Research on numerical simulation and influence factors analysis for springback

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Abstract. Accurately prediction the spring-back is great significance for plate cold forming. Finite element numerical simulation software is used to establish hull plate surface cold forming finite element model. The key technologies such as 3D model of finite element numerical simulation, the constitutive relation and cell division are analysed. And the amount of springback numerical simulation compared with the experimental results verify the credibility of the finite element simulation. At the same time the affection of material, sheet thickness and curvature radius for spring-back are analysed combined with simulation results to find the spring-back regular.

Key words: Springback; numerical simulation; curvature radius; thickness

1. Introduction

In the process of plate forming, plastic bending appears because of the die stamping and as the same time a part of elastic deformation accompanied, after stamping mould unloading, these elastic deformation energy is released. this is the reason of the springback.

Since twentieth Century, many scholars at home and abroad have done a lot of research on springback prediction. Every NUMISHEET international conference has released questions about springback. And the number of published papers has increased year by year. Daw-Kwei Leu[1] proposed a pure bending mechanical model for thin plates considering the thickness anisotropy coefficient R and the hardening index n, which is used to evaluate springback, bending and maximum bending moment. Z.T.Zhang[2] of the University of Michigan based on Hill’s non two yield criterion and incremental theory and considering three kinds of hardening model (i.e., kinematic hardening and isotropic hardening, hardening of the complex direction), the springback under various complex cyclic loading models were analyzed in detail. Zeng Danielle et al. [3] introduced an anisotropic material hardening model based on an improved yield surface hardening model, which is mainly applied to the simulation of springback of those materials with faster hardening characteristics such as advanced high strength steel. Tang et al. [4] based on the establishment of a hybrid reinforcement model of the bauschen effect, the model of this material has been used in the finite element ABAQUS software at present. Zang shunlai et al. [5] comprehensively considered the prediction accuracy and simulation time of springback, the shell element s4r with reduced integral was used to simulate the springback in tension bending.
The main work of this paper is to further discuss the numerical simulation method suitable for the springback research of cold press forming of plates on the basis of the previous research, and to analyze the cold bending springback through the finite element simulation method. on the basis, support vector machine method is used to predict and study the springback.

2. Key techniques for forming

2.1. The Equivalent Treatment of Square Pressure
The actual structure of square pressure head is welding composed of square blocks and hemispheres. The square pressure head will revolve around the center of hemisphere in the cold compaction. It is very small when compared with pressure head distortion and boards in the model of finite-element. So there is only a slight effect for the accuracy of the result when ignored pressure head distortion. The model of square pressure head is processed into rigid body for saving time, whereas it just acts on its centroid for constraint of rigid body. According to the motility characteristic of square pressure head and the restrictive pattern of finite-element, the actual square pressure head is equivalent to cuboid models. It is consistent that the height of the cuboid centroid to the work surface and the height of the center of square pressure head to work surface, meanwhile it remains the same size 58mm×58mm for contact work surface[6]. We can build structural model of hull plates by solid-works as shown in Figure3.

![Fig 1. Model finite-element of square pressure head](image1)

![Fig 2. Linear kinematic hardening model relationship of stress-strain](image2)

2.2. Material constitutive model
Constitutive equations are the basis of finite element numerical simulation. Press plates used by most is steel plate. Generally, we can get pressed steel by many times of rolling and heat treatment. Due to rolling sheet of fiber and grain structure formed preferentially texture and it have obvious anisotropy.
This anisotropy have significant effects on its forming regularity. And anisotropic yield criterion is the focus of research in sheet metal forming.

Sheet arose plastic bending in the process of plate cold pressing and the neutral layers will move to concave. It makes the original neutral layer of material unloaded and even reverse loading and the condition was changed into press from tension. So Bauschinger effect needs to be considered, we can adopt the model of kinematic strengthening model[7].

The kinematic strengthening model is used to describe that the tensile yield strength increases while the compressive strength decreases correspondingly under the external load. The assumption is that during plastic deformation, the loading yield surface moves in the deformation direction, but the size and shape do not change.

The model of kinematic hardening model and double linear fitting of true stress-strain curve are used, as shown in Figure 2. In a simplified model, the tangent modulus and yield strength becomes the main material properties of parameters. When the tangent modulus and yield strength increase, resistance to deformation also enhanced. Under the same deformation, components of elastic deformation increases and after unloading elastic deformation of release rebound increases.

