The Effect of Bauschinger Related Parameters on Material Property of Dh780 and Springback Behavior of Longitudinal Beam

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Abstract. The application of high strength steel on automobile becomes more and more popular. So it is necessary to study the formability. In this paper, the effect of Bauschinger was studied. The material employed in this study is DH780. The influence of Bauschinger related parameters on material property was analyzed by changing the parameter values. Then, the effect on the springback behavior was studied after the finite element analysis. The part used was a longitudinal beam used in the automobiles. The related Bauschinger related parameters were Transient Softening Rate, Stagnation Ratio, Young’s Reduction Factor and Young’s Reduction Rate. The results were achieved after the analysis. The transient softening rate K shows a significant effect on the stress-strain curves. The increase of transient softening rate K leads to the decrease of reversed stress and the increase of springback.

1. Introduction

The springback of high strength steel gained great attention in recent years [1]. Fei et al. [2] analyzed the springback behavior using experiment and simulation method. The v-free bending equipment was employed. The microstructure was also observed and studied. Ma et al. [3] studied the influence of process parameters on springback of high strength steel in terms of a stamped part and analyzed the relationship between springback and other process parameters in stamping high strength steel. Sumikawa et al. [4] studied the springback behavior using finite element analysis, experiments and mathematical analysis. The springback prediction accuracy resulted from finite element software can be improved by considering the nonlinear elastoplastic behavior and others. Lim et al. [5] researched the time dependence of springback of high strength steel. Several materials were employed in this study. The Young’s moduli show significant effect on the time-dependent springback.

At the same time, it is necessary to study the influence of the Bauschinger effect on the springback of high strength steel. To enrich this research area, the effect of Bauschinger related parameters on material property of DH780 and springback behavior was analyzed.

2. Design of Test

The parameters related to Bauschinger effect are transient softening rate, stagnation ratio, young’s reduction factor, young’s reduction rate and so on. And in this research, the three important factors are studied. They are Transient Softening Rate, Stagnation Ratio, Young’s Reduction Factor and Young’s...
Reduction Rate. The effect of these parameters on the stress-strain curves was analyzed. The range of transient softening rate $K$ is from 0.005 to 0.09; the range of stagnation ratio $s$ is from 0 to 1; and the range of young’s reduction factor $E_r$ is from 0 to 0.5. The basic values of these four parameters, namely transient softening rate, stagnation ratio, young’s reduction factor and young’s reduction rate are 0.014, 0.9, 0.13 and 40 respectively.

Test 1 is designed for the effect of transient softening rate $K$ on material properties of DH780 and springback behavior of longitudinal beam.

**Table 1.** The values of Bauschinger related parameters are designed for test 1 in terms of the effect of transient softening rate $K$.

| No. | $K$   | $s$ | $E_r$ | X  |
|-----|-------|-----|-------|----|
| 1   | 0.005 | 0.9 | 0.13  | 40 |
| 2   | 0.01  | 0.9 | 0.13  | 40 |
| 3   | 0.014 | 0.9 | 0.13  | 40 |
| 4   | 0.05  | 0.9 | 0.13  | 40 |
| 5   | 0.09  | 0.9 | 0.13  | 40 |

Test 2 is designed for the effect of stagnation ratio $s$ on material properties of DH780 and springback behavior of longitudinal beam.

**Table 2.** The values of Bauschinger related parameters are designed for test 2 in terms of the effect of stagnation ratio $K$.

| No. | $K$   | $s$ | $E_r$ | X  |
|-----|-------|-----|-------|----|
| 1   | 0.014 | 0.1 | 0.13  | 40 |
| 2   | 0.014 | 0.3 | 0.13  | 40 |
| 3   | 0.014 | 0.5 | 0.13  | 40 |
| 4   | 0.014 | 0.7 | 0.13  | 40 |
| 5   | 0.014 | 0.9 | 0.13  | 40 |
| 6   | 0.014 | 1.0 | 0.13  | 40 |

Test 3 is designed for the effect of Young’s reduction factor $E_r$ on material properties of DH780 and springback behavior of longitudinal beam.

