

Development of Precision Rolling Machine

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ABSTRACT

This paper proposes a rolling machine that forms fine corrugated section patterns for thin sheets. A prototype of the machine was made and the performance of the machine was tested. As compared with press forming, rolling has the advantages of the high forming limit, the low forming reaction force, the easy control of the thin sheet's curve and high productivity. We confirmed these four advantages by using finite element analyses and the prototype rolling machine. Stainless steel sheets and titanium sheets, which were one of the materials with a low forming limit, were used. Firstly, the rolling showed a 1.3-times higher forming limit than the press forming in the case that a fine corrugated section pattern was formed in a stainless steel sheet of 22-mm square sizes. Secondly, the forming reaction force of the rolling was about one-twentieth of the press forming without coining, and the experimental results agreed with the finite element simulation. As for the third advantage of the control of the thin sheet's curve, formed sheets with little curve were obtained by choosing a suitable angle. Fourthly, the trimming process, which was necessary for realizing high productivity, was examined. The half cut process by the rotary cutter, which was used to cut stainless steel sheets with PET films, was applied to the trimming process. The effect of the sword angle on cutting the section shape was investigated. Finally, the possibility of a high speed and mass production process for forming metal sheets with a fine corrugated section pattern was demonstrated by connecting the trimming machine to the rolling machine.

INTRODUCTION

Consumer goods, for example automobiles and home appliances, demand many characteristics, such as reasonable price, efficiency, lightweight and adaptability to the environment. The multi-functionalization of materials leads to a cut in the number of parts and can reduce the cost of materials, assembly and recyclability. Therefore, it is an effective means to realize lower cost, weight reduction and adaptability to the environment with required performance. As an example of the multi-functionality of parts in steel sheets, consider a steel sheet on which a fine corrugated section pattern has a higher strength and larger surface area than a non-formed type. Furthermore, a formed pattern can be used as a route for gas and liquid in a refrigerator. So the formed steel sheet has multi-functionality and is adapted to frame parts with a cooling function, for instance a polymer electrolyte fuel cell used for fuel cell cars. The forming of a fine corrugated section pattern for thin steel sheets is generally done by press forming. However, compared with the press forming, rolling has the advantages of low forming reaction force and high productivity. Therefore, we developed a precision rolling machine that can adjust the position of the rolls in the axis and circumference direction with micrometer order accuracy. The development process of the machine is reported in this paper.

1. DEVELOPMENT CONCEPT OF A PRECISION ROLLING MACHINE FOR FORMING A FINE CORRUGATED SECTION PATTERN

(1) (2) (3)

The precision rolling method for forming a fine corrugated section pattern is shown in [Figure 1](#). This rolling machine has a pair of rolls that have precision carved parts. Its shape is transcribed when forming on a thin steel sheet. The illustration of the fine corrugated section pattern in this test is shown in [Figure 2](#). When the coolant channel is formed on a thin sheet as shown in [Figure 2](#), compared with the press forming, the rolling has four advantages.

- High forming limit
- Low forming reaction force
- Easy correction of the sheet warp
- High productivity

Firstly, the high forming limit is induced by the difference in the forming condition. In the A-A section in [Figure 2](#), in the case of the press forming, the forming is done under the plane strain condition. The other side of the precision rolling yields the closely uniaxial tensile condition. Because of the small deformation constraint in the rolling direction, the rolling shows a higher forming limit than the press forming. Secondly, the low forming reaction force is given by the difference in the forming area. In the press forming, the fine corrugated section pattern is formed simultaneously. In the rolling it is formed consecutively. So the reaction force of the rolling is lower than that of the press forming. The low reaction force can lead to the downsizing and lowered cost of the machine. Thirdly is the easy correction of the sheet warp of the formed sheet. It is controlled by the strip running tension and angle. Compared with a bead in the press forming, the strip running tension can give the thin steel sheet larger force, and it can produce a larger correcting effect. Finally, high productivity can be realized by the continuous line that consists of the rolling process and the trimming process.

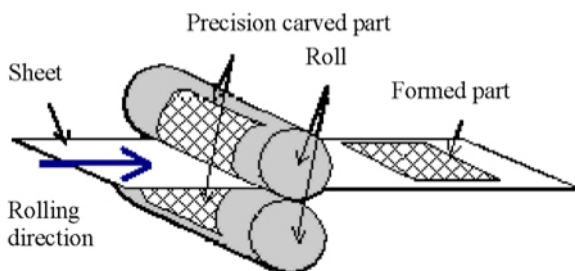


Figure 1. Illustration of the precision rolling method

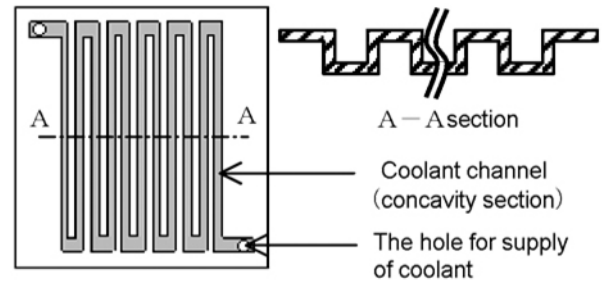


Figure 2. Illustration of fine corrugated section patterns

2. FORMING TEST AND FEM SIMULATION RESULTS

2.1. COMPARISON OF THE FORMING LIMITS OF THE PRECISION ROLLING AND THE PRESS FORMING

In order to verify the effect of the precision rolling, the forming limits of the precision rolling and the press forming by the forming test were compared. The size of the fine corrugated section pattern was 22mm². The material used was SUS304 3/4H that is general stainless steel. The mechanical properties of SUS304 3/4H are shown in [Table 1](#). The photos of a fine corrugated pattern formed till the same height by the precision rolling and the press forming are shown in [Figure 3](#). The precision rolling formed a stainless steel thin sheet with a fine corrugated pattern without cracking, although the sheet was cracked by the press forming. The comparison of the forming limits of the fine corrugated pattern of two methods is shown in [Figure 4](#). The vertical axis of [Figure 4](#) is the non-dimensionalized height by the forming limit height of the press forming. The forming limit height of the precision rolling was 1.3 times higher than that of the press forming in this case.

Table 1. Mechanical properties of SUS304 3/4H

YS N·mm ⁻²	TS N·mm ⁻²	El %	Hardness HB
≥800	≥980	≥10	≤340

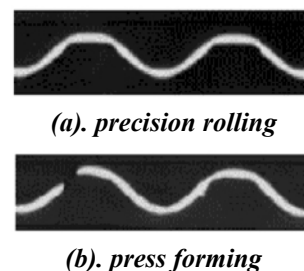


Figure 3. The cross section of the formed sheets