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Forming of Aluminum Helical Gear by Twist Extrusion Processing

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The extrusion has the advantage that the product of complex shape can be manufactured at a low price without passing two or more processes. However, the cross-sectional shape is always constant in the processing principle in an existing extrusion technique. Therefore, it has been thought that it is difficult to form the products with the twist by the extrusion. However, a lot of researches on new extrusion processing to be accompanied with torsion molding are done in recent years [1-3].
In this paper, the forming of the aluminum helical gear by the twist extrusion processing was tried. A6063 was used as an aluminum alloy and cold extrusion was performed. We changed the shape of billet and the molding department length of die and experimented. Prescribed torsion angle and pressure angle are given to the die used. Therefore, torsion angle and pressure angle were measured as a formability assessment of extrusion molding.

Keywords: *twist extrusion, helical gear, formability assessment.*

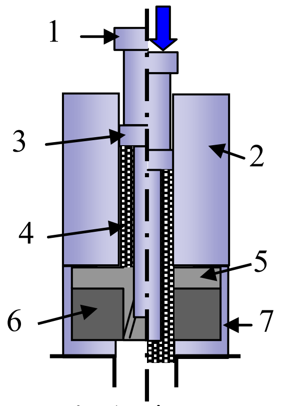
1. Introduction

Recently, the demand for the product to which the twist processing including the helical gear used for the decelerator of car and the office automation apparatus such as copiers and printers is applied has risen. Most of these products are produced with a highly accurate cutting, the precision forging and the secondary fabrication. However, these processing methods have the disadvantage such as bad machining efficiency and high cost. On the other hand, the extrusion has the advantage that the product of complex shape can be manufactured at a low price without passing two or more processes. However, the cross-sectional shape is always constant in the processing principle in an existing extrusion technique. Therefore, it has been thought that it is difficult to form the products with the twist by the extrusion.

In this paper, the forming of the aluminum helical gear by the twist extrusion processing was tried. To impart the twist to the extruded material, the prescribed angle of twist is given to the die used. In this study, the shape of billet and the molding department length of die were changed. And, the formability of the gear in those conditions was investigated.

2. Experimental Methodology

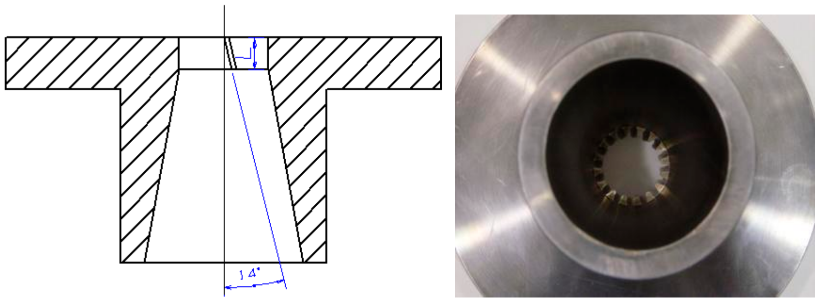
In this experiment, the billet which machined the round bar of the aluminum alloy A6063 into outer diameter 27.8×180mm (solid billet) and outer diameter 27.8× inside diameter 14.5×180mm (hollow billet) as an experiment sample is used. In addition, in order to investigate influence with a billet size, the division billet whose height is 20mm and 30mm was prepared, and the division billet is extruded in piles. **Fig.1** shows the diagrammatic illustration of the experiment tool produced with hot-working tool steels SKD61 (hollow billet).



No.	Tool name
1	Punch
2	Container
3	Dummy block (Mandrel)
4	Billet
5	Die
6	Backer
7	Die holder

Fig.1 Diagrammatic illustration of the experiment tool

Fig.2 shows the details of die and die appearance. The pitch cylinder torsion angle β is 14°, the normal pressure angle α is 20°, and number of grooves n is 16 (The addendum circle torsion angle β_k is 15.42°, and the transverse pressure angle α_s is 20.56°.) . Molding department length L is the one of 5mm and the one of 10mm. It experimented by the extrusion conditions shown in **Table 1** using the 400ton vertical hydraulic press.