**Table 3.** The values of Bauschinger related parameters are designed for test 3 in terms of the effect of Young’s reduction factor $E_r$.

| No. | $K$   | $s$ | $E_r$ | X  |
|-----|-------|-----|-------|----|
| 1   | 0.014 | 0.9 | 0.001 | 40 |
| 2   | 0.014 | 0.9 | 0.05  | 40 |
| 3   | 0.014 | 0.9 | 0.1   | 40 |
| 4   | 0.014 | 0.9 | 0.13  | 40 |
| 5   | 0.014 | 0.9 | 0.2   | 40 |
| 6   | 0.014 | 0.9 | 0.3   | 40 |
| 7   | 0.014 | 0.9 | 0.4   | 40 |
| 8   | 0.014 | 0.9 | 0.5   | 40 |

3. **FE Model**

There are several parts in the FE model of a longitudinal beam, including punch, die, blank and so on. Figure 1 (a) shows the blank figure (gray in color) and die (red in color) and Fig. 1 (b) shows the formed part after springback process.
Figure 1. The blank figure (gray) and die (red) (a) and the part after springback (b).

The material used in this model is DH780, and the basic properties of DH780 are given in the following. The yield stress is 518 MPa; n is 0.16; Rm is 809.6 MPa and Ag is 16.9%. The stress-strain relationship concerning the Bauschinger effect is shown in the following figure (Fig. 2).

Figure 2. The stress-strain relationship concerning Bauschinger effect of DH780

In this paper, the springback behavior is mainly focused and analyzed. And after the forming process, the springback occurs. The effect of Bauschinger related parameters on springback is reflected after changing the value of parameter.

4. Results and Discussion

4.1. Effect of Bauschinger Related Parameters on Material Property of DH780
1) The effect of transient softening rate K on the stress-strain relationship.
Figure 3. The effect of transient softening rate $K$ on the stress-strain relationship with different values of (a) 0.005, (b) 0.05 and (c) 0.09.

It can be seen from the above figures that with the increase of the value of transient softening rate $K$, the reverse loading curve of stress-strain relationship becomes smoother and the elastic modulus becomes lower, and the reversed stress decreases significantly.

2) The effect of stagnation ratio $s$ on the stress-strain relationship.
Figure 4. The effect of stagnation ratio s on the stress-strain relationship with different values of (a) 0.1, (b) 0.5 and (c) 1.0.

The results show that with increasing the stagnation ratio s value, the stress-strain curve of reverse loading part becomes flat, and the absolute value of reversed stress decreases.

3) The effect of Young’s reduction factor Er on the stress-strain relationship.

Figure 5. The effect of Young’s reduction factor Er on the stress-strain relationship with different values of (a) 0.001, (b) 0.2 and (c) 0.5.
It can be seen from the above figure that the effect of Young’s reduction factor $E_r$ on the stress-strain relationship is insignificant.

4.2. Effect of Bauschinger Related Parameters on Springback Behavior of Longitudinal Beam

1) The effect of transient softening rate $K$ on the springback and thickness distribution of the formed longitudinal beam part.

(a) $k=0.005$, the maximum springback value is $2.667$, the minimum springback value is $-8.642$; the maximum thickness is $2.294$, the minimum thickness is $1.736$.

(b) $k=0.05$, the maximum springback value is $3.812$, the minimum springback value is $-14.29$; the maximum thickness is $2.266$, the minimum thickness is $1.728$.

(c) $k=0.09$, the maximum springback value is $4.239$, the minimum springback value is $-17.89$; the maximum thickness is $2.250$, the minimum thickness is $1.728$.

**Figure 6.** The results for the effect of transient softening rate $K$ on the springback and thickness distribution of the formed longitudinal beam part.

