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Deformation by V-bending of Thick Plate Metal 5083

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This study has been performed to investigate mechanism in V-bending process in thick plate metal. Purpose of this research is to find out difference of mechanism between thick and thin plate metals. As usual V bending process like bottoming and coining uses V type die. In these cases, plate will pressed up between punch and die, so it will bear many complicated effects. Accordingly, this search used U type die to confirm fundamental effects of bent plate. For that, this research conducts a series of experiments in V-bending process by changing die-open width. As a result, it is quantitatively clarified that the die width has some amount of effect on the unique phenomena in thick-plate bending such as saddle type deformation, reduction of bending curvature from the punch radius, and the deduction discrepancy from theoretical value.

Keywords: *thick plate, V-bending, deduction, camber, A5083.*

1. Introduction

Bending is a fundamental and common process, which has been applied in industry for hundreds of years. There are many research works [1-5] on bending process for thin plate metal with thickness of 3mm or less, which is used as components for various products. On the other hand, bending process for thick plate metal has also been applied according to the diversity of market needs, only for special usage. Therefore, only a few research works have been presented and the expertise is still limited. Ogawa shows some examination results of thick-plate-metal bending up to 6mm thickness. In the present research, experimental examination is carried out with emphasis on the effect of the die width on the bending behavior of thick plate metal with 10mm thickness: deformation in the width direction, spring-back and deduction of total length. As a result, it is quantitatively clarified that the die width has some amount of effect on the unique phenomena in thick-plate bending such as saddle type deformation, reduction of bending curvature from the punch radius, and the deduction discrepancy from theoretical value.

2. Experiment instruments and plate

Fig. 1 shows composition of die, punch and plate (thick plate) at bending process. The plate is hot-rolled 5083 aluminum alloy, and it is not subjected to heat treatments. Rolling direction and die-open width direction are set same. Mechanical properties of thick plate are the following. Tensile strength and total elongation are σ_B=315MPA, ϕ=27.4% at rolling direction and σ_B=334MPA, ϕ=24.7% in the direction vertical to rolling direction. Size of thick plate is following. Thickness is t=10mm, length is a=200mm, width is b=100mm. V type punch with tip radius R_p=10mm and die with R_d=10mm shoulder are used in bending process. Bending angle is 90°as shown in same figure. Punch and die are made by S45C. Hardening processed SKD11 shaft has been inserted in tip of punch and shoulders of die.

Bending process was conducted with 7 kinds of the open width V_d ranges from 40 to 100 mm, so it is 4 to 10 times of thickness t. The number of test pieces for an experiment is one. The position of left end of the plate from the die-open ing L is constantly set as 50 mm as shown in the figure. An universal tensile test machine is used in this the experiment. Two displacement transducers with

±1 μm high precision are used for the measurement of bending angle during and after bending. Plate was bent at room temperature and used petroleum-based lubricating grease. Fig. 2 shows the cross section at A in Fig. 1. Thick plate becomes saddle type shape after bending process as shown in Fig. 2. As the extrados of plate expands and the intrados contracts in longitudinal direction, the former contracts and the latter expands in the ridge direction due to volume constancy. In this paper, examination of the influence on deformation of thick plate and spring-back of changing die-open width V_d was added.