Molding department length L [mm]	5,10
Groove torsion angle $\beta(\beta_k)$ [deg.]	14(15.42)
Pressure angle $\alpha(\alpha_s)$ [deg.]	20(20.56)
Number of grooves n	16

Fig.2 Details of die and die appearance

Table 1 Extrusion conditions

Billet	Material		A 6063
	Dimensions	Sollid	D27.8×180mm
		Hollow	D27.8×d14.5×180mm
			D27.8×d14.5×20mm×9 piece
			D27.8×d14.5×30mm×6 piece
Extrusion ratio			1.29(Sllid), 1.40(Hollow)
Ram speed [mm/s]			0.5
Extrusion temperature			R.T.
Friction condition			Lubricant (Graphite)

Fig.3 shows the outline of the method of measuring the torsion angle. In the measurement of the torsion angle, the angle between the parallel lines of extrusion molding A and the approximation line of addendum B is measured. **Fig.4** shows the measurement position of torsion angle. In non-division billet, the measurement starting point is taken in position of 5mm from a top as a measurement position, and takes the measurement position every 10mm from the starting point. Moreover, in

division billet, position of 5mm from a top and bottom and the central part of the billet are taken as a measurement position for every division billet.

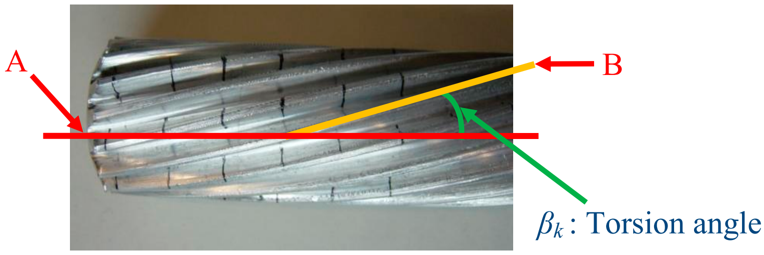


Fig.3 Outline of the method of measuring the torsion angle

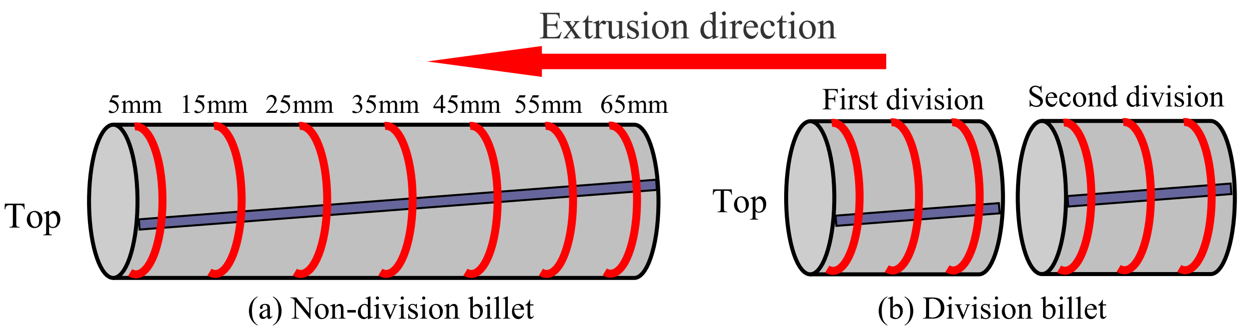


Fig.4 Measurement position of torsion angle

Fig.5 shows observation side and measurement point of pressure angle. There are A-side (the side where aluminum is molded along tooth grooves of a die) and B-side (the side where aluminum is molded turn around tooth grooves of a die) as a observation side. It takes the measurement point every 90° based on arbitrary teeth. In non-division billet, the measurement starting point is taken in position of 5mm from a top as a measurement position, and takes the measurement position every 20mm from the starting point. Moreover, in division billet, it is the same as the measurement position of a torsion angle.

