The Determination and Application of Yoshida-Uemori Material Model Parameters for DP Steel

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Abstract: Recently, the high strength steel material has been applied in the automotive manufacture very widely. However, the high strength of the high strength steel would cause great springback, which is serious for the manufacture and fabrication. So how to increase the springback prediction gained much attention. To improve the springback prediction in finite element (FE) model, the Bauschinger effect of the high strength steel should be analyzed. And the Yoshida-Uemori (Y-U) hardening material model is studied for the Bauschinger effect. In this study, the Yoshida-Uemori (Y-U) hardening material model is described and the parameters for this material model were calculated for DP780 according to the cycle tensile-compress tests. The material parameters for Y-U model of DP780 were put into the FE software and the simulations were conducted for U-stamping. The different material parameters were used to evaluate the effect of various material parameters. It can be seen from the results that with the increase of the blank holder force, the springback value of U part decreases in terms of the Bausinger effect. Some model parameters show the significant effect on the springback. And several parameters show the insignificant effect on the springback. The significance order can be measured. And the proper material parameters can be chosen for the simulations.

1. Introduction

The springback of high strength steel is a relatively common defect in forming metal sheet, and many researchers paid attention to it[1, 2]. The finite element method (FEM) and experimental method were also employed to analyze and study the formability of high strength steel. It is hard to avoid the springback and the researchers developed the method to calculate and predict the springback. And the Bauschinger effect of material was considered in FE model to improve the predictability[3]. Gary et al.[4] studied the formability and mechanical performance of several kinds of the materials of the high strength steel. The effect and influence of the material properties on the springback value was studied and analyzed. The results of these several kinds of materials employed in the study were compared. The Bauschinger effect of the materialwas also researched and investigated. A. Ghaei et al.[5]employed the FE simulation method with the test method to research and study the defect of thespringback of the high strength steel.The validation of the FE simulation resultswith the experimental ones was checked, which given a relatively good consistence. Gau et al.[6] also studied the Bauschinger effect mathematically and experimentally. The stress generated in this study of the used material was also carefully considered. The springback value results were also obtained in many methods and they are compared. Kinzel et al.[7] carried out and conducted many experiments to study the Bauschinger effect to improve the springback prediction. Different kinds of materials were employed and analyzed in this study, including HS steel, AKDQ steel and BK steel. Chongthairungruang et al.[8] studied and analyzed the springback effect in automotive component manufacture. In the Finite element (FE) simulations, many models were employed and used, such as Hill's 1948, Barlat-Lian's 1989 model and Yoshida-Uemori model. Yoshida[9] analyzed and studied the constitutive model with good capability to describe precisely the metal deformation. At the same time, a new equation is proposed for the FE simulation in consideration of Bauschinger effect. The simulation result generated in this study shows a very good consistency with this conducted experimental result.

In this study, the Bauschinger effect related equations were described and the values of the parameters were determined. The simulations were conducted to study the springback distribution and blank holder force effect. The simulation result considering the Y-U material model was compared with other result with Hill model and experiment result.

2. The Calculation of Y-U Material Model Parameters

The Yoshida-Uemori (Y-U) hardening material constitutive model is very useful for predicting and describe the springback of the material. The Y-U material model is also becoming more and more popular in recent years in the FE model for predicting the springback distribution. For example, the Y-U model is employed in many FE codes, such as autoform R8, Pamstamp, Dynaform. The parameters in Y-U model can be calculated and determined according to the cycle stress-strain curves. The stress-strain curves of the material DP780 for the cycle tensile-pressing tests for DP780 is shown in the following Figure[10]. The data of cycle stress and strain shown in the following figure is the experimental and tested results of tension and compression of the high strength steel DP780.

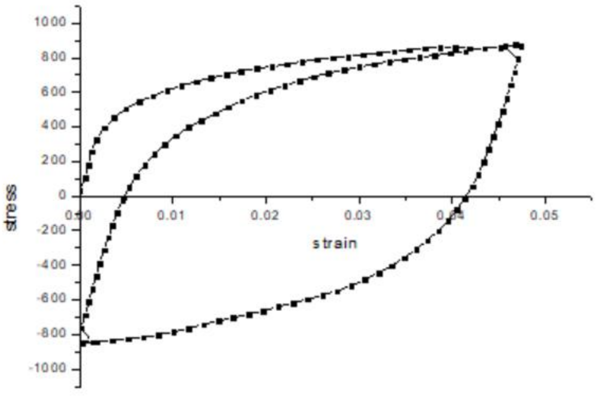

Figure 1: The stress-strain curves for cycle tensile-pressing tests for DP780 [10].

First, the parameters of the Y-U model, such as B, Rsat, b and m in this equation (1) can be calculated and determined based on the tensile stress curve of the material.

