Investigation on the springback of high strength steel

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Keywords: springback, high strength steel, DP1180, strain

Abstract: In this study, the investigation on the high strength steel produced by Shougang Group was conducted. The material investigated in this study includes DP780 and DP1180. The material was cut into square and printed with mark points for strain analysis. The blank was bended into several angles and measured the springback angle and strain distribution. The following analysis was conducted. The results show that the springback angle increases with the decrease of bending angle. The material of DP1180 has an obvious springback behavior. The strain distribution can be measured after bending experiment using strain marking points printed and measure equipment. In terms of DP780, the maximum strain increases with the decrease of the bending angle. And the maximum strain is about 14.1% with the bending angle of 30°. In terms of DP1180, the maximum strain and bending angle don't show a linear trend. And the maximum strain is about 15.9% with the bending angle of 30°.

1. Introduction

Recently, the springback behavior of high strength steel gained much attention and effort from the researchers all around the world. Gau et al. [1] studied the springback behavior in consideration of Bauschinger effect, using theoretical and experimental method. The internal stress and reresidual stress were also studied. Gary et al. [2] analyzed the springback in metal forming process, and several kinds of metals were used. The material property including Bauschinger effect was analyzed. The experimental method was used and the springback angle for several kinds of metals was comparaed. A. Ghaei et al. [3] analyzed the springback of high strength steel using the experiments and FE simulations. The validation of simulation results was also checked. Chongthairungruang et al. [4] employed the channel part to analyze the springback of the high strength steel. The FE simulation method was also used and the microstructure could also be checked. Wenyu Ma et al. [5] studied the effect of friction coefficient and blank holder force on the springback and formability of high strength steel. Lim et al. [6] analyzed the effect of time dependence on the springback results. The time showed different effect on different kinds of materials. Wenyu Ma et al. [7] used the longitudinal beam simulation to analyze the influence of Bauschinger related parameters on the springback of high strength steel. In this study, the effect of bending angle on the springback and strain distribution was analyzed using the experimental method. The strain distribution for the part was scanned using very equipment and measured.

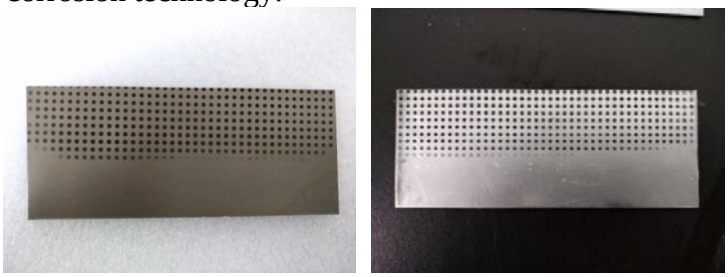
2. Experimental

2.1. Material

The material used in this study is high strength steel, including DP780 with the thickness of 1.5 mm and DP1180 with the thickness of 1.4 mm. The material was produced by Shougang Group. And

  DOI: 10.25236/mmmce.2019.145

the DP780 is coated with Zinc coating. And the DP1180 is conducted with continuous retreat. The workpiece was cut into the size of 120 mm ×50mm, and the long direction is the rolling direction. The workpiece was used for bending experiment and the half of the workpiece along the long direction is printed with mark points for strain distribution analysis in the following process after the bending tests. The mark points for strain distribution analysis were printed before the bending test using electrochemical corrosion technology.



(a) DP780 (b) DP1180.

Fig. 1. The workpieces used for bending with mark points

2.2. Experiment design

The test was conducted in 3-points bending test equipment for these two materials. As the thickness of these two materials is different, the bending angle is slightly different.

Table 1 The material and bending angle used in the experiment.

No.	Material	Bending angle 1	Bending angle 2	Bending angle 3	Bending angle 4
1	DP780	90.0	60.3	45.0	30.1
2	DP1180	89.9	60.1	44.8	29.9

2.3. Results and discussion

After the bending tests, the springback was measured and recorded. And the strain distribution was measured and recorded for further analysis. The relationship between the springback angle and bending angle for DP780 and DP1180 was shown in the following figures. It can be seen from the figure that the springback angle increases with the decrease of the bending angle for both DP1180 and DP780. The low bending angle results from the large deformation. And the plastic deformation occurs, leading to the large residual stress. The large residual stress would result in large springback angle. The DP1180 is a extra high strength steel with very high yield stress, so the residual stress would be large after the bending deformation. The springback angle for DP1180 is so obvious, so it is necessary to pay more attention to the springback behavior of DP1180.

