Effect of Material Property on the Springback in Stamping of High Strength Steel

Wenyu Ma, Jianwei Yang, Jun Zhang, Xuebin Zheng, and Chunguang Li

***Abstract*—The effect of material property on the springback of part in stamping process is significant. And it is necessary to study the influence. Traditionally, the material property indices concerned are tensile strain hardening exponent (r), Plastic strain ratio (n), and yield stress. In this study, the effect of tensile strain hardening exponent (r), plastic strain ratio (n) and yield stress on the springback was studied with the help of the design of test, FE analysis, Response surface analysis. The springback increases with the increase of n value and yield stress. And r value shows a slight effect.**

***Index Terms*—Springback, material property, high strength steel.**

I. Introduction

The high strength steel becomes more and more popular in recent years. Wang *et al*. [1] used theory, simulation and experiment to study the material property and formability. Three-point bending and other methods were also employed.

Springback is an obvious defect in the application of high strength steel. Much effort has devoted to the analysis of springback. Ingarao *et al*. [2] analyzed the relationship between the springback and forming factors. The compromise between springback and thinning is also studied. And the multi-objective solution is employed to solve the conflict between different indexes. A. Ghaei *et al*. [3] studied the springback of high strength steel and the nonlinear elastic loading-unloading-reloading is considered in this paper. The simulation software used is ABAQUS. The simulated result was also compared with experimental one, and good correlation is shown. Chongthairungruang *et al*. [4] analyzed the springback effect in terms of the high strength steel using FE simulation and experiment. The model for elastic modulus change is also established and the microstructure is also investigated. The pre-strain effect is also considered and different material models are also considered. Sumikawa *et al*. [5] improved the springback prediction accuracy in consideration of nonlinear elastoplastic behavior. The Yoshida-Uemori model and proposed model were used, and comparison between model-predicted results and experimental ones was conducted. The response surface analysis is an effective method in research analysis and also employed in other papers [6], [7].

Manuscript received May 30, 2018; revised September 3, 2018.

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DOI: 10.7763/IJET.2019.V11.1114

The material property affects the formability including springback significantly. So it is necessary to analyze the relationship between the springback and material properties. The material properties concerned in the material formability are tensile strain hardening exponent (r), Plastic strain ratio (n), and yield stress. And these three properties are treated as important factors.

In this study, a FE model of traditional S-shaped U-channel was established. This model of S-shape U-channel can be used to capture the springback variation. The effect of material property on the springback was analyzed with the help of finite element analysis method, response surface analysis. Then the conclusion for the effect of material property on the springback was achieved.

II. The Design of Test

The n is the symbol of tensile strain hardening exponent, the larger the n value is, the better. It indicates a good formability. The r is the symbol of plastic strain ratio. It is the ratio of strain in width against the strain in thickness direction. A large r value indicates that the thinning is weak and the formability is good. The y is the symbol for the yield stress. The yield stress can also reflect the formability. And the high yield stress indicates the material has a hard property. Generally, the material is expected to get high strength and good formability. And the yield strength affects the springback of the part significantly.

The experiment design method Box-Behnken was used to design the tests. The number of the tests is 13. There are three design variables, namely tensile strain hardening exponent (r), Plastic strain ratio (n), and yield stress. Each factor has three levels. The levels of tensile strain hardening exponent (r) are 0.8, 1.1 and 1.4. The levels of plastic strain ratio (n) are 0.14, 0.16 and 0.18. The levels of yield stress (y) are 350, 375 and 400 MPa. The design of tests is shown in the following table.

After the FE simulation, the value of springback is measured. And the springback of the corner is the maximum and recorded and listed in the following table. The total thirteen tests were run, and the corresponding value of springback can be calculated after the springback step.

III. FE Model

The FE model includes four main parts. They are punch, die, blank and blank holder. The punch, die and blank holder are rigid, and the blank can be deformed into a targeted shape (see Fig. 1).