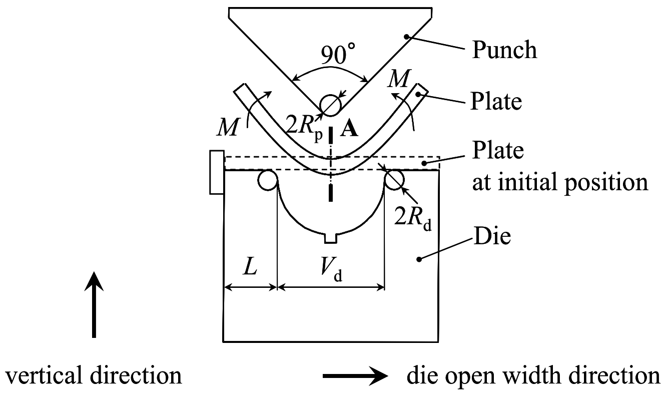

Fig.1 Schematic illustration of die and punch in plate bending

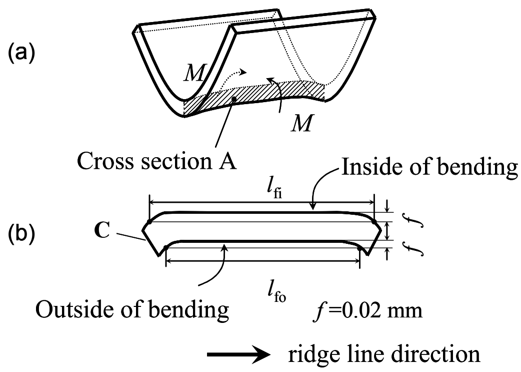

Fig.2 Cross section of bent plate

3. Results of experiment

3.1 Punch load at bending process

Fig. 3 shows photo of plate at the end of bending. Space is produced between punch and thick plate at bending process. It means plate does not deform precisely to the shape of punch as shape of punch. Fig. 4 shows relationship between punch stroke and load as a parameter die-open width V_d. When the punch load P reaches 150 kN, the plate was released from the punch and die. Point S indicates the situation whereby plate edge and punch slope starts to contact. On the other hand, point T indicates the situation whereby the clearance between punch slope and die shoulder c is equal to plate thickness t as shown in Fig. 3. Although punch load monotonously increases up to the maximum point due to work hardening, it slightly decreases before reaching point S. Punch load monotone increases by work hardening, but after that decreases little bit. It is because the vertical component of force at the die shoulder decreases with increase of bending angle, while work hardening is small from a certain punch stroke resulting in a constant moment. This is because of bending moment increases from the beginning of bending process but after some time bending process will done almost without increasing moment. The smaller the die-open width, the larger the Punch load is. From point S to T, the gap g between the punch slope and the plate decreases. After reaching point T, punch load will increase quickly without increase of stroke.

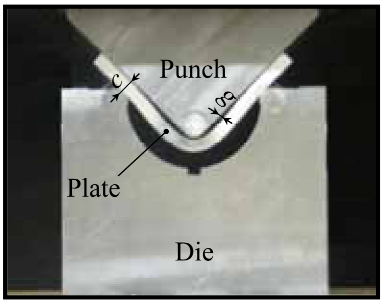

Fig.3 Photograph of bending view

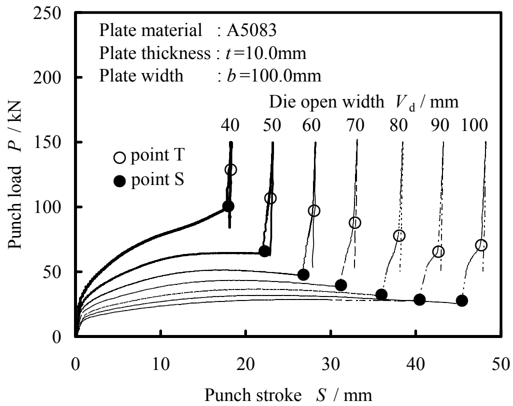

Fig.4 Load change during bending

3.2 Deformation of thick plate metal in bending process

This research examine bending radius, dent, spring-back, flat length, camber, bending deduction. Fig. 5 shows deformation process of thick plate metal in bending process. Thick plate placed on the die and supported by die shoulders is bent by tip of punch like shown in figure (a). The thick plate is indented between die shoulders and the punch when the punch stoke reaches 40kN as shown in Fig. 5(b), after that contacting area of thick plate and punch slope is increased. In a word, space between thick plate and punch slope is decreased then bending process will end. As shown in Fig. 5(c), there is still space between thick plate and punch slope, even after the punch load reaches 150 kN. Although the shape of thick plate fits to the punch slope except at the punch tip at the end of bending process as shown in Fig. 6, the thick plate deforms to the shape of dashed line because of spring-back. Bending radius is almost the same as punch tip radius R_p, because more plastic deformation is produced around tip of punch. However, the other part of the plate comes apart from the punch slope due to elastic recovery.

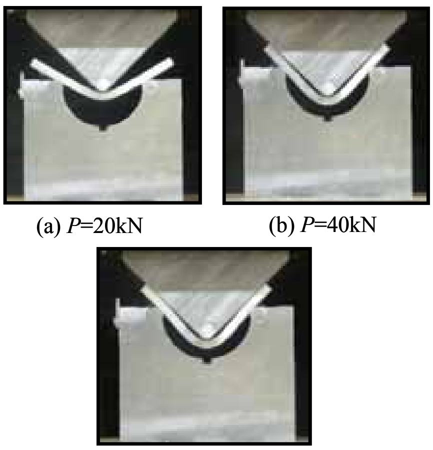
(a) P=20kN (b) P=40kN (c) P=150kN

Fig.5 Process of bending (V_d=100 mm)

