DEVELOPMENT OF TWISTING METHOD OF SHEET METAL USING TAPER ROLLER

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Keywords: Taper Roller, Twisting, Rolling, Skew Angle, Sheet Metal

Abstract. Twisted shape of metal, like a propeller or screw, are usually manufactured by machining. However, machining processes generate many metal chips, resulting in yield loss. This paper proposed a new processing method called, “Twist rolling”, which uses a pair of tapered rollers to obtain a continuous twisted shape. The effect of taper and skew angles on twist angle was investigated. The finite element analyses (FEA) and experiments were conducted for clarifying the effect of taper and skew angles. A commercial code, ELFEN, was used for the FEA, and a prototype machine was built for the verification using aluminum sheet metals. The FEA and experimental results were qualitatively in good agreement. The twist angle increased with the increase of the taper and skew angles. The sheet metal angle increased with the decrease of the sheet thickness. This study successfully verified the feasibility of the proposed method, “Twist rolling”.

1. INTRODUCTION

Rolling is a processing method for reducing sheet to a predetermined thickness and is highly productive. A rolling method is proposed for bending a sheet metal in an in-plane manner by changing the gap in lateral direction of the sheet[1]. Cutting and casting are often used for obtaining a continuous twisted shape such as that used for screws and propellers. These methods can manufacture highly accurate shapes, but they suffer from low yield due to large amounts of chips, residual stress, and low production efficiency. In existing research, a forging method that forms a rough twisted shape by sequential hitting is proposed using cross-arranging rod-shaped tools[2]. However, this method not only has accuracy problems such as residual unevenness on the surface but also low forming efficiency. Hence, this study proposes a new processing method called "Twist rolling" which can obtain a smooth twisted shape by using rollers. Twist rolling produce products by single processing, therefore it is expected to reduce costs by eliminating material wastage and to enable mass production with high productivity. The formed products are being considered for use as liquid stirring parts, heat exchangers, propellers, screws, and turbine blade[3].

In this study, the relationship between optimal processing conditions and formed product shape will be clarified by examination of proper rollers using finite element analysis (FEA). An overview of the machine is shown in the **Figure 1**. By using the obtained processing parameters, it will be possible to investigate more effects of processing conditions on the formed products, and to gain knowledge about various twist rolling processes ranging from a few millimeters to several meters, as used in society.

