CONCAVE CIRCULAR SPINNING OF CIRCULAR TUBE USING DISK TOOLS

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ABSTRACT

Spinning is a flexible tube forming method and is a very effective manufacturing technology[1] for the demand of short production runs in a variety of sizes and shapes. However extensive experimental and analytical research has not been carried out. The concave circular spinning experiments of an aluminum circular tube are examined to produce tubes of various shapes. The experiment is carried out by using a CNC prototype spinning machine[2], which has been built by the authors. The spinning accuracy, spinning force, wall thickness, axial direction deformation and asymmetry of the spinning area are experimentally examined for various spinning conditions. The characteristics of the tube spinning are clarified in this report.
Keywords: *metal forming, tube forming, spinning, spinning force, tube thickness*

1. INTRODUCTION

The forming technologies and requirements which are applicable to short production runs in a variety of sizes and shapes have been increasing. Spinning is a very effective manufacturing technology for short production runs in a variety of sizes and shapes, because it is applicable to a wide range of product dimensions (diameter and thickness) and can be used to form almost all metals except brittle metals. On the other hand, the tube has a high flexural rigidity and torsional rigidity as compared with its weight, therefore the tube consumption is increasing for many products and the weight of industrial parts is being reduced.

Then, the authors have made a prototype CNC spinning machine to form tubes of various shapes. In this report, the concave circular spinning of aluminum circular tubes is carried out using disk tools. The effects of the spinning conditions are experimentally examined for the spinning accuracy, spinning force, wall thickness, axial direction deformation and asymmetry of the spinning area, and the characteristics of the tube spinning are clarified.

2. EXPERIMENTAL METHOD

2.1 Experimental condition

The aluminum(A1100) circular tube is used in the experiment. The diameter D_1 is 50.0mm and the thickness t_0 is 1.0mm as shown in Fig.1. The mechanical properties of tube are as follows; ultimate tensile strength is σ_0 = 135MPa and the elongation is δ =3.3% and tube is not heat treated.

Fig.1 shows the formed tube shape and spinning rollers. The roller's diameter is 90mm, it is disk shaped and the radius of the edge is r_1=5.0mm. The disks are made of S45C(Japanese Industrial Standard). The rollers can rotate in the arrow direction as shown in Fig.1 when they touch the tube and the tube is spun. In this report, the radius of the spinning circle is called groove radius R, and the radii are R= 10,20,30mm. The tube is contracted 0.5mm by each roller for one spinning process. The feeds are set on 9 patterns from 5mm to 45mm at every 5mm. The tube is rotated at 270rpm and the feed pitch is 1.0mm.

2.2 Spinning machine

Fig.2 shows a prototype CNC spinning machine which has been built by the authors. One end of tube⑩ is fixed by a chuck, and the other end is fitted in a support-rod⑬ which is threaded into a supported stand⑪ and is free in the axial direction. The roller's pushing force (spinning force) is measured by a Load-cell⑨.

The process of the spinning experiment is shown as follows. The rollers are set in the original position. The original position is where the rollers touch the tube. The spinning sizes (groove radius R, minimum diameter of spinning part D_2 and original position etc) are input to a micro-computer. The rollers are moved to the original position setting by AC servo motors①⑥⑦. The tube is rotated by an AC servo motor②. The rollers push the tube 0.5mm per locus, and move the groove radius, setting R, by AC servo motors. When one stroke finishes, the rollers turn back to starting position. The rollers push a tube 0.5mm again and move to the same groove radius. Repeating those processes, a tube is formed to setting feed. When the spinning finishes, the rollers move to the original position and stop. After that, the tube's rotation is stopped.

