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Transverse bending deformation analysis of 3D surface part in continuous roll forming process

M Wang[1*] , S C Yang[1], G L Lu[2] and J H Cao[3]

[1]School of Engineering, Changchun Normal University, 677 Changji North Road, Changchun, P. R. China, 130032
[2]Key Laboratory for Bionic Engineering (Ministry of Education), Jilin University (Nanling Campus), 5988 Renmin Street, Changchun, P. R. China, 130025
[3]School of Mechanical and Electrical Engineering, Xinxiang University, 191 Jinsui Street, Xinxiang, P. R. China, 453003

wangmi3214@126.com

Abstract. This paper introduces a newly developed technique called continuous roll forming process which is applied to manufacture 3D surface part with various shapes, especially for doubly curved parts. In continuous roll forming process, the twin bendable rolls are placed to form a nonuniform roll gap. The bendable rolls rotate in opposite directions around the bend axis with equal angular velocity. The sheet metal is bitten into the roll gap by friction force and compressed nonuniformly across its width. At the present, how to precisely predict transverse bending deformation of 3D surface part has become a critical issue for guiding practical forming in the continuous roll forming process. This work focuses on analysis of the transverse bending deformation characteristics in continuous roll forming process.

1. Introduction

Roll bending process is widely used to manufacture cylindrical or conical sections with constant cross section[1]. However, the requirements for products in production practice tend to be personalized and varied, needing more completed surface part. Flexible roll forming is a new way to manufacturing various 3D surface parts with complex cross section. Discrete-roll forming was developed by Shim et al by using the multiple roll sets to form doubly curved plates in whole region with only one pass[2, 3]. Li et al proposed continuous flexible forming process composed of an up and two down flexible rolls, and the configuration of three flexible rolls are adjusted by multiple points on the basis of the shape of the target part[4]. Continuous roll forming process explored by Cai et al is a novel roll bending technology to translate a flat metal plate into 3D surface part.[5, 6] As shown in figure 1, the continuous roll forming device is composed of an up and a down bendable rolls, and the configurations of the bendable rolls can be controlled in accordance with the desired shape of the formed part. The sheet metal is deformed in the local region between the up and down bendable roll, and with the bendable roll rotation with the bend axis, and the sheet metal is moved by the friction between and continuously deformed line by line.

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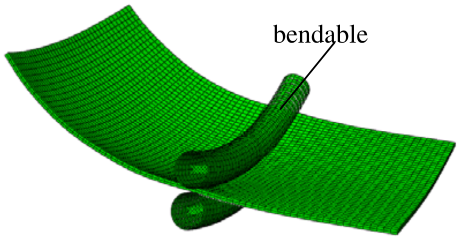
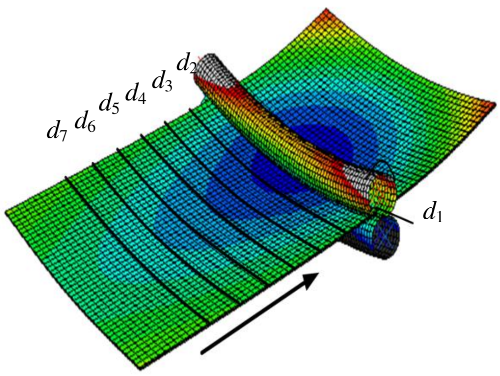


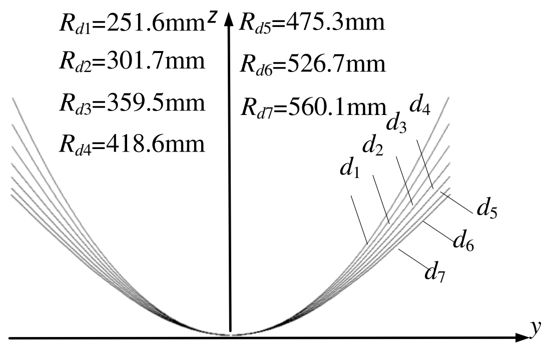
Figure 1. Diagram of geometric feature of deformation zoon