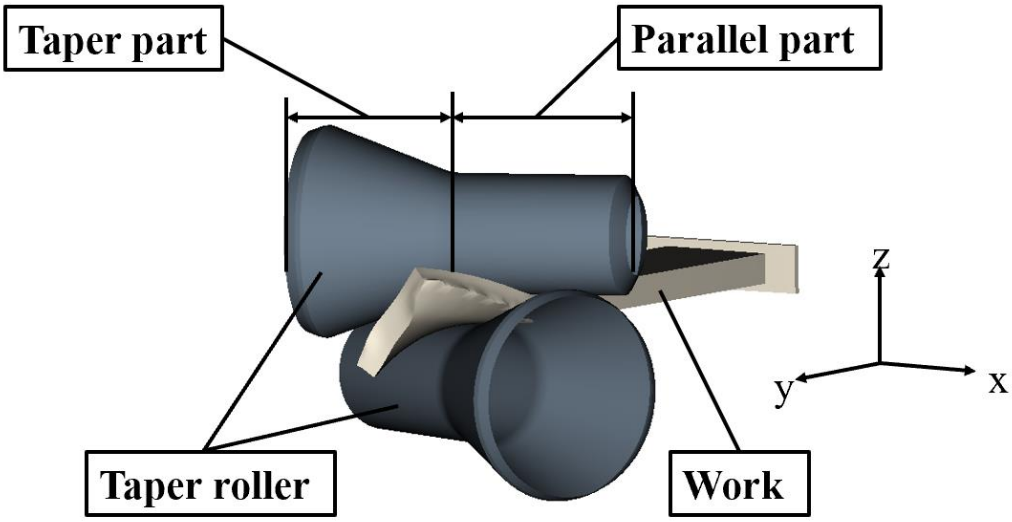


Figure 1: Outline of processing machine

2. MATERIAL AND METHODS

In this study, a pair of taper rollers is used to twist rolling of sheet metal. The appearance is shown in **Figure 2**. The roll has a tapered part and a parallel part. A twisted product is obtained by passing the work piece between taper rollers installed above and below. **Figure 3** shows the definition of the skew angle φ of the roller. The effects of changing these taper angles θ, skew angles φ, and the thickness of the work piece t on the specific twisted angle were investigated. An overview of the analysis is shown in **Figure 4**. Aluminum aloy 1050 sheet was selected as the experimental material since good processing characteristics. A commercial code, ELFEN, was used for the FEA. The analysis conditions are shown in **Table 1**.