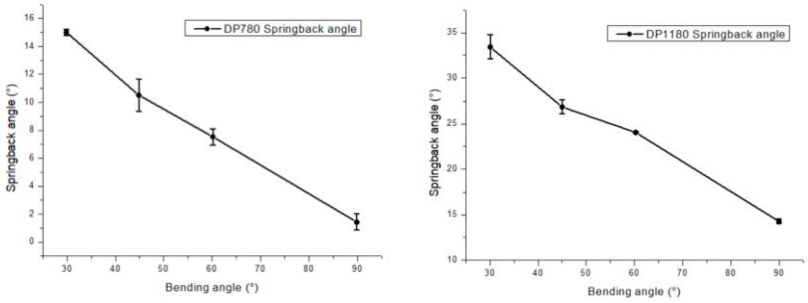


Fig. 2. The relationship between the springback angle and bending angle for materials of DP780 and DP1180.

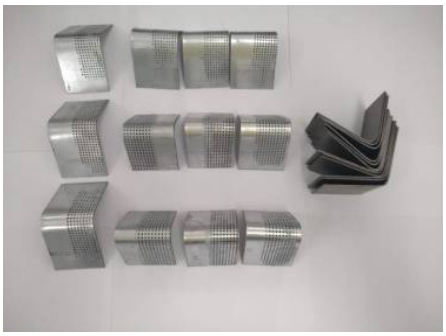


Fig. 3. The workpiece after the bending. The bending angle is 90°, the material is DP780 of 1.5 mm.

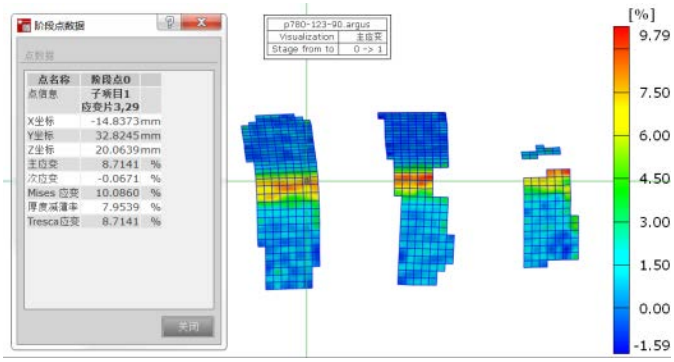


Fig. 4. The strain distribution for the bending part of DP780 of 1.5 mm with bending angle of 90°. There are 3 parts in the figure.

The strain distribution of the out surface of the workpiece can be analyzed by the special equipment. The mark points were printed on the blank surface before the deformation and then this blank was bended. In the bending process, the blank surface with mark points was on the outside surface, so it is easy for scanning and recording the strain distribution. Then the outside surface of the workpiece can be analyzed for strain distribution. The figure shows the strain analysis results for DP780 with the bending angle of 90°. The large deformation occurs in the corner and the straight side has little deformation. The one point can be detected for strain values, including major strain, minor strain, thinning rate and so on, which is also shown in the figure. Then the value can be recorded for further analysis.

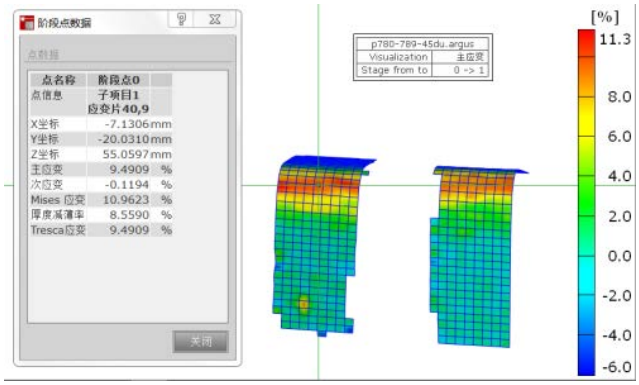


Fig. 5. The strain distribution for the bending part of DP780 of 1.5 mm with bending angle of 45°. There are 2 parts in the figure.

The strain distribution for DP780 with the bending angle of 45°is shown in the figure. The corner has the large plastic strain value, and other place has the low strain value. The large plastic strain concentrates around the bending corner, the other places have little deformation. It can be seen from the analysis that the major strain is about 9.49%, and the minor strain is about -0.1194%. At the same time the thinning rate is about 8.56%.