2. Transverse bending deformation in continuous roll forming process

In order to understand the transverse bending process of the sheet metal, the radius of the transverse curvature of cross section at different positions is analyzed. As shown in figure 2, the transverse bending deformation at seven positions (d_1, d_2, d_3, d_4, d_5, d_6, d_7) along the direction of motion are extracted and shown. The radius of the transverse curvature of cross section at d_7 is 560.1 mm, and the radius of the transverse curvature is decreased from d_7 to d_1 and reaches minimum at d_1 with the value 251.6 mm. It can be found from the changing regularity of the radius of the transverse curvature of cross section, the sheet metal has been bent in a certain distance from the roll gap, and the radius of the transverse curvature of the sheet metal is becoming more close to the radius of the transverse curvature of the bendable roll when closing to the deformation zoon. It can be assumed that the sheet metal deforms gradually in the process of approaching the bendable roll, and the transverse bending deformation is finally completed in the contact deformation zone. Figure 3 shows the variation of transverse curvature of sheet metal, the ratio of the distance to the roll gap to the sheet metal width is abscissa, and the transverse curvature at corresponding position is ordinate. For different positions on the sheet metal, at more distant positions from the roll gap, the less transverse curvatures are found, that is to say, the transverse deformation of the sheet metal is produced gradually.



(a) Simulation process



(b) Radius of the transverse curvature of cross section

Figure 2 Profile curves and radii of curvatures of cross-section

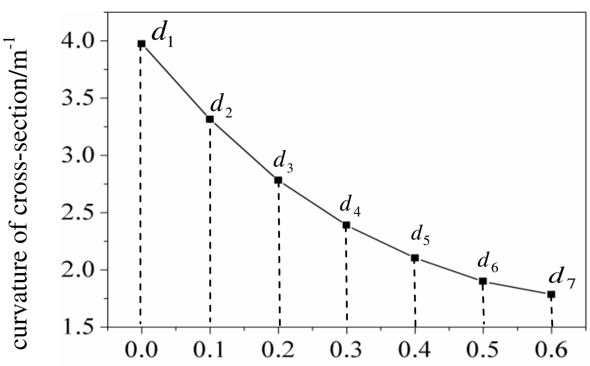


Figure 3. Variation of curvature of cross-section `

3. Numerical simulations

In the continuous roll forming process, the sheet metal deformed in the deformation zoon in a very short time, and the forming process is affected by many factors, so it is difficult to observe the deformation process through experiments. The numerical method was employed to study the deformation process in the continuous roll forming process. Based on the numerical simulation, visualization results of the deformation process can be obtained. Equivalent stress of the sheet metal in continuous roll forming is shown in figure 4.

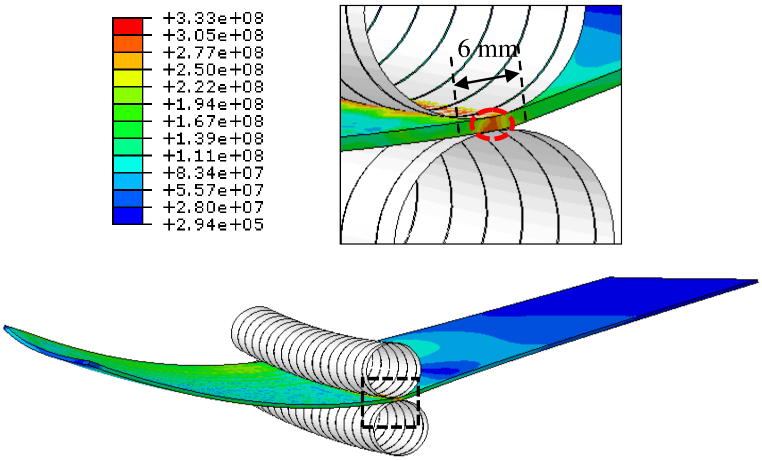


Figure 4. Equivalent stress in continuous roll forming

According to the above analysis, the stress condition of the sheet metal in different positions of the deformation zoon is varied. Figure 5 shows the diagram of geometric feature of deformation zoon, it can be observed that the equivalent stress of the sheet metal between the up and down bendable rolls is large, and the maximum value of 333 PMa appears in the deformation zone. Since the equivalent stress varies greatly near the deformation zoon, the stress state in the area near the deformation zone with width 6 mm is analyzed. The stress state in deformation zone is complex and divided into several zones. Figure 5 gives the cross section (*EE′*, *AA′*, *DD′*) in deformation zone and the longitudinal fibers of the formed parts. *AA′* is in the middle of the deformation zone, *EE′* and *DD′* are the cross sections with the distance of 3mm from the left and right sides of the *AA′*. The longitudinal fiber l_1, l_2, l_3, l_4, l_5 are uniformly distributed between the middle and the edge.