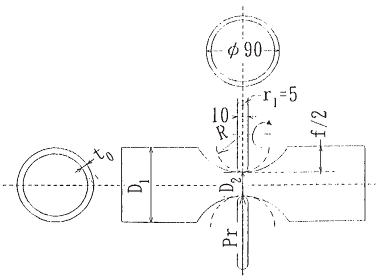
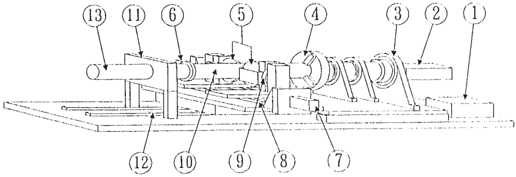


Fig.1 Forming shape and spinning rollers



① AC servomoter (For movement of roller stand)
② AC servomoter (For rotation of tube)
③ Decelerator
④ Chuck
⑤ Rollers
⑥⑦ AC servomoter (For movement of rollers)
⑧ LM guide
⑨ Load cell
⑩ Tube
⑪ Support stand
⑫ LM guide
⑬ Support rod

Fig.2 Prototype CNC spinning machine

3.EXPERIMENTAL RESULT

3.1 Effects of spinning accuracy

Fig.3 shows the relationship between the setting feed f and the actual feed $\Delta D=D_1-D_2$ (D_2 is minimum diameter of spinning area) as a function of groove radii R. The actual feeds do not depend on groove radii R or setting feeds f and the actual feeds are agree with setting feeds f. When the feed is 5.0mm, the difference between the setting feed and actual feed is caused by the tube's elastic recovery. When the feed is 45mm, the difference between them is caused by the tube thickness increment.

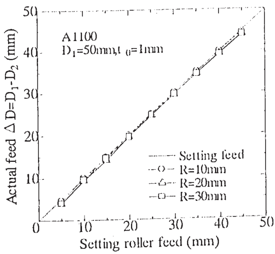


Fig.3 Setting feed and actual feed

3.2 Effects for spinning force

The relationship between the spinning time and roller spinning force Pr, is shown in Fig.4 at 15 passes of the rollers on the groove radius R= 20mm. As the rollers approach the chuck at the end of the spinning pass, the roller spinning force increases. Because, the rollers form the non-spinning area.

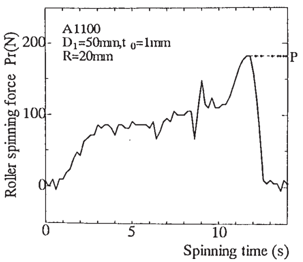


Fig.4 Spinning time and roller spinning force

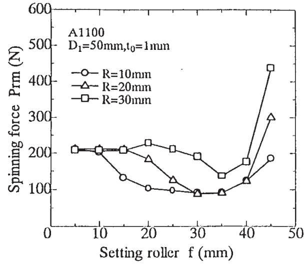


Fig. 5 Setting feed and spinning force

The relationship between the setting feed f and the maximum spinning force Prm (Prm is maximum roller spinning force on each setting feed shown in Fig.4) is shown in Fig.5 as a function of the groove radius R. As the groove radius R increases, the maximum spinning force Prm increases. The reason for this is as follows; as the groove radius R increases, spinning area increases. And the contact area between roller and tube increases. After setting feed f becomes more than 35mm, the spinning force Pr increases by reason of tube's thickness increment.

3.3 Effects of tube thickness

The relationship between the distance from center (a minus sign(-) means chuck side and a plus sign(+)means free side) and thickness strain distribution is shown in Fig.6 as a function of the roller setting feeds f at the groove radii are R=10,30mm. The tube is formed symmetrically with respect to the center at the groove radius R=10mm, but the axial length is stretched at the groove radius R=30mm. As the groove radius R becomes larger, the tube thickness of the chuck side increases.

The relationship between the setting feed and the thickness strain at center of spinning area is shown in Fig.7 as a function of the groove radius R. From the figure, as the groove radius R becomes smaller, the tube thickness becomes thinner. Because the spinning deformation mechanism elongates the stretch forming and the ratio of the stretch deformation becomes larger with decreasing groove radius. After the setting roller feeds f becomes more than 30mm, the tube thickness increases. This is because the deformation in the center of the spinning area becomes a plane strain state, by reason that the axial direction deformation becomes smaller and the rollers contact with the tube at only the center of the spinning area.