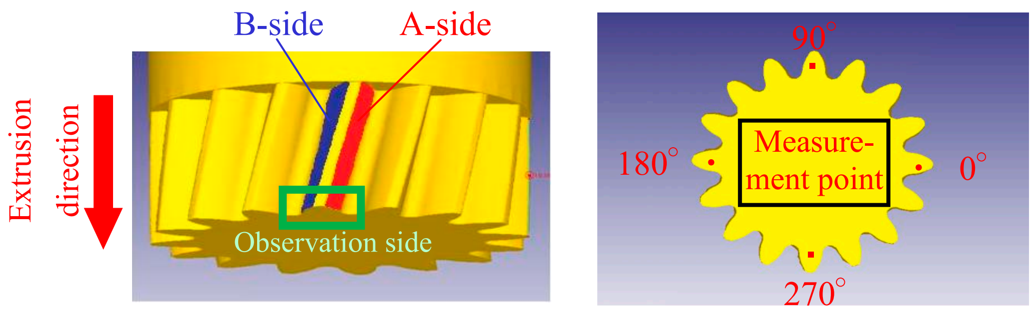


Fig.5 Observation side and measurement point of pressure angle

3. Experimental Result and Consideration

3.1 Influence of billet shape

In this section, the non-division billet is extruded by using die of L=10mm as extrusion conditions. **Fig.6** shows influence of billet shape on molding torsion angle. From Fig.6, the difference between solid billet extrusion and hollow billet extrusion to molding the twist angle is hardly seen. From this, hollow billet extrusion which can perform control of a bend of extrusion molding by mandrel and the abbreviation of punching is examined.

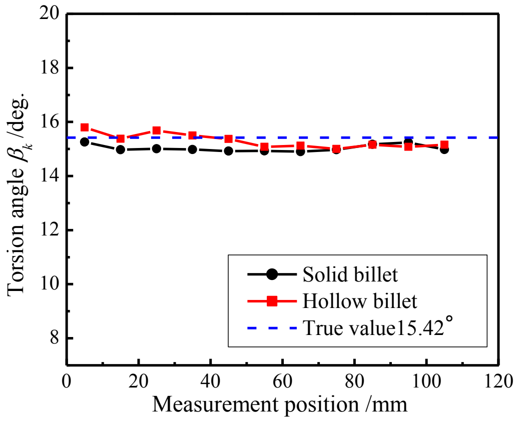
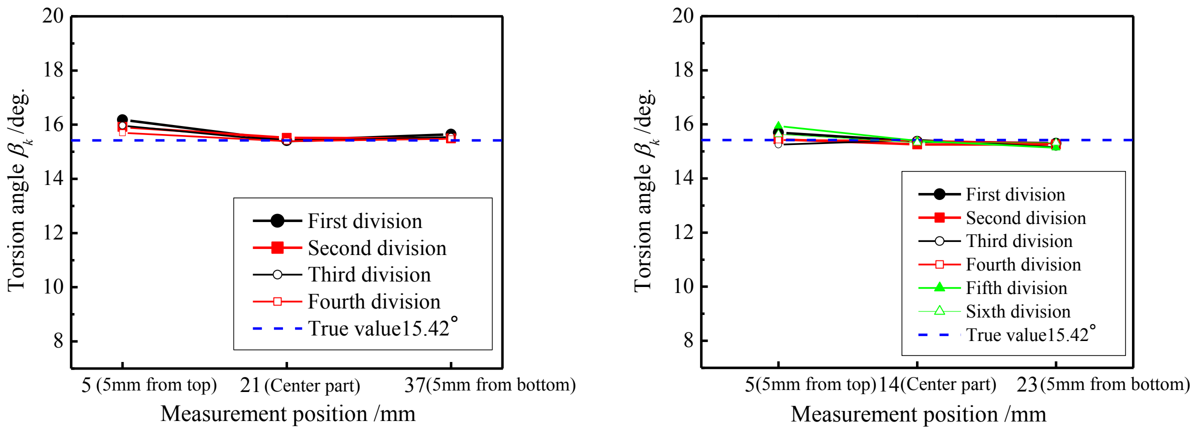


Fig.6 Influence of billet shape on molding torsion angle

3.2 Influence of Billet Size

In this section, the hollow billet is extruded by using die of *L*=10mm as extrusion conditions. **Fig.7** shows influence of billet size on molding torsion angle. From Fig.7, in center part and 5mm from bottom, it can be confirmed to take a value close to true value. However, the error margin occurs in 5mm from top. As the cause which such an error generates, **Fig.8** shows the photograph of the shape after extrusion. From Fig.8, it turns out that near the perimeter of extrusion molding extruded first remained in the bottom according to the flow velocity difference, and has overlapped with the top of extrusion molding extruded next. Moreover, the crack occurs remarkably in the division part. It is thought that the error margin by such the one influences molding the torsion angle with 5mm from top.

Fig.9-11 shows the pressure angle error when non-division billet, 30mm-division billet and 20mm-division billet are extruded. From these figures, it can check that a pressure angle error is comparatively small by B-side. However, in 20mm-division and 30mm-division, it turns out in A-side that the big error has occurred by 5mm from top or bottom which is the division part of a billet. Then, the pressure angle error of the center part of the division billet in A-side is shown in **Fig.12**. From Fig.9 and Fig.12, in the division billet center part, it can check that a pressure angle error becomes small. Moreover, the difference by 20mm division and 30mm division is hardly seen.