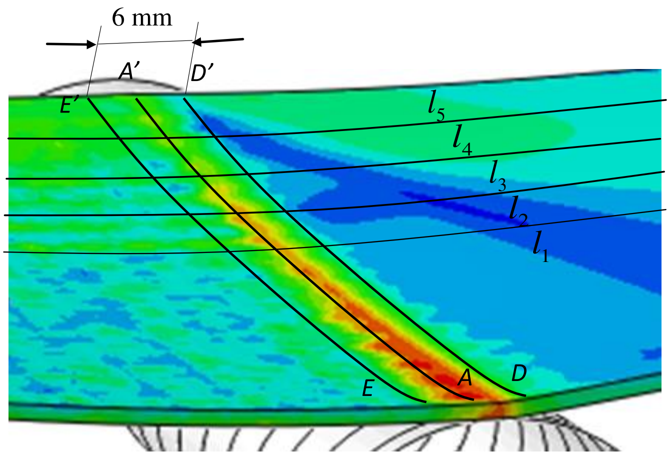


Figure 5. Diagram of geometric feature of deformation zoon

Figure 6 shows the equivalent stress distribution and minimum principal stress distribution. It can be found that the equivalent stress is large in the middle (*AA′*) and small on both sides (*EE′* and *DD′*), and from l_5 to l_1 the equivalent stress are gradually decreased. Contrary to the equivalent stress, the minimum principal is small in the middle (*AA′*) and large on both sides (*EE′* and *DD′*), and the minimum principal increases gradually from l_5 to l_1.

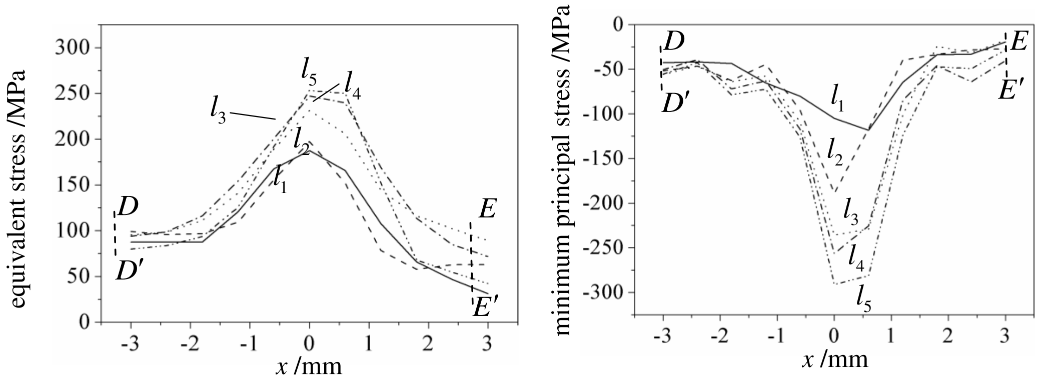


Figure 6. Equivalent stress and minimum principal stress in deformation zoon of negative Gaussian curvature

4. Conclusions

Continuous roll forming is a novel forming technology for manufacturing 3D surface part based on bendable rolls. This paper focuses on the transverse deformation of sheet metal, the transverse deformation of sheet metal at different position is studied through simulation and the stress distribution of the sheet metal in the forming process is analyzed. The numerical simulation results show that the sheet metal has been bent in a certain distance from the roll gap, and the transverse curvature of the sheet metal is becoming more close to the transverse curvature of the bendable roll when closing to the roll gap. For manufacturing a Negative Gaussian curvature part, the equivalent stress is large in the middle and small on both sides. Contrary to the equivalent stress, the minimum principal is small in the middle and large on both sides.

Acknowledgements

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