2014

Numerical analysis of spiral roller of chain-die former

Shenglan Zhu
*University of Wollongong, sz876@uowmail.edu.au*

Yong Sun
*University of Wollongong, ys994@uowmail.edu.au*

Shichao Ding
*University of Wollongong, sding@uow.edu.au*

Publication Details

Numerical analysis of spiral roller of chain-die former

Abstract
Chain-die Forming is a novel sheet metal forming technology developed recently. It effectively minimizes the redundant deformation during forming in order to reduce residual stresses to very small values even to zero in product, which is impossible to be achieved through conventional roll forming. Better quality of products therefore can be expected with the development of this new technology. This article is to use FEM to analyze the stresses developed in the spiral roller which is one of the key elements in a Chain-die former. In order to optimize the design of Chain-die former, the results of equivalent stress have been collected and analyzed to understand the capability of the spiral roller. Maximum working load as an important index therefore can be determined. The comparison between spiral roller and simple hollow roller is also discussed.

Keywords
die, chain, roller, spiral, former, analysis, numerical

Disciplines
Engineering | Science and Technology Studies

Publication Details

This conference paper is available at Research Online: http://ro.uow.edu.au/eispapers/1952
Numerical Analysis of Spiral Roller of Chain-die Former

Shenglan Zhu, Yong Sun and Shichao Ding

Faculty of Engineering, University of Wollongong, Wollongong, NSW 2522, Australia

Abstract. Chain-die Forming is a novel sheet metal forming technology developed recently. It effectively minimizes the redundant deformation during forming in order to reduce residual stresses to very small values even to zero in product, which is impossible to be achieved through conventional roll forming. Better quality of products therefore can be expected with the development of this new technology. This article is to use FEM to analyze the stresses developed in the spiral roller which is one of the key elements in a Chain-die former. In order to optimize the design of Chain-die former, the results of equivalent stress have been collected and analyzed to understand the capability of the spiral roller. Maximum working load as an important index therefore can be determined. The comparison between spiral roller and simple hollow roller is also discussed.

Keywords: Chain-die Forming, finite element analysis, spiral roller, equivalent stress.

PACS: 02.70.Dh

INTRODUCTION

Roll forming is a conventional forming technology which is the widely used in manufacturing. However, even over a century development, roll forming still has a series of deficiencies that limits its application such as roll forming Advanced High Strength Steel (AHSS) and so on.

In the 1970s, Suzuki et al. proposed a tri-axial surface deformation model which illustrated that all other strains, except transverse bending strain, are redundant strain components, and should be minimized or eliminated in a good forming process [1]. Panton et al. explained that the longitudinal strain and shear strain cannot be both eliminated at the same time which means in practice, the strain will lie between these two extremes and will coexist during the forming process [2-4].

As a result, the roll forming turns to be a method which highly relies on the engineer's experience during the manufacture process. Even though the theories of roll forming have been developed and the research on it has been continued. "Trial and error" approach is still the main principle to improve the roll forming technology.

To break through the bottleneck, the concept of Chain-die Forming was introduced by Ding [5]. Chain-die Forming is an extension from roll forming which can be understood as a roll forming process with a pair of large virtual rolls. The deformation length in Chain-die Forming can be dramatically stretched by increasing the virtual roll radii to very large dimensions. The research carried out by Zhang [6] illustrates that it is possible for Chain-die Forming to minimize the longitudinal strain to a small level which is unachievable by roll forming.

As Chain-die Forming begins to show its superiority and gradually accepted by industries, it is necessary to study the structure of the Chain-die former so that this newly developed technology can be improved. Spiral rollers, as the key elements of the Chain-die former, withstand almost the whole working load during the forming process. The strength of the spiral roller decides the amount of the working load can be exerted and also the quality of the product. Therefore, it is significant and crucial to study the strength of spiral rollers and relative structure.