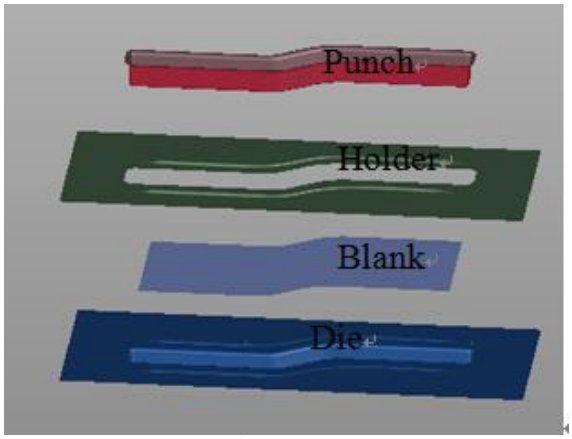


Fig. 1. FE model for stamping and springback.

IV. Analysis and Discussion

The FE software was used to analyze the effect of these material property parameters on the springback. The FE model is a typical S-shaped U channel, and the figure is a formed one with springback value distribution. The maximum springback value is located at the right corner. The maximum springback value can be recorded and listed in the table. Then the following analysis can be conducted (see Fig. 2) .

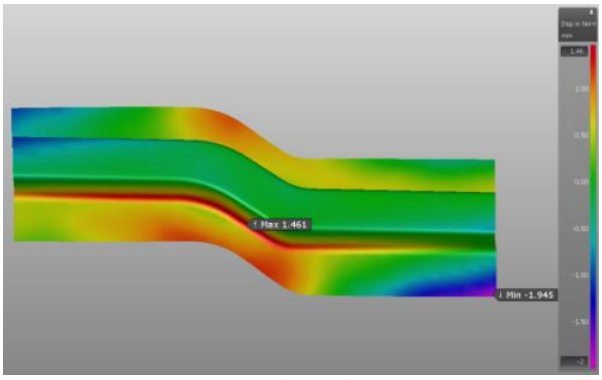


Fig. 2. The springback distribution for the formed S-shaped U-channel after springback process.

V. Results and Discussion

The figure shows the relationship between the springback value and material characters, including r value and n value (see Fig. 3).

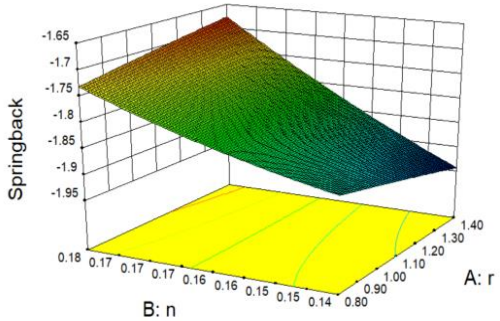


Fig. 3. The response surface for the effect of r value and n value on the springback.

It is shown in the figure that the springback increases with the increase of n value. However, the r value shows slight effect on the springback.

The relationship between the springback and material properties, including r value and yield stress is given in the following figure (see Fig. 4).

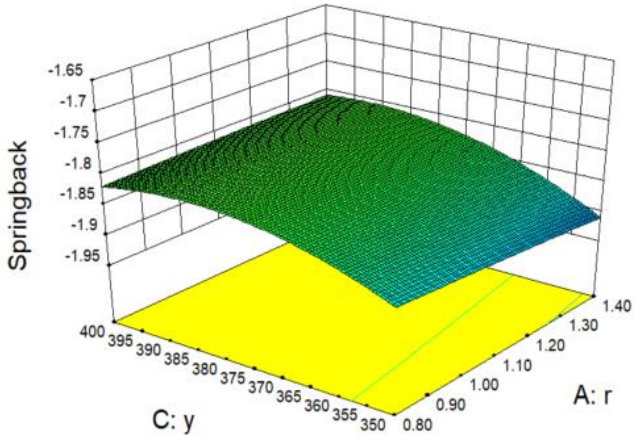


Fig. 4. The response surface for the effect of r value and yield stress on the springback.

It can be seen from the figure that the springback increases with increasing the yield stress, and the springback has insignificant relationship with the r value.

The relationship between the springback and material properties, including yield stress and n value can be achieved and analyzed. The related 3-D figure is given in the follows (see Fig. 5).