In order to ensure the reliability of numerical simulation, tangent modulus and yield stress shall be given reasonable parameters to fit the material facts. According to the spring-back of plate test results, we can give the material parameters. In the spring-back simulation, sheet metal thickness and material properties should be set in metal forming simulation parameters [8].

| Table 1. Material parameters |
|-----------------------------|
| Elastic modulus E0/MPa      | tangent modulus Et/MPa | yield stress σy/MPa | Poisson's ratio μ | Density ρ/kg·m-3 |
| 2.06×10^5                  | 2.0×10^4               | 345                | 0.3              | 7.85×10^3       |

2.3. Elastic constraint
In the sheet of constraining facets, we need predefined constraint nodes in the sheet to eliminate the rigid mold after removing the sheet displacement. So the example select near the center point of the sheet constraints[9-10]. Then click on the button of Constraint and selected the constraint position and click OK to define the constraint, sheet constraints determine the effect diagram as is shown in Figure 3.

[Fig 3. Sheets of the constraints imposed]

[Fig 4. Forming effect]

3. The calculation results analysis
After preprocessing is complete, the task and the task files submitted to the solver to calculate. Calculation is completed. The forming files is input processor Eta-Post-Processor[9]. The various parameters of the plank can be observed and analyzed after forming. Sheet forming effect as shown in figure 4.

The distribution of principal stress is shown in figure 5 and spring back is shown in Figure 6. As can be seen from the figure 6, the springback amount of the plate gradually increases outward from the
center of the plate, with the largest springback amount at the edge of the plate. According to the data in the figure, the forming curvature is 1600 mm, the diameter is 800 mm, the thickness is 10 mm, and the maximum springback amount of the stamping forming of the "spherical" hull plate made of Q345 steel is 10.941 mm.

4. Forming springback impacting factors research

Sheet forming is a very complicated process and will be accompanied with spring-back in the forming process. There are many factors that can affect plate spring-back, such as plate thickness and sheet forming radius of curvature, and so on. This section will be further to explore the effects of various factors on sheet metal stamping forming spring-back as the result of numerical simulation.

4.1. The effects of material for springback

Sheet forming radius of curvature is an important factor to influence plate springback. In order to study the properties of plate material for springback effect, the yield strength of the material Q235 and Q345 are selected and analyze the effect of sheet material for spring-back by the results of numerical simulation. Experiment of steel thickness is 10mm and its all diameter is 800mm and all curvature radius is 1600mm.

We can get that the sheet metal form’s springback maximum value of the steel whose material is Q235 is 8.675mm and we can get that the sheet metal form’s springback maximum value of the steel whose material is Q345 is 10.941mm. By the result of the numerical simulation, we can draw a conclusion that the more if the yield strength of the plates, the more that the springback value of sheet metal forming. By analyzing this reason that can interpret this situation, we can get that the yield strength of the plate is the plate when starting a permanent plastic deformation stress and the more yield strength of plates, the more moment that need to load at a certain deformation degrees, so the springback value of loading moment is greater.

4.2. The effects of radius of curvature for springback

With the material properties of the plate, the radius of curvature of the plate is also an important factor affecting the spring-back of sheet metal. Sheet in order to study the effect of curvature radius for springback in sheet forming, we use the palates whose material is Q235 steel and diameter is 800mm and thickness is 10mm as example, different plate thickness forming spring-back numerical simulation were done. According to data for analysis, we orderly select curvature radius is 3000mm, 2600mm, 2200mm, 1800mm, 1600mm. Different form of spring-back in sheet metal forming under the maximum radius of curvature as shown in table 2.