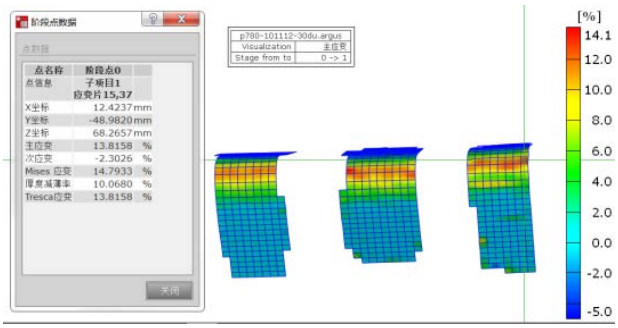


Fig. 6. The strain distribution for the bending part of DP780 of 1.5 mm with bending angle of 30°. There are 3 parts in the figure.

The strain distribution for DP780 with the bending angle of 30° is shown in the figure. The corner has the large platic strain value, and other place has the low strain value. It can be seen from the analysis that the major strain is about 13.8%, and the minor strain is about -2.3%. At the same time the thinning rate is about 10%.

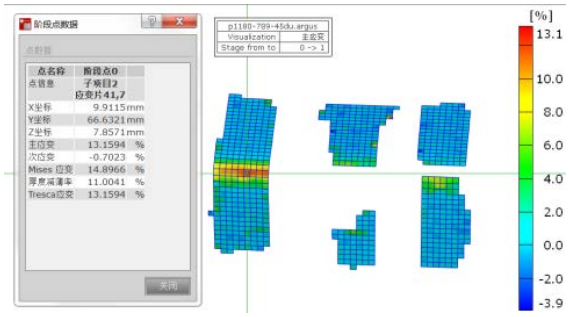


Fig. 7. The strain distribution for the bending part of DP1180 with bending angle of 45°. There are 3 parts in the figure.

The strain distribution for DP1180 with the bending angle of 45°is shown in the figure. It is similar to the DP780, the corner has the large plastic strain value, and other place has the low strain value. The large plastic strain concentrates around the bending corner, the other places have little deformation. It can be seen from the analysis that the major strain is about 13.16%, and the minor strain is about -0.7023%. At the same time the thinning rate is about 11.0%.

Table 1 The springback angle result and strain analysis for DP780 bending.

No.	Theoretical bending	Actual mean bending angle	deviation	Springback	deviation	Corresponding maximum strain
1	89.90	91.33	0.58	1.43	0.58	8.71
2	60.13	67.67	0.58	7.54	0.58	9.85
3	44.82	55.33	1.15	10.52	1.15	11.30
4	29.86	44.87	0.23	15.01	0.23	14.10

The table illustrates the relationship between the springback angle and the maximum strain. With the decrease of the bending angle, the springback angle increases, and the maximum strain increases too. Because the large bending deformation would lead to the large strain deformation on the outside surface of the blank, the maximum strain then has a large value.

The springback angle increases with the decrease of the bending angle, and the springback angle is obviously larger than that of the DP780. And with the increase of the springback angle, the corresponding maximum strain value also increases. However, the increase trend with the increase of springback angle is not obvious as that of the DP780, which may be due to the high strength of DP1180, so the concentrated strain would occur easily.

Table 2 The springback angle result and strain analysis for DP1180 bending.

No.	Theoretical bending	Actual mean bending angle	deviation	Springback	deviation	Corresponding maximum strain
1	89.99	104.27	0.25	14.28	0.25	11.86
2	60.26	84.30	0.10	24.04	0.10	15.70
3	44.99	71.83	0.76	26.85	0.76	13.20
4	30.07	63.50	1.32	33.43	1.32	15.90

It can be seen from the result that the maximum strain deformation value of DP1180 is larger than that of DP780 for the same bending angel, even the springback angle of the DP1180 is much larger than that of DP780. So it illustrates that it is easier for DP1180 to have the strain concentration.

3. Conclusion

1) The springback angle increases with the decrease of bending angle for both DP780 and DP1180.

2) The springback angle DP1180 is more obvious than that of DP780.

3) In terms of a certern bending angle, the DP1180 has a larges maximum strain than that of DP780.

4) In terms of DP780, the maximum strain increases with the decrease of the bending angle. And the maximum strain is about 14.1% with the bending angle of 30°. In terms of DP1180, the maximum strain and bending angle don’t show a linear trend. And the maximum strain is about 15.9% with the bending angle of 30°

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