During the tensile and compressed process, the first part of tensile part is similar to the traditional tensile test of material, and the mechanical data of this part can be captured. However, in terms of this tension and compression process, the specimen also often crushed due to the compress stress in the compression process. Thus in the compression process, the specific tool should be designed and used to avoid the crush of the tested material.

$$\sigma_{bound}^{(fow)} = B + R + \beta = B + (R_{sat} + b)(1 - e^{-m\bar{\varepsilon}^p}) \quad (1)$$

where, $\sigma_{bound}^{(fow)}$ is for the tensile curve during the first tension process; B material parameter illustrated in the above equation is represented for the yield stress of this part of the tension; R_{sat} is represented for the saturated value of this stress bounding surface; b is the value represented for the translation of this very curve bounding surface; m is represented as the rate of the evolution of this stagnation surface; $\bar{\varepsilon}^p$ is represented as the plastic strain.

The material parameters can be calculated and determined according to the fitting results of the tensile stress curve. The values for these material parameters mentioned in the model and equations are calculated and determined and the results of these calculated values of parameters are given and shown in the following table. The material parameters for these equations related to the Bauschinger phenomenon can be fitted very well using the mathematical tool. In consideration of the softening part of the stress curve of the DP780, the corresponding equation for the relationship between stress and strain is shown and given in equation (2);

$$\sigma_{B0}^{p} = 2\beta_0 = 2b(1 + e^{-m\varepsilon_0^p}) \quad (2)$$

σ_{B0}^{p} is represented as the softening part with the value of 200 MPa; ε_0^p is the plastic strain of the materialcorresponding to the maximum stress; The b material parameter illustrated in this equation has been mentioned above.

Second, the material parameters related to the Young's modulus can be tested and then calculated and determined according to the fitting of the equation (3) after the special several experiments.

$$E=E_0-(E_0-E_{sat})[1-exp(-\xi\varepsilon_p)] \quad (3)$$

where, the E_0 is represented as the first initial value of these Young's modulus; E_{sat} is represented as the saturated value of these series Young's modulus; ξ is represented as the rate of the decrease and reduction of the materialYoung's modulus. Then the fitting and calculating process can be conducted using the mathematical tool or other program.

Third, the fitting and determination of the material parameter c can be calculated and determined according to the reduction and decrease of this softening stress in the curve of the material. The related corresponding equations areshown in equations (4) and (5).

$$\sigma_B^{(t)} = B + R - Y + \alpha^* \approx 2ae^{-c\hat{\varepsilon}^p} \quad (4)$$

$$a = B + R - Y \quad (5)$$

where, the $\sigma_B^{(t)}$ is represented as the reduction and decrease of the softening stress of the material; $\hat{\varepsilon}^p$ is represented as the plastic strain value according to this material DP780 stress. And Y parameter given in the above equation is given as a yield stress of this study; so this value of the material parameter of c illustrated in the above equation can also be shown and calculated.

Fourth, the material parameter h of DP780 can be given and set in the very range of 0 to 1. It can be set as default firstly, and then it can be changed and modified to match the simulated value with the experimental value.

Fifth, the swift model parameters of DP780 should be fitted, calculated and determined. As the Y-U model is used in the FE code software with a swift model in some FE code and software. However, it can also be ignored and skipped under the condition that the FE software doesn't have the swift model. The swift model and equation parameters of DP780 can be calculated and determined using a mathematical tool program and software by fitting the stress-strain curve with the elastic and the plastic data. The related values for the swift model can also be calculated and determined. The other related parameters for the DP780 material model in FE code and software can be given and set as default. The value of parameter r0 is the initial value of the stagnation, which is generally given and set as default. The value of the a0 is the distance between the bounding surface of DP780 and the yield value of DP780. At the same time, the values of C1 and C2 are given and set as the default values. The b_{sat} is represented as a saturated value of the DP780 bounding surface transition. The parameter values of the steel DP780 are shown as below. In some FE codes and softwares, the material parameter value with this equation should be corresponded.

Table 1: The calculated values for the Y-U model parameters of the steel equation DP780.

Y [MPa]	Rsat [MPa]	m	C [MPa]	n	ε_0	μ	E_{sat} [MPa]
420	402	43	2201	0.289	0.0001	0.1	170000
ξ	a_0 [MPa]	C_1	C_2	b_{sat}	h	r_0 [MPa]	
67	140	500	500	9	0.5	0	

3. FE Model

The FE model for checking and validating the validity of the material model of DP780 was established. At the same time, the FE code model of the stamping includes several parts, including the punch, die, blank holder and blank. The material of high strength steel used in this FE code model is the DP780 with ablank thickness value of 1.5 mm. The specific dimension of the tool used in this model and FE simulations is designed and given according to that of the experimental tool ones. The punch corner mentioned in this model is 8 mm for the radius; the width value of the stamping punch tool designed and used in this code and model is 200 mm. The punch is generally put downside. The thickness value of the stamping punch tool designed and used in this code and model is 100 mm. The corner radius value of the drawing and stamping die designed and given in this code and model is 8 mm. The die is designed and set upside. The width value of the stamping tool of the die designed and provided in this software and model is 220 mm. The thickness value of the tool of the die designed and used in this code and model is 100 mm. The thickness of the tool should be suitable for the blank placement. The corner radius value of the stamping tool of blank holder designed and used in this code and model is 8 mm. The width value of the drawing blank holder designed and given in this model is 220 mm. At the same time, the thickness value of the blank holder designed and mentioned in this model is 100 mm. The thickness of blank produced and given in this code and model is 1.6 mm. The dimension of the blank of high strength steel produced and employed in this simulation and model is 500 mm length and 50 mm width. The shape of the part stamped in this FE model is a

U-stamping. The experimental tool for the stamping of the high strength steel has the corresponding dimensions.

