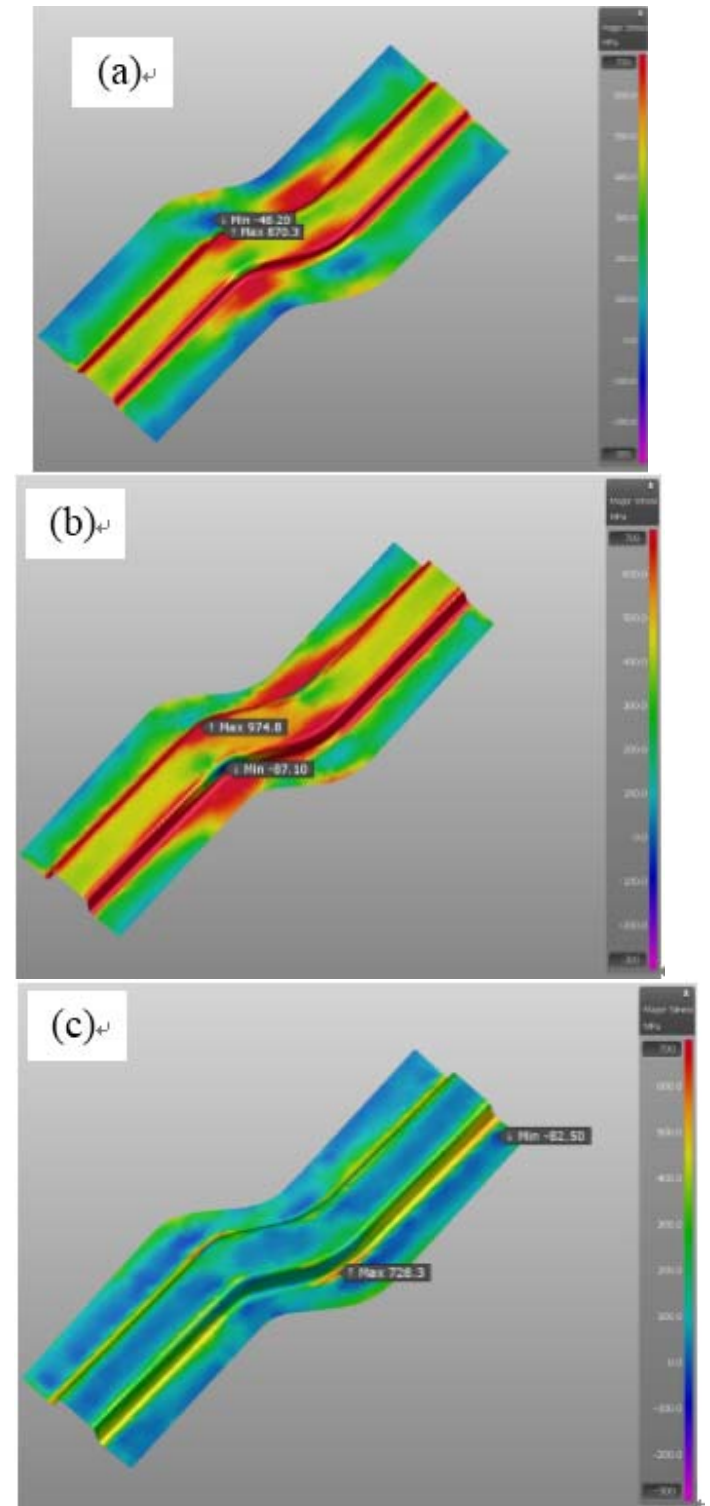


FIGURE II. THE MAJOR STRESS DISTRIBUTION IN THE MIDDLE OF STAMPING (A), AT THE END OF STAMPING (B) AND AFTER SPRINGBACK (C)

