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Spring-back of flexible roll forming bending process

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Abstract. Simulations are now widely used in the field of roll forming because of their convenience. Simulations provide a low cost, secure and fast analysis tool. Flexible roll forming provides the desired shapes with a one time forming process. For roll forming, the velocity of the sheet and friction are important factors to attain an ideal shape. Because it is a complicated process, simulations provide a better understanding of the roll forming process. Simulations were peformed using ABAQUS software linked to elastic–plastic modules which we developed taking into account of interactions between these fields [1]. The application of this method makes it possible to highlight the strain-stress and mechanical behaviour laws and the spring-back. Thus, the flexible roll forming and bending process can bewell described by the simulation software and guide the actual machine.

1. Introduction

Cold roll forming now is widely used in the automotive and construction industries. Cold roll forming is a sheet pass a group of rolls and gets a desired shape. Because of its high productivity and low variable cost, roll forming have a great advantage compare to other forming process. With the roll forming process, we can easily get the shape of the sheet which we want and more suitable for mass production in factory which are very important. Although roll forming is an old technique and have been studied by many researchers but there are still some problems are not well solved such as spring-back. There are many factors can affect the sheet deformation in roll forming process and how to control these factor are very important in the simulation [2].

The roll forming process is operated between roll forming multi-stages continuously. And roll forming a profile is formed in several forming steps from an unreformed strip to a finished profile. The scientific design of passes is worked out by combining the theoretical analysis with the finite element analysis in accordance with the principles of cold roll-forming, thus as the desirable high-quality bending sections achieved through the combination of the theory with practice.

Recently, sheet forming become more and more important in industry production. To find a way for mass production with an easier way is necessary. Compare with the stamping and other process, roll forming is better in mass production and have a cheaper cost [3]. In this study, flexible roll forming bending process is designed to predict the bending process and the sheet mechanical behavior after deformation [4].

Discontinuous manufacturing technologies, such as stamping and stretch-forming, produce a product at one time. The discontinuous flexible forming process, which is based on the usage of reconfigurable die, does not require expensive conventional die and time consuming setup operations,

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and thus is suitable and efficient for the small quantity production of doubly curved sheet metals.

2. Objectives and approach

In In this paper we are going to develop a flexible roll forming process for the slope sheet, concave sheet and convex sheet. The mechanical properties are studied and the spring-back is calculated in this paper [5].

We export the CAD model of the rolls and sheets form Solid works and the simulation was calculated using the commercial finite simulation program ABAQUS.

The steps of this investigation were:

- Model a given sheet which has a constant bending width and determine the rolls shape and dimension. the appropriate superscript value just after the surname and just before the address:
- Define the roll forming process and conditions in ABAQUS such as mesh and interactions.
- Determine the rotation center of the roll and establish the boundary conditions for the roll make them moving forward as desired.
- Optimization of the roll forming process with the simulation results and determines better parameters such as velocity and friction.

3. Simulation and analysis

The SGARC 440 material is very common and cheap sheet steel, SGACR 440 with a Young's modulus of 207 (GPa) and Poisson's ratio of 0.28 [6]. The elastic-plastic properties, including the true stress and strain are given in table 1 and the true stress-strain curve derived from these data is display in figure 1.

Table 1. Mechanical characteristics of SGRC 440 steel.

	Young's modulus	Tensile strength	Yield Strength	Poisson 's Ratio
SGARC440	207000 [MPa]	440 [MPa]	300 [MPa]	0.28

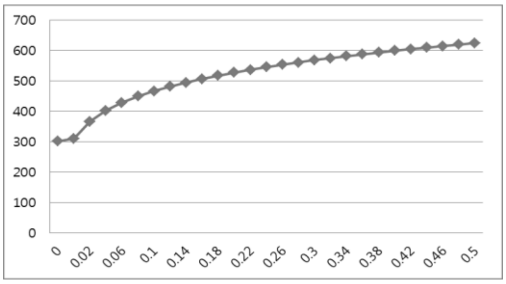

Figure 1. True plastic strain (mm/mm).

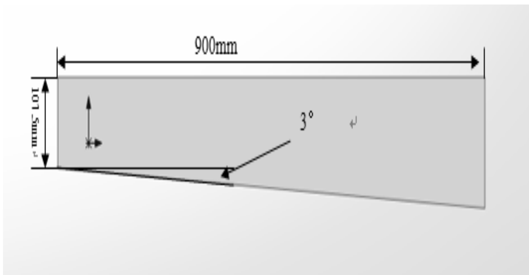

Figure 2. Dimension of sheet with 3degree.

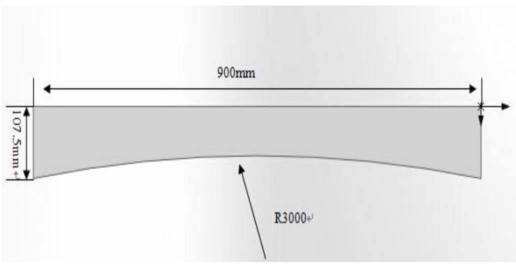

Figure 3. Dimension of concave sheet.