| r/mm  | 3000  | 2600  | 2200  | 1800  | 1600  |
|-------|-------|-------|-------|-------|-------|
| maximum springback/mm | 18.788 | 15.373 | 13.183 | 11.541 | 10.941 |
From the table 2 and Figure 8 we can get that the deformation of the sheet metal forming is increasing along with sheet metal radius of curvature decreased. However, the sheet maximum springback will gradually decrease and the maximum elastic deformation of the decreasing trend is gradually flattened. We can get the reason of this situation by analyzing. The main reason of sheet spring-back is that plates stored part of the elastic deformation in deformation process. This energy release account for the spring-back in sheet. Thus elastic deformation are major factors affecting the spring-back of sheet metal during the deformation process. In the process of sheet metal forming, as the radius of curvature decreases. The proportion of plastic deformation will increase during the deformation process of the sheet metal forming is increasing. The sheet that close to the outer layer. Accordingly elastic deformation of proportion will be reduced gradually. In the meanwhile, the area that Close to the Center of sheet material layers near the pure elastic regions will produce plastic deformation gradually. So it make that the proportion of elastic deformation is smaller in the process of sheet metal forming. Correspondingly, elastic energy is less and less that stored in Sheet metal. Thus, after un installing stamping Sheet spring-back due to elastic deformation energy release is an increasingly small. And with the increasing deformation of sheet metal forming, sheet metal deformation during elastic deformation of components reduce the rate gradually become slow again. Thus, lead to maximum amount of spring-back of sheet metal decrease gradually leveling off.

4.3. The effects of thickness for springback

With sheet forming radius of curvature, the thickness of the plate is also an important factor affecting plate spring-back.

In order to study the effects of plate thickness on the spring-back, based on the curvature radius of 1600 mm, 800 mm diameter, material for Q345 steel plate as an example, different plate thickness forming spring-back numerical simulation were done.

The thickness with 6 mm, 10 mm, 14 mm, 18 mm plate forming spring-back numerical simulation were done, different thickness maximum spring-back shown in the table 3.

| thickness /mm | 6    | 10   | 14   | 18   |
|--------------|------|------|------|------|
| maximum springback/mm | 13.14 | 11.08 | 9.97 | 9.581 |

Fig 7. Diagram between the maximum springback springback and radius of curvature/mm
Fig 8. Diagram between the maximum and thickness

The conclusion can be get from the table 3 and Figure 8. Spring-back gradually decreases with the increase of the thickness of the plate and the spring-back decreases gradually flatten out.

Because of the curvature same the deformation is also the same. With the increase of the thickness relative bending radius \( R/t \) decreases and inverse association relationship between them. The value of the relative bending radius \( R/t \) is smaller, the bending deformation is greater. So with the decrease of the relative bending radius, plate deformation degree increase. But in the total deformation, the ratio of the elastic deformation is gradually reduced, so the spring-back also became smaller after unloading.

5. Conclusion
In this paper, study spring-back numerical simulation for forming and springback are studied. The key technologies of spring-back numerical simulation are analyzed and verify the reliability with experimental results. And respectively studies the influence of thickness and curvature radius for spring-back, get the following conclusion:

1) Along with the decrease of the curvature radius, the deformation is increase and the springback value is gradually reduced and the largest amount the spring-back decrease trend gradually flattens out.
2) Spring-back gradually decreases with the increase of the thickness of the plate and the springback decreases gradually flatten out.

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References
[1] Daw-Kwei Leu, Simplified approach for evaluating bend ability and springback in plastic bending of anisotropic sheet metals, Journal of Materials Processing Technology 66,1997: 9-11.
[2] A M Prior. Applications of implicit and explicit finit element techniques to metal forming[J]. Journal of Materials Processing Technology.1994,(45):649-656.
[3] Zeng Danielle, Xia Z.A Modified mroz model for springback prediction [J]. Journal of Materials Engineering and Performance, 2007, 16(3):293-300.
[4] Tang Bingtao, Zhao Guoqun, Wang Zhaqing. A mixed hardening rule coupled with Hill48' yielding function to predict the springback of sheet U-bending[J]. International Journal of Material Forming, 2008,(3): 169-175.
[5] Zang shunlai, Ding rixian, Guo cheng, etc. Influence of element size and number of integration points on springback simulation accuracy of stamping [J]. Journal of plastic engineering, 2010, 17(5): 10-14.
[6] Li Shuangyin. Hull plate cold forming springback research[D]. Wuhan: Wuhan university of technology, 2011.

[7] Chen wenliang. Sheet metal forming CAE analysis tutorial[M]. Beijing: Mechanical industry press, 2005: 73-75.

[8] Xiong Qinghua, Ma liang. Plate forming simulation software DYNAFORM[J]. CAD/CAM and Manufacturing informatization, 2006, (2): 51-53.

[9] Se Yun Hwang, Jang Hyun Lee, Yong Sik Yang, Mi Ji Yoo. Springback adjustment for multi-point forming of thick plates in shipbuilding[J]. Computer-Aided Design. 2010, 42: 1001-1012.