According to the above figures, with the increase of transient softening rate $K$, the minimum springback value decreases, that is to say, the absolute value of minimum springback increases. Because with increasing transient softening rate $K$, the transient softening effect increases, the yield stress after the tension decreases, which leads to a large springback value. Thus, the absolute value of springback raised.

2) The effect of stagnation ratio $s$ on the springback and thickness distribution of the formed longitudinal beam part.
(a) $s=0.1$, the maximum springback value is 3.160, the minimum springback value is -11.52; the maximum thickness is 2.293, the minimum thickness is 1.735.

(c) $s=0.5$, the maximum springback value is 3.139, the minimum springback value is -11.06; the maximum thickness is 2.257, the minimum thickness is 1.734.

(f) $s=1.0$, the maximum springback value is 2.823, the minimum springback value is -10.58; the maximum thickness is 2.286, the minimum thickness is 1.733.

Figure 7. The results for the effect of the stagnation ratio $s$ on the springback and thickness distribution of the formed longitudinal beam part.

The results above illustrate that with increasing the stagnation ratio $s$, both the maximum and minimum absolute springback values decrease.

3) The effect of Young’s reduction factor $E_r$ on the springback and thickness distribution of the formed longitudinal beam part.

(a) $E_r=0.001$, the maximum springback value is 2.424, the minimum springback value is -9.322; the maximum thickness is 2.298, the minimum thickness is 1.733.

(e) $E_r=0.2$, the maximum springback value is 3.252, the minimum springback value is -11.32; the maximum thickness is 2.286, the minimum thickness is 1.734.

(h) $E_r=0.5$, the maximum springback value is 4.943, the minimum springback value is -16.72; the maximum thickness is 2.281, the minimum thickness is 1.736.

Figure 8. The results for the effect of Young’s reduction factor $E_r$ on the springback and thickness distribution of the formed longitudinal beam part.
What can be seen from the above results is that with the increase of Young’s reduction factor $E_r$, both the maximum and minimum absolute values of springback increase. However, it affects the thickness weakly. The maximum thickness value decreases but not obviously.

5. Conclusions
1) With the increase of the value of transient softening rate $K$, the reverse loading curve of stress-strain relationship becomes smoother and the elastic modulus becomes lower, and the reversed stress decreases significantly.

2) With increasing the stagnation ratio $s$ value, the stress-strain curve of reverse loading part becomes flat, and the absolute value of reversed stress decreases.

3) The effect of Young’s reduction factor $E_r$ on the stress-strain relationship is insignificant.

4) With the increase of transient softening rate $K$, the minimum springback value decreases, that is to say, the absolute value of minimum springback increases. Because with increasing transient softening rate $K$, the transient softening effect increases, the yield stress after the tension decreases, which leads to a large springback value. Thus, the absolute value of springback increases.

5) With increasing the stagnation ratio $s$, both the maximum and minimum absolute springback values decrease.

6) With the increase of Young’s reduction factor $E_r$, both the maximum and minimum absolute values of springback increase. However, it affects the thickness weakly. The maximum thickness value decreases but not obviously.

References
[1] B. Chongthairungruang, et al., Experimental and numerical investigation of springback effect for advanced high strength dual phase steel. Materials and Design, 2012. 39: p. 318-328.

[2] Dongye Fei, P.H., Experimental and numerical studies of springback in air

[3] V-bending process for cold rolled TRIP steels. Nuclear Engineering and Design, 2006. 236: p. 1847–1851.

[4] Ma, W. et al, Study on the cold stamping of oil sump tank for the thickness and springback. IOP Conference Series: Materials Science and Engineering. 381: P.955-959.

[5] S. Sumikawa, A. Ishiwatari and J. Hiramoto, Improvement of springback prediction accuracy by considering nonlinear elastoplastic behavior after stress reversal. 2017. p. 46-53.

[6] H. Lim, M.G.L.J., Time-dependent springback of advanced high strength steels. International Journal of Plasticity, 2012. 29: p. 42-59.