(a) 30mm-division (b) 20mm-division

Fig.7 Influence of billet size on molding torsion angle (hollow billet)

Fig.8 The photograph of the shape after extrusion (30mm-division billet)

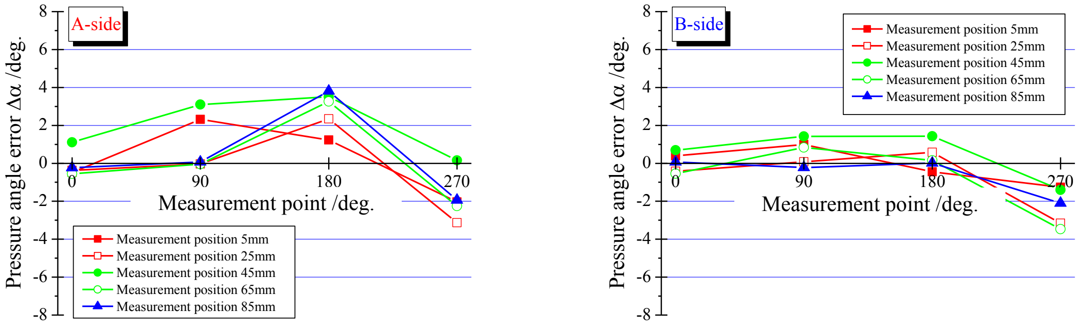


Fig.9 Pressure angle error when non-division billet is extruded (hollow billet)

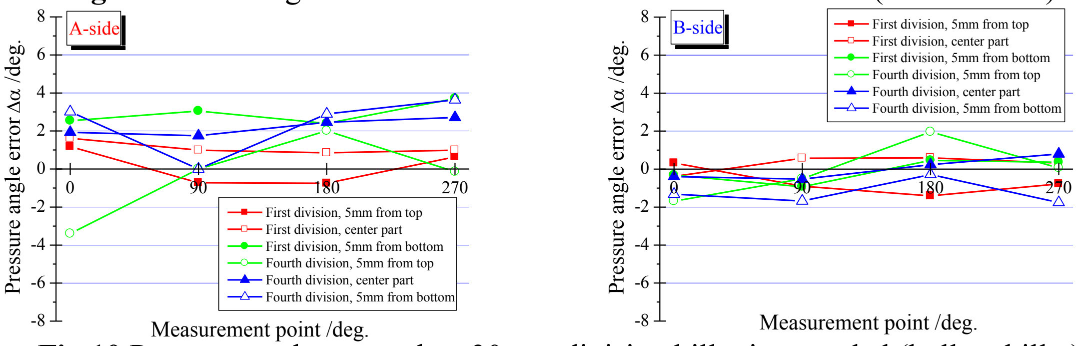


Fig.10 Pressure angle error when 30mm-division billet is extruded (hollow billet)

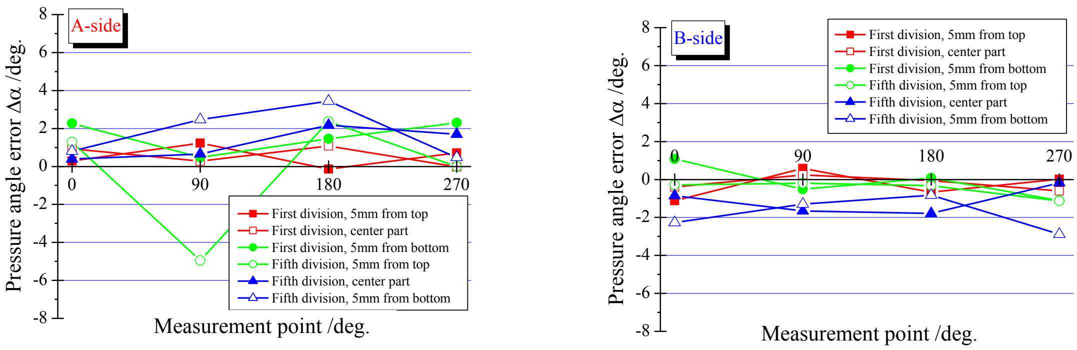
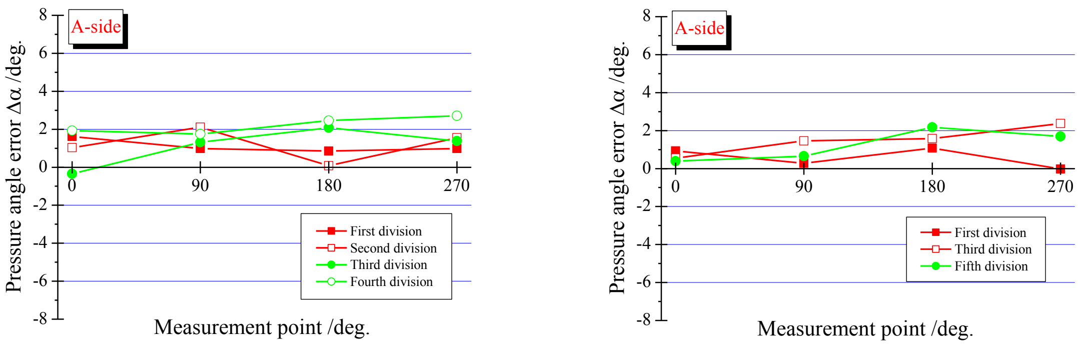


