A Parametric Study on Cold Roll Forming with Partial Thermal
Ya ZHANG, Dong-hong KIM, Ha-phong NGUYEN and Dong-wong JUNG*
Department of Mechanical Engineering, Jeju National University, 1 Ara 1-dong, Jeju-si, Jeju, South Korea
*Corresponding author

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Abstract. Roll forming has a significant and a puzzling peculiarity [1]. The significant aspect is that roll forming has been one of the most useful manufacturing methods in modern industry. The puzzling aspect of the roll forming is that there are still many problems in the manufacturing process to be solved. This paper develops a model which with partial thermal and make comparison it with the usual cold roll forming [2]. A simulation program has been developed in order to examine the roll forming process. The program is based on the finite element analysis of shape and roll forming under dynamic, explicit condition.

Introduction

Roll forming is a kind of sheet metal forming method which widely used in the modern industry. Because of its high production rates and the possibility to form complex geometries, you can find it in many different products, for example buildings, household appliances and vehicles.

Several forming steps have been applied 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 the desirable high-quality bending sections achieved through the combination of the theory with practice [3]. The roll forming machine is shown on the Figure 1.

In the roll forming process, the material is formed by rotating rolls that arranged in sequence. The material to be formed has a resistance against bending caused by its stiffness and material property. Therefore, the starting deformation point will not be the same for different materials.

Figure 1. The roll forming machine.

Finite Element Model

The investigated material, AZ 31 aluminum, is one kind of common cold roll forming sheet aluminum with a Young’s modulus of 44.8 (GPa) and Poisson’s ratio of 0.35 [4]. In Table 1, the detail parameters are given in Figure 2. A tensile test of the material indifferent temperature is present.

Table 1. Simulation parameters used in finite element model.

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<th>Young’s modulus</th>
<th>Density</th>
<th>Poisson’s ratio</th>
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<tbody>
<tr>
<td>AZ31</td>
<td>44.8 [GPa]</td>
<td>1.77 [g/cm³]</td>
<td>0.35</td>
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</table>
Sheet dimension was shown on the Figure 3. Because of the sheet is symmetry, there just a half of the sheet has been considered in this simulation. The sheet is 900mm in the longitude direction and 107.5mm in the width direction. The edge of the sheet is a part of a circle with the radius of 3000mm.

![Figure 3. Dimension of convex sheet.](image)

**Design of Roll Forming Process**

The continuous flexible roll bending process is complicated from a finite element (FE) perspective. Its features include contact phenomena, large strain plasticity, and large displacements. Hence, the following assumptions were applied for the purpose of computational efficiency [5]:

1. The flexible rolls were conceived as rigid bodies.
2. The material of the sheet metal was assumed to be homogeneous, with a bilinear stress–strain relationship.
3. The weight of the sheet metal was neglected.
4. The static and dynamic friction coefficients were considered to be constant on the contact lines between the flexible rolls and the sheet metal.
5. Plane strain conditions prevailed.

For the element used in this simulation is S4R. S4R is widely used in sheet simulation for its good precise and small time consumption. [6]The position control of the sheet is conducted by defining a rotation in the Y direction. The movement in X and Y direction are fixed. The boundary conditions are performed by defining the centerline of the sheet.

![Figure 4. Heating region of the sheet.](image)

As shown in Figure 4, the red color area is the thermal area. The thermal temperature is 200°C. This area is corresponding to the bending region. We assumed that the thermal in this simulation is consistent and any kind of heat transfer is ignored in this roll forming process.

**Process and Simulation Results**

As shown in the Figure 5 and Figure 6, the stress distribution of the sheet after roll forming with partial thermal. The maximum stress of the partial thermal sheet is 102.8Mpa. Compare with the stress distribution in Figure 8, the maximum stress is 31.11Mpa. The maximum stress in cold roll forming is much smaller than the one with partial thermal. These results correspond to the bending
theory and the literature. The maximum stress happened in the bending region and the minimum stress all occurred in the middle of the sheet where there are no plastic deformations. In simulation, only deformation areas are considered. The tensions before and behind of the deformation area are not considered.

![Figure 5. Sheet after roll forming with heating.](image)

![Figure 6. Sheet after roll forming without heating.](image)

To analyze the effect of the flexible roll forming, the stress and strain distribution during roll forming is investigated along the edge of the sheet in the initial region of the sheet. As previously mentioned, the roll forming direction is from the right to the left. The path is developed in the sheet which we get the stress and strain distribution along this path as Figure 7 shows.

![Figure 7. The path for the stress and strain distribution.](image)

The comparison of the stress is shown on Figure 8 and Figure 9. Figure 8 shows the stress distribution of the sheet with partial heating, and Figure 9 shows the sheet without partial heating. As the initial metal strip is passing through the roll stands, the increase of stress distribution of the roll-formed profile is accumulated by the incremental increase of the stress at each forming roll as shown in Figure 8 and Figure 9. The stress at each forming roll increases. As the bending angle increase, the stress comes to a peak at the last group of the rolls. The sheet which been partial thermal is much bigger than the one without thermal. This is because of the thermal stress increase in the sheet with partial thermal.

![Figure 8. Stress distribution with heating.](image)

![Figure 9. Stress distribution without heating.](image)

Despite the stress distribution in the roll forming process, the strain is also an important parameter. As the same method to the stress, the strain distribution along the edge of the sheet are
shown on the Figure.10 and Figure.11. The strain with partial thermal come to a peak at the bending area. At the region without deformation there just have small strain. This is same both in the sheet with thermal and without thermal.

![Figure 10. Strain distribution with heating.](image1)

![Figure 11. Strain distribution without heating.](image2)

**Conclusion**

In the present study, partial thermal of the cold roll forming with AZ31 aluminum has been developed. We analyzed the stress and strain distribution of the sheet. With these simulations, we can conclude out that:

1. Through the simulation, the stress distribution of the sheet in flexible roll forming has been well understood.
2. The partial thermal of roll forming decreed the buckling defect in flexible roll forming process.
3. The strain of the initial region change smoother in the partial thermal roll forming compare with the cold roll forming.
4. The stress of the partial thermal roll forming becomes bigger because of the heating. The maximum stress of the partial thermal roll forming is about two times bigger than the cold roll forming.

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**References**