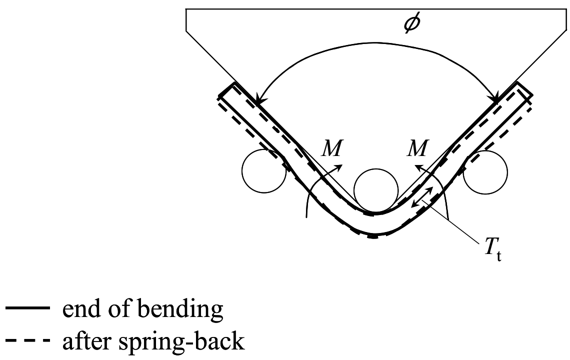

Fig.6 Bending situation at the end of bending (P=150kN)

Fig. 7 shows the effect of die-open width V_d on inside bending radius ρ_i and outside bending radius ρ_o after unloading. At the bending process, inside bending radius ρ_i is smaller than tip radius of punch R_p in the vicinity of punch tip. After unloading and spring-back, inside bending radius ρ_i is still smaller than tip radius of punch R_p in the case die-open width is under than 70mm. This phenomenon is called spring-go [6]. On the other hand, inside bending radius ρ_i is bigger than tip radius of punch R_p when die-open width V_d is bigger than 70mm. It is because spring-back increases with increase of V_d as the area of elastic and plastic deformation expands. Outside bending radius ρ_o is around 25mm. Fig. 8 shows relationship between dent of plate Δd_0 and die-open width V_d. Dent of plate Δd_0 is proportional to die-open width V_d. It is because deformation area of thick plate increases when die-open width V_d gets longer.

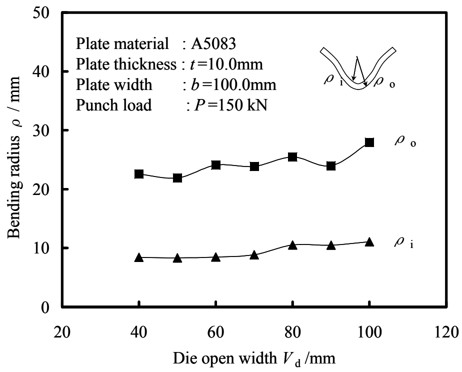

Fig.7 Relationship between die open width and bending radius of plate

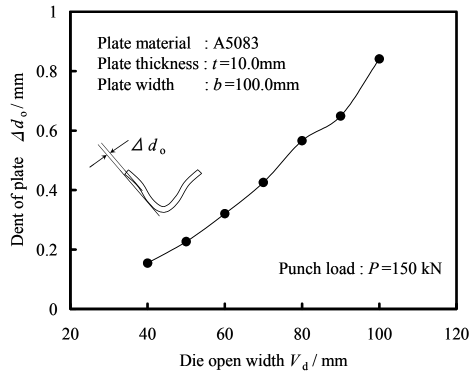

Fig.8 Relationship between die open width and dent of plate

4. Results and examination

Spring-back ϕ_b is defined as the difference between the flange-angle ϕ and the punch angle 90° as follows:

$$\phi - 90^\circ = \phi_b \tag{1}$$

Fig. 9 shows effect of die-open width on spring-back. Spring-back increases when die-open width increases. The increasing tendency is similar to that of inside-bending radius ρ_i in Fig. 7. Further examination was conducted on the plate deformation along the ridge line of bending. Although the similar deformation along the ridge line might occur in thin-sheet bending, the amount of deformation is relatively small compared to the width of the sheet, and it might be able to be ignored. In the case of thick plate bending, the deformation along the ridge line cannot be ignored and the plate significantly deforms as shown in Fig. 2. In order to evaluate the deformation, flat length on the bending inside l_{fi} and outside l_{f0}.are defined as shown in Fig. 2. Here the flat part is the area where the warpage is less than 0.02mm. The shape of the ridge was measured at the interval of 0.02mm using displacement transducer with high precision of 1 μ m. Fig. 10 shows the effect of die-open width on flat length along in the ridge line direction. Flat lengths in both inside and outside parts are constant regardless of die-open width because all plates are bent in the same shape. Inside flat part is longer than outside part because inside part of plate will be pressed by tip of punch and straightened.