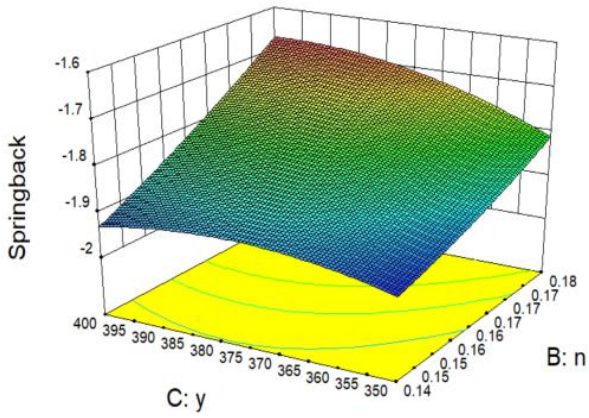


Fig. 5. The response surface for the effect of n value and yield stress on the springback.

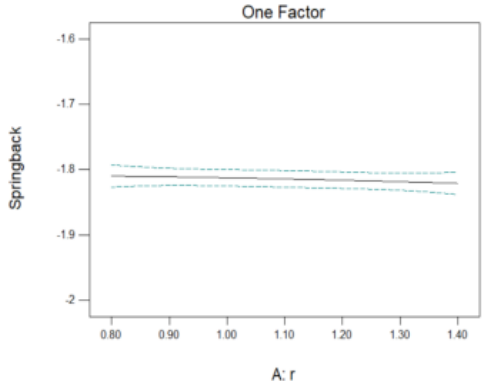
The above figure shows the relationship between the springback and n value and yield stress value. The springback value increases with the increase of n value. When the n value is large, the springback increases with the increase of yield stress, and when the n value is small, the effect of yield stress shows tiny effect on the springback. Generally, the springback increases with the increase of n value with the yield stress range of 350 MPa to 400MPa.

In the data analysis software, the effect of one factor in the springback can be got. In the one factor analysis part, the r value shows a slight effect on the springback. And the n value affects the springback significantly, the springback increases significantly with the increase of n value. And with the

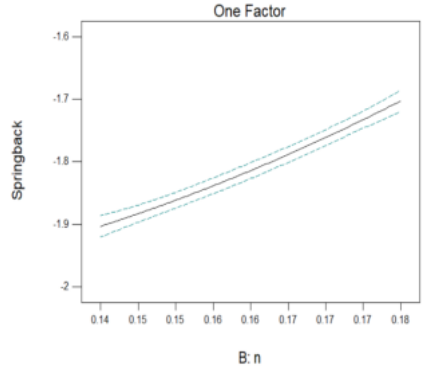
increase of yield stress, the springback increases. In the figure, *y* is short for yield stress.

TABLE I: THE TEST DESIGN AND THE CORRESPONDING RESULTS

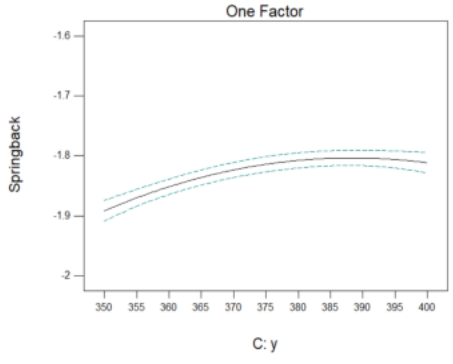
Run	A:r_m	B:n	C:y	Springback
1	0.8	0.16	400	-1.823
2	0.8	0.18	375	-1.728
3	0.8	0.16	350	-1.864
4	0.8	0.14	375	-1.876
5	1.1	0.14	400	-1.916
6	1.1	0.18	350	-1.825
7	1.1	0.16	375	-1.814
8	1.1	0.14	350	-1.953
9	1.1	0.18	400	-1.667
10	1.4	0.18	375	-1.667
11	1.4	0.16	350	-1.904
12	1.4	0.16	400	-1.820
13	1.4	0.14	375	-1.945



(a)



(b)



(c)

Fig. 6. the effect of r value (a), n value (b) and yield stress (c) on the springback for one factor effect.

VI. CONCLUSION

In this study, a FE model of S-shaped U-channel is established and applied to analyze the effect of material properties on the springback. The relationship between springback and material properties (yield stress, r value and n value) can be got. Generally, the springback increases with the increase of the yield stress, the increase of n value. And the r value shows slight effect on the springback.

ACKNOWLEDGMENT

The authors are grateful to Professor Jianguo Lin, Royal Academy of Engineering and Department of Mechanical Engineering, Imperial College, UK for the guidance and help. The authors also thank Professor Baoyu Wang from university of science and technology Beijing, very much for the guideline and help.

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