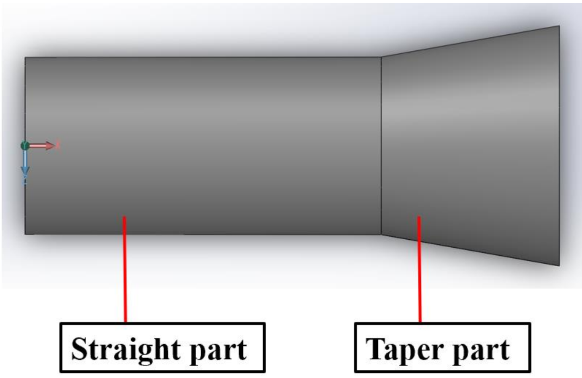


Figure 2: Taper roller

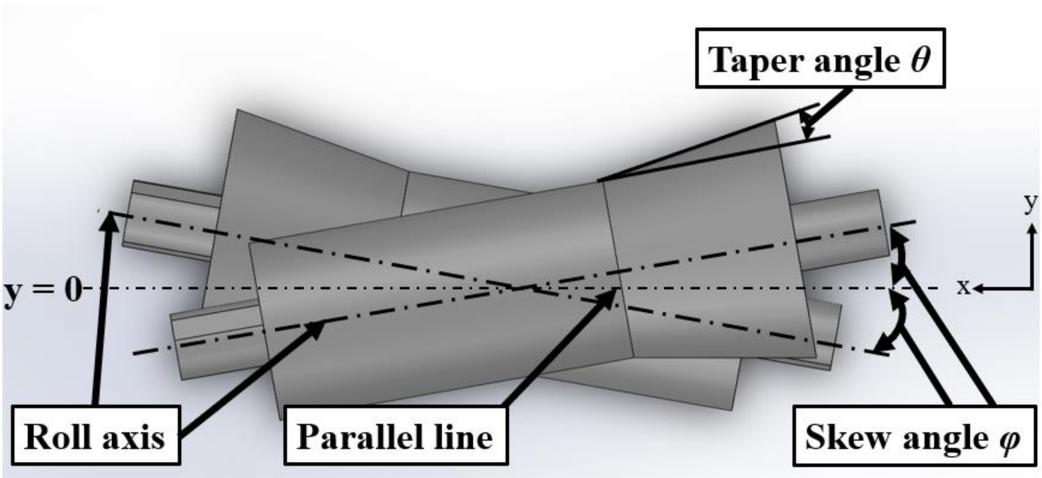


Figure 3: Skew angle of rollers

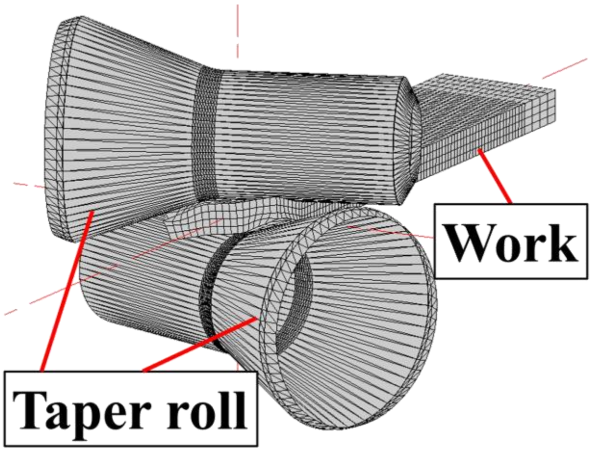


Figure 4: Schematics of analysis

Table 1: Analysis condition

Work material	AA1050
Roll material	Rigid
Work materials thickness t /mm	3, 4, 5
Work materials width b /mm	20
Work materials length l /mm	80
Taper angle θ / °	5, 10, 15, 20, 25
Skew angle φ / °	5, 10, 15, 20, 25

3. RESULT AND DISCUSSION

3.1 Analysis result

In this study, the specific twisted angle was used for evaluation. The specific twisted angle is defined as β. The results of the analysis are shown in **Table 2**.

Table 2: Forming limit of analysis

(○···Success, ×···Failure due to interference)

Conditions	Result				
Taper angle θ / °	5	10	15	20	25
(φ = 20 °, t = 5mm)	○	○	○	○	×
Skew angle φ / °	5	10	15	20	25
(Taper 20 °, t = 5mm)	×	○	○	○	○
Work thickness t / mm	1	2	3	4	5
(θ = 20 °, φ = 20 °)	×	×	○	○	○

3.2 Effect of taper angle on specific twist angle

The effect of the taper angle on the specific twisted angle β for a skew angle φ = 20° and a sheet thickness of t = 5 mm is shown in **Figure 5**. This result suggests that the specific twisted angle of the work piece increased, as the taper angle increased. It is thought that the vertical displacement of the contact point between the workpiece and the roller has increased, as the result of taper angle increased. **Figure 6** shows an image of the formed product when the taper angle θ is 20°.

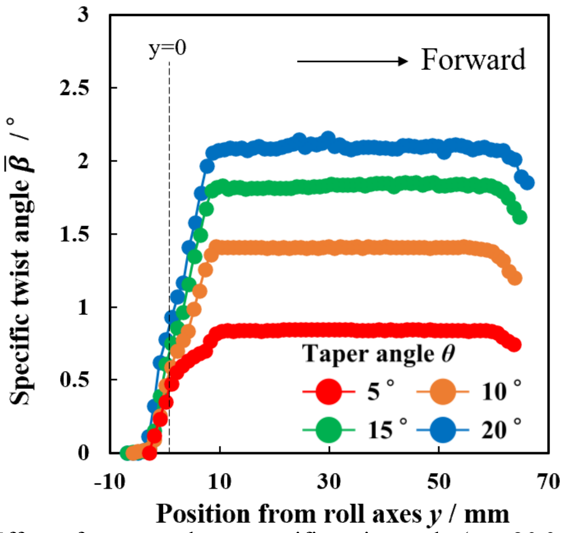
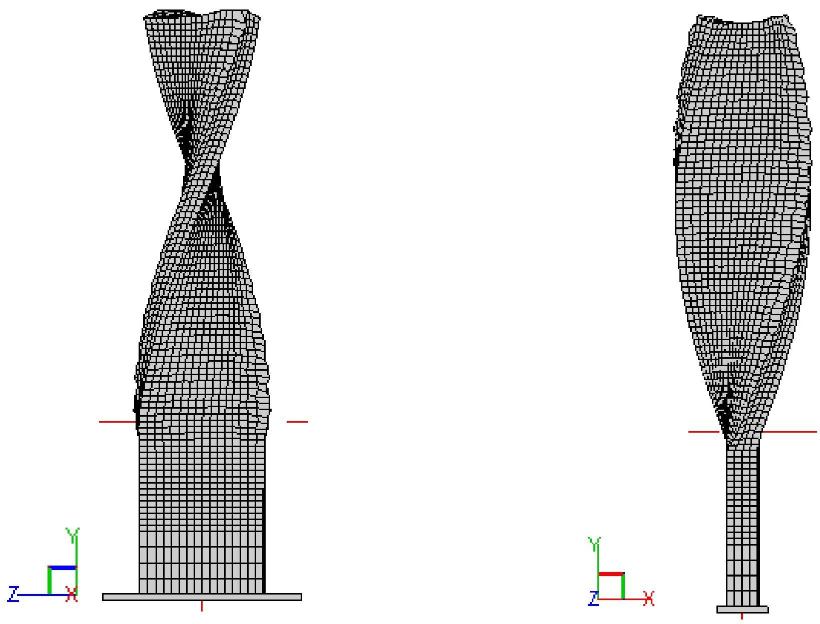