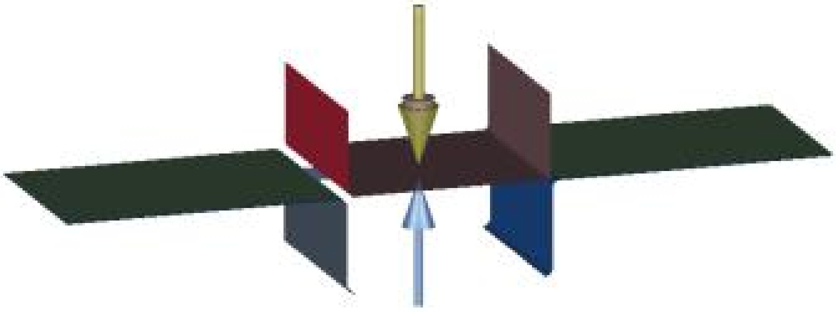

Figure 2: The FE model employed in this study of high strength steel stamping for the simulation.

4. FE Simulation

A lot of FE simulations were run and conducted to calculate and check the effect of the parameters on the part springback distribution. The effect and influence of this process parameter of blank holder force (BHF) on the springback was studied and evaluated. The effect and influence of the BHF values of the 30 kN and 200 kN on the springback of DP780 was analyzed and conducted. At the same time the significance ratio of each equation parameter was also studied and evaluated. First the cold stamping process of DP780 was run and conducted and then the flat blank of DP780 was formed and stamped into the U-shaped part. And then after the stamping, the stress of the formed U-shaped DP780 part was released and the springback of DP780 U part occurred. Then the springback value of the DP780 U-shaped part was given and recorded for further analysis.

5. Results and Analysis

In terms of the BHF of 30 kN, the left springbak value and the right springback value were respectively 30 mm and 29.4 mm. In terms of the BHF of 200 kN, the left springbak value and the right springback value were respectively 19 mm and 17 mm. With the increase of the BHF, the springback value of DP780 part decreases.

Figure 3: The effect of the blamk holder force 30 kN on the springback.

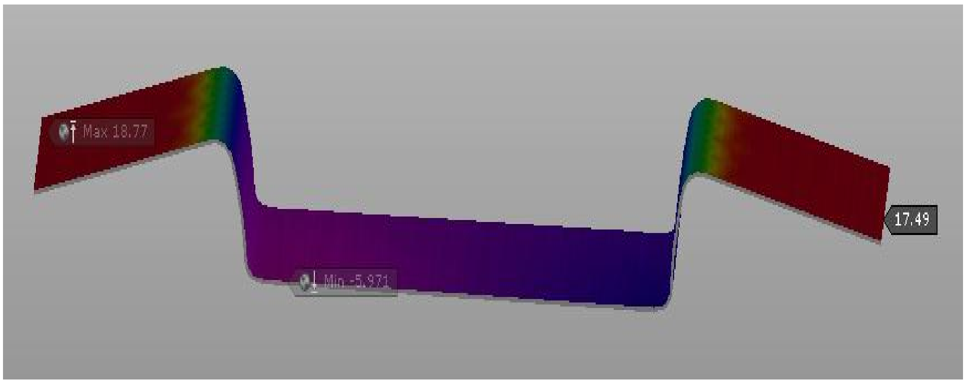

Figure 4: The effect of the blank holder force 200 kN on the springback.

In terms of the significance of each material process parameter for the springback value, the results were calculated and shown in the following table. This result can be the reference for the researchers who researched the Y-U model and the Bauschinger effect, who would modify and improve the material model parameter accurately. After many simulations and calculations, the significance analysis was achieved. The method of determine the parameter importance ratio is to change the material parameter value and get the corresponding springback result, then calculate the effect of the variation of the material parameter on the springback result. The significant parameter would affect the result mostly. The order of the significance order of material parameters is given in the following table.

Table 2: The significance order for the model parameters for DP780.

Y [MPa]	Rsat [MPa]	m	C [MPa]	n	ε_0	μ	E_{sat} [MPa]
9	10	6	13	4	1	2	15
ξ	a_0 [MPa]	C_1	C_2	b_{sat}	h	r_0 [MPa]	
8	7	12	14	11	3	5	

6. Conclusions

In this paper, the determination of the material model parameters of Y-U model was calculated and described for several steps and the Y-U model with the value of process parameters was applied to the finite element analysis. The conclusions of the study were listed below.

1) The Y-U material model can be used to describe the Bausinger effect of the material with the determination and calculation of material process parameters mentioned in the equations.

2) With the increase of the blank holder force, the springback value of DP780 U-shaped part decreases in consideration of the Bausinger effect.

3) Some model parameters of Y-U model show the significant effect on the springback and other parameters of Y-U model show the slight effect on the springback. The significance order can be measured and determined.

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