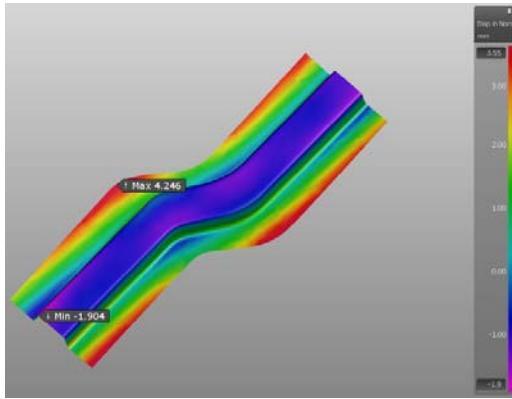


FIGURE III. THE MAXIMUM SPRINGBACK VALUE AFTER STAMPING OF S-SHAPED FOR CASE 9

B. Mathematical Statistics Analysis

Traditionally the results were analyzed and transferred to increase the robustness. The sound against noise (S/N) ratio can be got in two parts. The S/N ratio is obtained from the Mean Square Deviation (MSD).

$$S/N = -10\log(\text{MSD}) \quad (1)$$

Because the springback value is the lower the better, so the corresponding transfer equation is chosen [12]:

$$\text{MSD} = (Y_1^2 + Y_2^2 + \dots + Y_N^2)/N \quad (2)$$

The overall mean S/N ratio for these nine values is obtained:

$$\overline{S/N} = \frac{1}{9} \sum_{i=1}^9 (S/N)_i \quad (3)$$

The sum of squares can be calculated using the following equation:

$$SS_i = \sum_{j=1}^3 ((S/N)_{ij} - \overline{S/N})^2 \quad (4)$$

The summation can be got as the equation shown below

$$SS = \sum_{i=1}^4 SS_i \quad (5)$$

The effect percentage contribution can be achieved:

$$\% \text{contribution} = 100 \times (SS_i/SS) \quad (6)$$

After the calculation and data transformation using the equations shown above, the results can be got and given in the following Table 5.

TABLE III. RESULTS FOR EACH TEST OF STAMPING S-SHAPE U CHANNEL

| Experiment | Parameter | | | | Springback | S/N ratio |
|------------|-----------|-----|-------|---|------------|-----------|
| | V | BHF | μ | t | | |
| 1 | 1 | 1 | 1 | 1 | - | - |
| 2 | 1 | 2 | 2 | 2 | 4.566 | 13.19072 |
| 3 | 1 | 3 | 3 | 3 | 5.348 | 14.56383 |
| 4 | 2 | 1 | 2 | 3 | 3.319 | 10.42015 |
| 5 | 2 | 2 | 3 | 1 | 6.283 | 15.96334 |
| 6 | 2 | 3 | 1 | 2 | 4.118 | 12.29373 |
| 7 | 3 | 1 | 3 | 2 | 4.311 | 12.69156 |
| 8 | 3 | 2 | 1 | 3 | 4.612 | 13.27779 |
| 9 | 3 | 3 | 2 | 1 | 4.929 | 13.85518 |
| | | | | | 4.678 | -13.4012 |
| | | | | | ave S/N | 13.29528 |

TABLE IV. ANOVA FOR SPRINGBACK OF S-SHAPED U CHANNEL

| Factor | Average S/N by factor level (S/N _{ij}) | | | Sum of squares (SS _i) | %Contribution |
|--------|--|----------|---------|-----------------------------------|---------------|
| | 1 | 2 | 3 | | |
| V | | | | | |
| BHF | -12.7249 | -13.6495 | 13.5114 | 0.4975419 | 7.982946 |
| u | -14.1439 | -13.5709 | -12.171 | 2.0602833 | 33.05677 |
| t | -13.2458 | -14.6428 | 11.9972 | 3.5031944 | 56.20795 |
| | -12.9619 | -13.5111 | 13.4129 | 0.1715452 | 2.752404 |
| | | | | 6.2325649 | 100 |

The influence contributions of punch velocity, BHF, friction coefficient and blank thickness on springback are shown in the above table. It can be seen that the influence contribution percentage of friction coefficient is 56.21%, and the contribution percentage of BHF is about 33.06%. The other two parameters, punch velocity and blank thickness are 7.98% and 2.75% respectively. The results are only for this test in terms of these four parameters with the specific ranges.

V. CONCLUSION

The influence of stamping process parameters on springback was analyzed using finite element method. And the results were analyzed using statistic method. The friction coefficient significantly affected the springback. The influence percent of friction coefficient is 56.21%. The influence

percentages of other process parameters of BHF, punch velocity and blank thickness are 33.06%, 7.98% and 2.75% respectively.

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