Figure 5: Effect of taper angle on specific twist angle (φ = 20 °, t = 5 mm)



(a) Front view (b) Side view

Figure 6: Work material after processing (Taper angle θ = 20 °)

3.3 Effect of skew angle on specific twist angle

The effect of the skew angle on the specific twisted angle β for a taper angle θ = 20° and a sheet thickness of t = 5 mm is shown in **Figure 7**. This result suggests that the specific twisted angle of the work piece increased, as the skew angle increased. The effect of the skew angle on the contact pressure is shown in **Figure 8**. The parallel part "A" of the roller serves to fix the workpiece vertically and the tapered part "B" serves to twist the workpiece. The distance Δl between the centers of A and B became large, as the skew angle increases from φ = 10° to 20°. As a result of the increase in Δl, the twisted angle increased because the roles of restraining and twisting the sheet worked strongly. From the above, it is considered that the specific twisted angle β increased as the skew angle increased.

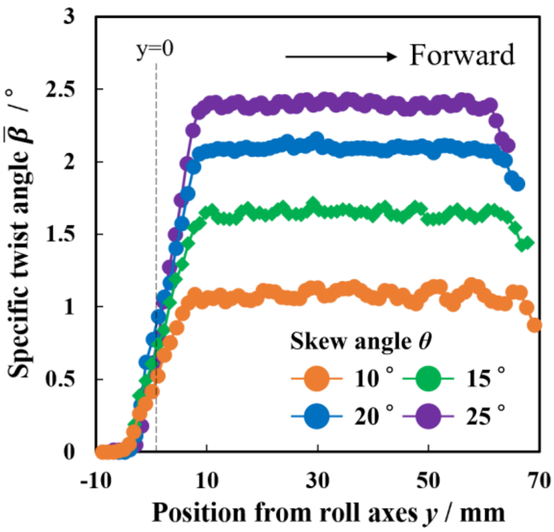
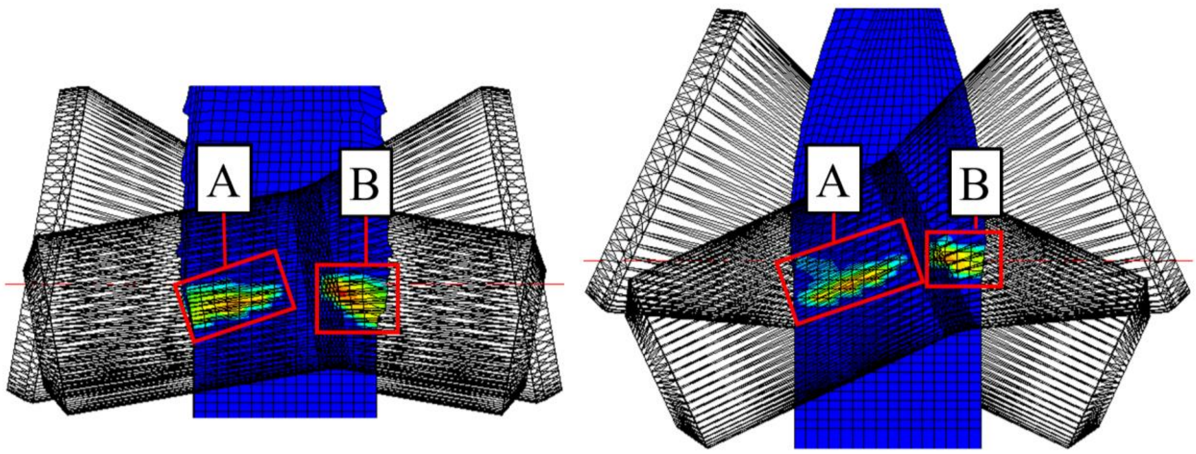
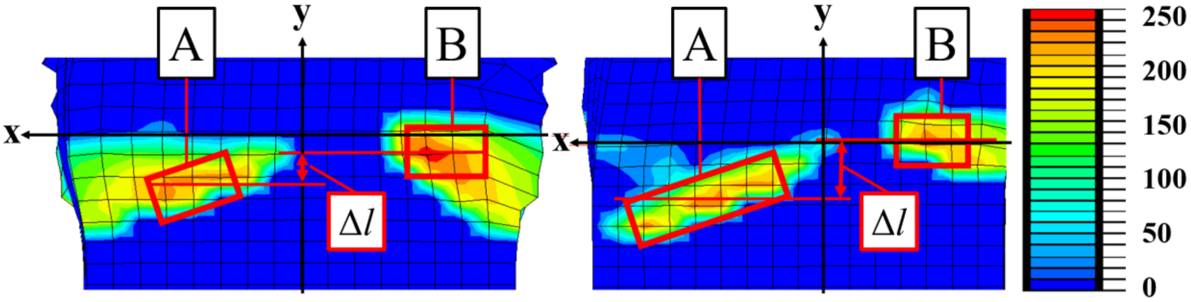