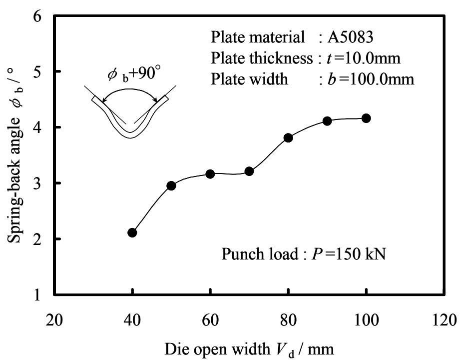

Fig.9 Relationship between die open width and spring-back angle

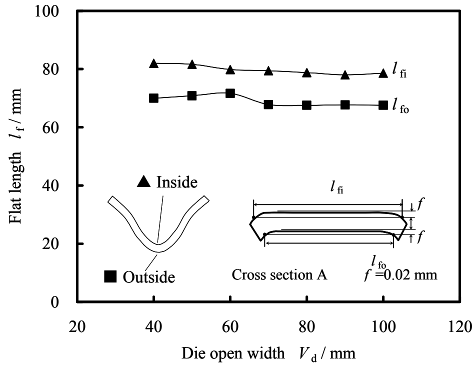

Fig.10 Relationship between die open width and flat length of plate

Inside the plate contracts in the longitudinal direction and outside expands because of bending moment M. However, in the ridge-line direction, inside part of the plate expands in the ridge-line direction and outside part contracts as shown in Fig. 2 due to volume constancy. In this bending process, inside the camber will be around 10mm, outside the camber will be 15mm. Fig. 11 shows the effect of die-open width on camber height h_s. Inside the camber of plate monotonously increases when die-open width increases, but outside the camber is not affected by die-open width because inside the plate is pressed by tip of punch and straightened. Decision of length of flange part is industrially important in bending process. For the evaluation of flange length, deduction δ is introduced as following equation:

$$\delta = l_{11} + l_{12} - l_0 \tag{2}$$

Where l_{11}、l_{12} is shown as this Fig. 12, Fig. 12 shows relationship between die-open width and deduction. Short dashed line shows value calculated by formula for thin plate. In case of thick plate deduction, this formula is useless because it is given for thin plate. Deduction δ increases when die-open width increases. Because the tensile force T_t shown in Fig. 6 expands the thick plate. The expansion of the plate increases when die-open width increases.

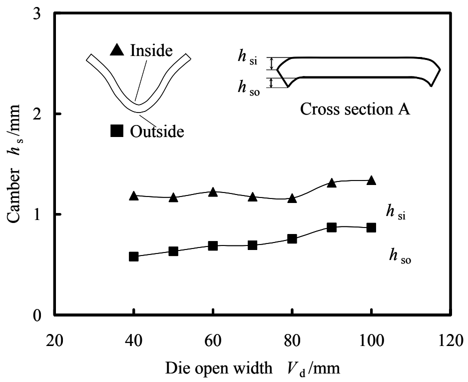

Fig.11 Relationship between die open width and camber

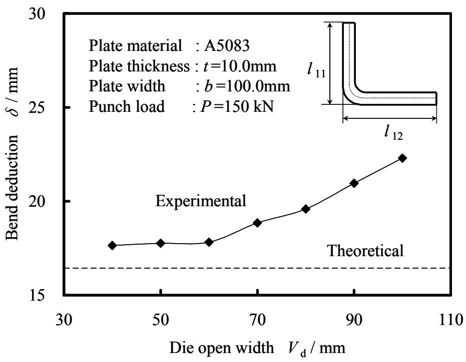

Fig.12 Relationship between die open width and bend deduction

5. Summary

Thick plate was bent with 7 kinds of dies from V_d=40mm(4t) to 100mm(10t) open width and used aluminum alloy thick plate (10mm). And result of the examination summary is following.

1. In case of die-open width from 40mm to 70mm, phenomenon spring-go is produced and in other cases phenomenon spring-back is produced.
2. Dent of plate increases proportionally to die-open width V_d.
3. The value of spring-back increases when die-open width increases. Maximum value was 4°.
4. Flat length in ridge line direction is not affected by die-open width at both sides of plate.
5. The value of camber increases proportionally to die-open width V_d outside the plate, and maximum value reached to 7% of thickness of the plate. On the other hand, inside the plate is pressed by tip of punch and straightened and is not affected by die-open width.
6. Bending deduction increases when die-open width increases.

References

[1] H.Moritoki: Transactions of the Japan Society of Mechanical Engineers 38-314.(1972)2514－2524.
[2] H.Kazama, K.Yagyu and Y.Nagai: Journal of JSTP. 45-516(2004)269－276.
[3] H.Ogawa, K.Tamura and T.Nakagawa: Journal of JSTP. 25-278(1984)238－244.
[4] T.Yamura: Journal of JSTP. 22-248(1981)968－974.
[5] H.Ogawa: Journal of JSTP. 43-493(2002)145－149.
[6] T.Maeda: Journal of JSTP. (1972)329－330