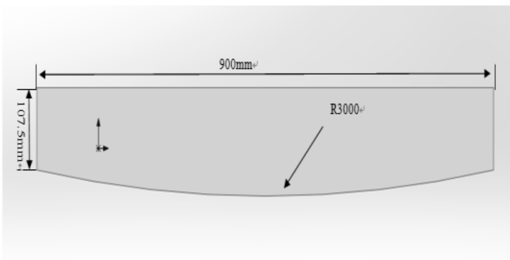

Figure 4. Dimension of convex sheet.

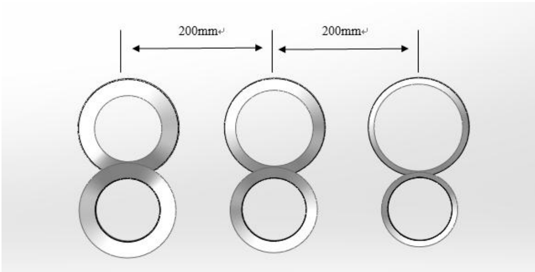

Figure 5. Distance between rolls.

With different design of rolls, sheet could be deformed successively into products with different section.Three experimental setups of flexible roll forming process are modeled.There three kinds of sheets and the dimensions are shown in figures 2, figure 3 and figure 4. For all sheets have a width of 900 mm and the length in longitudinal direction is 107.5 mm. The concave and convex sheets are part of circle which radius is 3000 mm. In this roll forming process, the sheet passes through the three groups of the rolls. The rolls from left to right are 15°, 30° and 45°.The metal sheets with the thickness of 1mm are used as the initial metal strip. The position of the rolls is given in figure 5. There are several of element types in ABAQUS. In this simulation we choose the quadrangular shell element (S4R) volume element with full integration.S4R element is the most stable element type and task less time for the Dynamic-implicit simulation in the roll forming design program [7]. After meshing, there are 3294 elements in the sheet, and the sheet is 900 mm long.

There are many ways in ABAQUS to control the rigid bodies, by referencing the velocity, rotation and displacement or load. We can choose any one to control the movement of the rigid body. For the sheet which has an angle with 3 degree is easier to use the velocity by defining the velocity in X-axis and Y-axis. However, defining the velocity in addition with the sheets which have concave edge or convex edge has some problems. It is better to use the rotation and displacement rotation with period amplitude. Period amplitude is Fourier series in actual.

French mathematician Fourier found that any periodic function can be used to constitute the infinite series of sine and cosine function to represent (sine and cosine function is chosen as the basis function is because they are orthogonal) [8].

In this function, s(x) is a function of the variable x and the function can be shown as below:

$$S_N(X) = \frac{A_0}{2} + \sum_{n=1}^{N} A_n \cdot \sin\left(\frac{2\pi nx}{P} + \Phi_n\right) \tag{1}$$

By which we can definite move path of the roll can be a periodic function. Therefore the roll will move as a circle with no displacement in third direction.

The sheet passes the rolls and bending continually. So for the boundary conditions of the sheet the rotation in the Y direction is fixed. The movement in X and Y direction are fixed. The boundary conditions are performed by defining the centreline of the sheet. Other directions are flexible to get a bending along the edge.

After introducing the boundary conditions, contact were defined between the rigid bodies and deform bodies. The interactions between them were surface to surface contact and definite by the step. It has been assumed that the friction between the roll and sheet is penalty and the friction coefficient is small enough.

The geometry of the strips after rolling deformation are shown in figure 6, figure 7 and figure 8. The experiment results are shown in figure 9, figure 10 and figure 11. The forming result is influenced by many factors such as the material property, the thickness, the velocity of the sheet and the friction coefficient of between the sheet and the roll. According to the stress distribution below we can know that the minimum stress occurs at the middle of the sheet which is unperformed zone. This is corresponding to the deformation theory.

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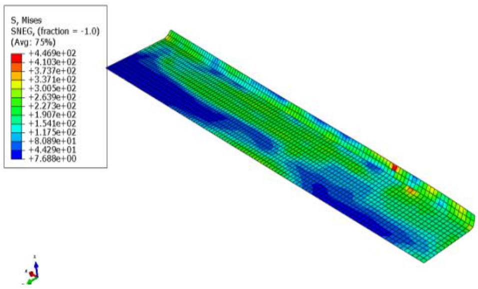