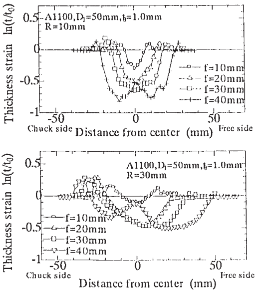


Fig.6 Thickness strain distribution

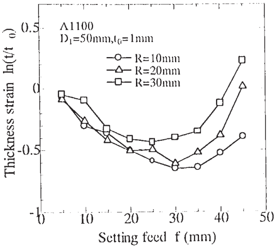


Fig.7 Setting feed and thickness strain at center of spinning position

3.4 Effects of axial deformation

The relationship between the setting feed and the axial deformation ΔL is shown in Fig.8 as a function of the groove radius R. As the groove radius R increases, axial deformation ΔL increase. As the groove radius R becomes larger, spinning area increases. The deformation ΔL, has a constant value at the groove radius R=10mm, except at the beginning of the spinning. After the setting feed f becomes more than 20mm, the rollers move only in the concave area, therefore axial restraint force works on the tube on both right and left side of the spinning area.

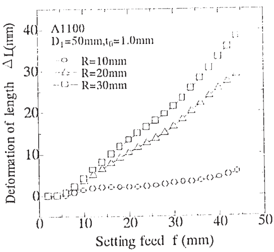


Fig.8 Setting feed and deformation of axial length

3-5 Asymmetry of spinning area

On this spinning, the tube become longer by reason that the tube end is free in the axial direction as stated in the former section. The asymmetry of the spinning area is examined in this section. The length of chord, which we will call Lr, when the tube shape is formed in the same as the locus of rollers. The length of chuck side from center of the spinning area will be called La and the length on the free side is designated L_b (shown in Fig.9).

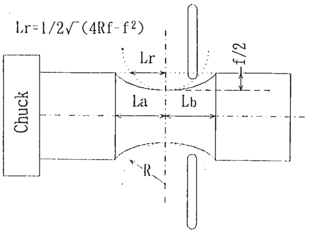


Fig.9 Asymmetry of spinning area

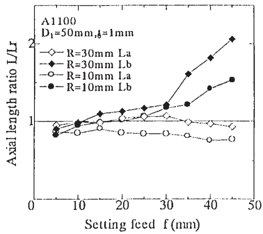


Fig.10 Setting feed and axial length ratio

The relationship between the setting feed and the length ratio L/Lr is shown in Fig.10 as a function of the groove radii R and La, Lb. As compared with Lb, La has constant deformation value in spite of the setting feed f increment. Because the La side is restrained in the axial direction, but the Lb side is free. The deformation of the La side is small and the spinning shape is equal to roller spinning locus at the groove radius R=30mm. But, when the groove radius becomes shorter and the feed increases, the axial compression force acts in the tube at the La side. Nevertheless, the Lb of the groove radius R=30mm is longer that of R=10mm. Because, as the groove radius R becomes longer, the spinning area increases.

4. CONCLUSION

The concave circular spinning experiments of circular tube ware carried out by the authors using a CNC prototype spinning machine. The characteristics of the tube spinning were clarified and the results are indicated as follows;

1)The tube's actual feeds agreed with the setting feeds, in spite of the groove radii R or the dimension of setting roller feeds f.

2)The spinning forces increased, as the groove radii R became larger.

3)The tube thickness becames thinner under the setting feed f=30mm, as the setting feed increased.

4)The tube thickness at the center of spinning area became thinner, as the groove radius R became smaller.

5)The deformation of the axial direction became larger, as the groove radius R increased.

6)La (chuck side) is closer to the setting value than Lb (free side).

References

[1] Japan society for technology of plasticity: spinning technology, nikkannkougyousinnbunnsya

[2] M.Murata,K.Kamimura,R.Muta: The Proceedings of the 48th Japanese Joint Conference for the Technology of Plasticity, 1997.11, 451