Figure 7: Effect of skew angle on specific twist angle (θ = 20 °, t = 5 mm)



(a) With taper roller (Left: Skew angle φ = 10°, Right: Skew angle φ = 25°)



(b) Without taper roller (Left: Skew angle φ = 10°, Right: Skew angle φ = 25°)

Figure 8: Effect of skew angle on contact area and pressure (P / MPa)

3.4 Relationship between sheet thickness and specific twist angle

The relation between sheet thickness and specific twisted angle β is shown in **Figure 9**. This result suggests that the specific twisted angle of the work piece decreased as the sheet thickness increased. The effect of sheet thickness on the specific twisted angle was very small.

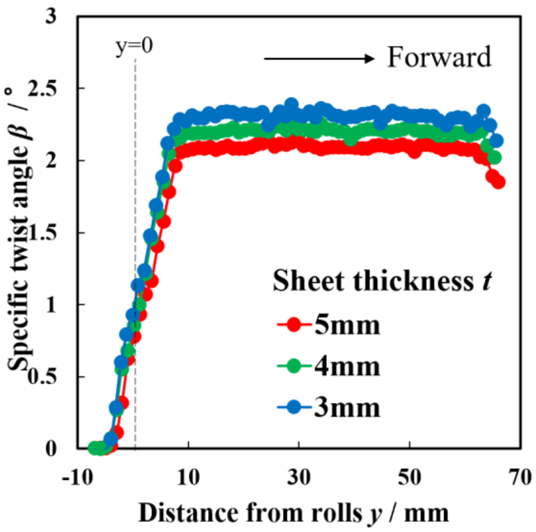


Figure 9: Effect of skew angle on specific twist angle (θ = 20 °, t = 5 mm)

4. CONCLUSIONS

The following conclusions can be drawn from the present research.

- A new processing method called "Twist rolling" was proposed to obtain sheet metal with a continuously twisted shape.
- The specific twisted angle of the work piece was increased, as the taper angle and skew angle of the roller were increased.
- The effect of sheet thickness on the specific twisted angle is small.

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