Figure 6. Simulation result of Sheet with 3°

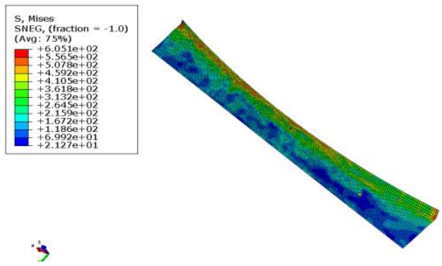

Figure 7. Simulation result of concave sheet°

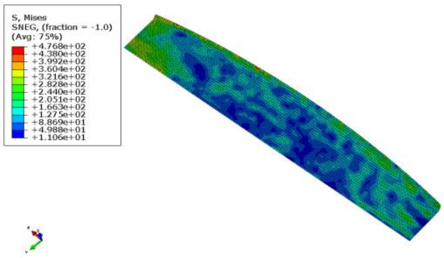

Figure 8. Simulation result of convex sheet

Figure 9. Experiment result of sheet with 3°

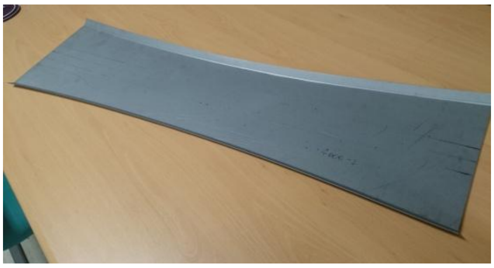

Figure 10. Experiment result of convex sheet

Figure 11. Simulation result of convex sheet

The comparison of the stress of the whole model is shown in figures 9, figure 10 and figure 11. What we can know from the figure is that the simulation results have a good agreement with the experiment results. For every simulation, the comparison of the simulation results and experiment results are very important. The experiment results can verify the simulation results. As shown in the figures above the biggest stress of the sheets is at the edge of the sheet and we can know the stress of the concave sheet is too big at some point .This is because of mesh distortion around the forming process.

Since the proposed process generates the bending dominant deformation, it is necessary to investigate the effect of spring-back. In order to analyse the spring-back, a Static, General step is carried out based on the problem defined. In order to compare the effect of spring-back through the roll forming process, nine points along the X-axis direction are calculate and illustrated in figure 12.

Spring-back is inherent to the material forming process especially in the bending process. These kinds of phenomenon have a great impact on the size of precision and productivity.

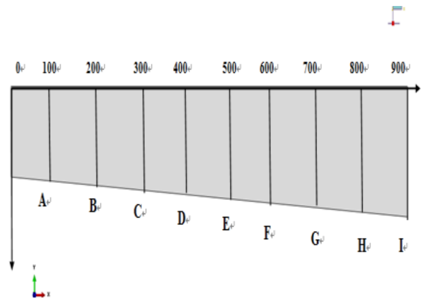

Figure 12. Measurement point for spring-back.

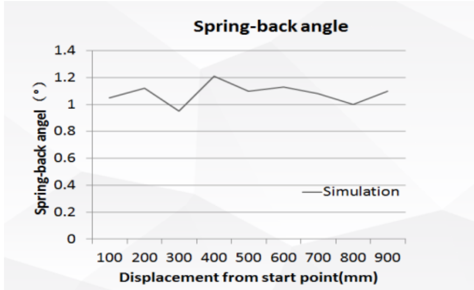

Figure 13. Spring-back angle of sheet with 3°.

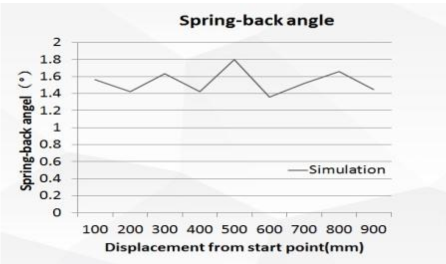

Figure 14. Spring-back angle of concave sheet.

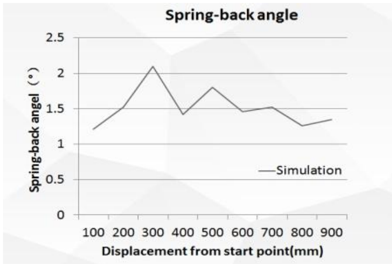

Figure 15. Spring-back angle of convex sheet.

Therefore, to get an accurate estimate of the amount of the spring-back angle in bending process is very important in roll forming design.

From the figure 13, figure 14 and figure 15, we can know that the spring-back angle is not consistency according the sheet the edge. For the sheet with 3°, the maximum spring-back angle occurs at the distance=400 mm. The maximum spring-back angle of the concave sheet occurs at the distance=500 mm. As for the convex sheet, the maximum spring-back angle occurs at the distance=300 mm.

4. Conclusions

In this paper, a new kind design of flexible roll forming bending process with Fourier series. Different kinds of sheet were analysed and we can conclude that the model can effectively predict the trends in the distribution of the strain-stress and energies. Through the simulation program, the important parameters are determined by taking account of roll stand distance and roll forming speed. With the study above, we can know that

- With the finite element simulation in ABAQUS we can get a better understanding of the roll forming process with an easy way and less time.
- The spring-back angles have been learned in this paper, from which we can analysis the deformation and find out how to reduce it.
- The roll forming process is analysis in this paper and the stress and distribution are learned. The simulation above can guide the optimization of the roll forming process in real produce.

From the process analysis above, we can design a reasonable roll forming process. But there are still many works need to do such as the buckling and flange wrinkling have not been studied in this paper. These kinds of defects are very important in roll forming process and should be considered to get better results.

Acknowledgments

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