Fig.11 Pressure angle error when 20mm-division billet is extruded (hollow billet)



(a) 30mm-division (b) 20mm-division

Fig.12 Pressure angle error when division billet is extruded (hollow billet, only center part)

3.3 Influence of Molding Department Length

In this section, the hollow and non-division billet is extruded as extrusion conditions.**Fig.13** shows influence of molding department length on molding torsion angle. From Fig.13, the difference between *L*=5mm and *L*=10mm to molding the twist angle is hardly seen.

Fig.14 shows pressure angle error when die of *L*=5mm is used. The thing that pressure angle error has become small can be confirmed by comparing Fig.14 with Fig.8. Especially, it is thought that the tendency is remarkable in A-side. As a cause to which such a tendency appears, at die of *L*=5mm, since the surface area of the molding department decreased and contact friction decreased, it is thought by A-side which is easy to be influenced by contact friction that pressure angle error would become small.

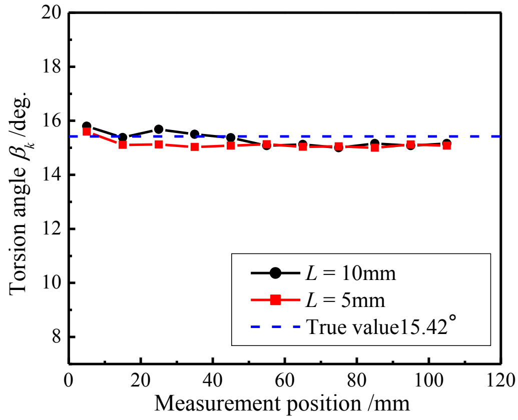


Fig.13 Influence of molding department length on molding torsion angle (hollow billet)

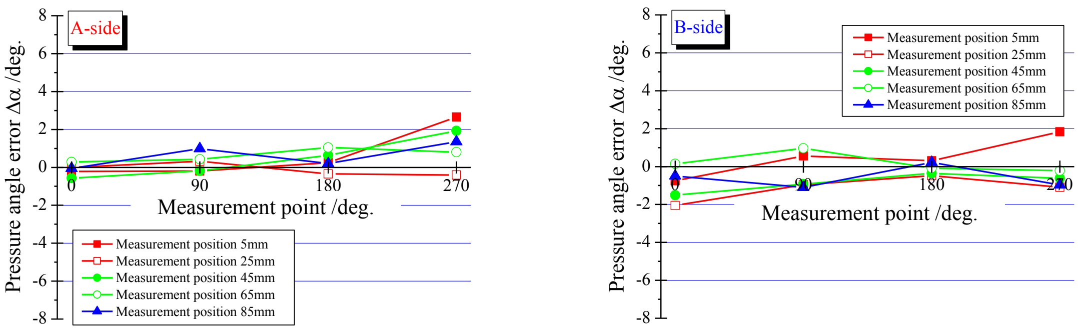


Fig.14 Pressure angle error when die of *L*=5mm is used (hollow billet)

4. Conclusion

1) By applying billet division, the torsion angle and pressure angle near a true value was acquired in the billet central part.
2) The crack appeared remarkably by dividing the billet compared with the case of non-division.
3) When molding department length was adjusted from 10mm to 5mm, a result near the ideal value was obtained for the pressure angle.

References

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