CONCEPT OF CHAIN-DIE FORMING

Figure 1 shows the key assemblies of a Chain-die former including two chain track boards, chain joints and die blocks. The two chain track boards are shaped in working surface with large radii. The chain joints are connected by pin shafts. And between the track board and chain joints there are rollers to transfer the pressure load. The paired separated die-blocks are mounted on the chain joints, and it forms a face to face forming space in working surface. In practical operation, the metal strip is fed into the forming space at the entrance. The friction between die blocks and the strip will drive the strip move forward. The strip keeps being formed while the forming space is gradually reduced.
FINITE ELEMENT MODELLING

Spiral roller, as shown in Figure 2(a), will be joined by the pin shafts similar as roll chains. The spiral rollers will spin due to the friction between the chain joints (as shown in Figure 2(b)) and roller, roller and track board, during the Chain-die Forming process. In this model, the spiral pitch of the roller is 9.5mm, outer diameter is 12mm, chain pitch is 12.5 mm and the length of the roller is 38mm. Track board, as shown in Figure 2(c), is designed as a guide way for chain joints to move along the working surface. The working surface is a curve shape with a large radius of 50 meter which is essentially an equivalent virtual radius of a roll in roll forming.

The local refined mesh on the contact areas between roll to chain-joints is as shown in Figure 3. In addition, the properties of the material used in this study are listed in the Table 1 and the uniform distributed load is applied on the upper surface of the chain joint. The simulation has been carried out under several forces (100N, 500N, 1500N, 3000N, 4000N and 4250N) and the Figure 4 shows the load set-up.

For the Chain-die former, there is assumed no transverse constrain during forming and therefore there is no load in X direction. A “Fix” support is defined at the bottom of the track board to maintain the track board stay in the same position during the simulation, as shown in Figure 5.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Values</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>7850</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>200</td>
<td>GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>600</td>
<td>MPa</td>
</tr>
</tbody>
</table>
RESULTS AND ANALYSIS

The FEM simulation is carried out by ANSYS Workbench 12.0. The simulation started from 100N force and increased the load to 4250N. Figure 6 is a contour diagram of the Von-Mises equivalent stress under load of 4250N and the maximum value is around 597MPa.

According to the Von-Mises failure theory, the maximum equivalent stress should be lower than the yield stress of the material (600MPa) without considering the other factors such as fatigue and loading condition. That means the spiral rollers can totally withstand a 4250N working load in a static condition. Considering the safety, fatigue and other factors, the maximum load has to be smaller than 4250 N and it can be used as a design index for the Chain-die former design. Alternatively, if the spiral roller’s material is improved, the capacity of the roller has to be re-analysed. It should be addressed that the stresses are distributed unevenly along the contact line (in transverse). This uneven distribution is caused by the spiral structure of the roller. High stresses occur at the protuberant surface where contacts with the chain-joint and the along the spiral groove there is nearly no stress. The highest stress occurs in the central area of the spiral roller.

It can be observed in Figure 7 that the equivalent stress and applied force is not a linear relationship but the line tends to be straight after 500N. This is caused by the increase of the contact area, the phenomenon is so called boundary non-linear.

Hollow roller is also studied with FEM in order to compare and understand the strength differences of the rollers. As shown in Figure 8 that the maximum equivalent stress in the normal hollow roller is around 197MPa which is approximately one third of the maximum of the spiral rollers. Although hollow roller is likely taking larger load, considering other factors in industrial application such as lubrication, dust tolerance, rigidity and so on, spiral roller is still considered in the first generation of Chain-die former design.
As the limitation of element number, the smallest edge size of the mesh in this study is about 0.4mm. It is still not small enough for the more accurate or convinced result. In Figure 6(b) and (c), more intensive stress located on the bottom surface than on the upper surface. It is possible due to the difference of the mesh quality between the upper and bottom surfaces.

CONCLUDING REMARKS

The FEA modelling for rollers of Chain-die former is established. Through the simulation, the equivalent stresses under different working loads have been studied. Based on the study, the specified spiral roller should have a capacity about 4000 N which can be used in Chain-die former design. As the spiral roller is more flexible than hollow roller, it is selected for the first generation Chain-die former design. The mesh quality also needs to be improved so that the results can be more analyzable and convincible.

The dynamic simulation is necessary for the further study as it can illustrate the variation in stress for spiral rollers during the operation of the forming process.

ACKNOWLEDGMENTS

The authors would like to thank Millipede Forming Pty Ltd and UniQuest for their financial support for the Chain-die Former project.

REFERENCES