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Research on Influence of Forming Conditions on Springback in V-bending Process of Aluminum Sheet Alloys

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It is important to reduce the weight of cars to protect the earth's environment. In order to achieve it, materials such as aluminum alloys and high tensile steels are applied. If these materials are formed by press machines in room temperature, large springback is observed in the formed parts comparing with conventional steels. In order to overcome this problem, if the amount of springback is reduced drastically, it is a very useful forming technique. The technique can reduce the development period of dies for forming sheet metal parts. Three forming processes have been investigated for reducing springback after V-shape bending. The results are as follows. 1) Forming in thickness direction at bent portion of specimen : The springback angle after forming was reduced with increasing forming in thickness direction. Numerical simulation was also performed for investigating the mechanism. 2) Two-time forming : The specimens were formed two times with same conditions. This process also can reduce springback. 3) Holding die in certain period at the lower dead point : It did not affect to springback. It can be said that some investigated forming conditions can reduce springback greatly.

Keywords: *V-bending, springback, FEM simulation, bottoming*

1. Introduction

Recently, the application of the aluminum alloys and the high tensile steels to the automotive body parts is very useful for lightening automobiles [1]. As a result, the decrease of the global environment load can be expected. However, the springback of those materials after the forming process with press is larger than that of the ordinary steel sheets. Therefore, a large cost and the man-power are required to develop the dies in the production preparation stage of the automobiles. Therefore, the decrease technologies of the springback are strongly demanded. The predicting technologies using FEM simulation which can apply to the development of the dies for sheet metal forming parts and reducing springback in V-bending process were investigated [2-5]. The influence of the bottoming of dies which reduces the thickness of the sheet metal and the two-time forming to springback has not investigated enough. In this research, V-bending process was applied. Because it is one of the main process which causes springback. Some forming processes such as forming in thickness direction at bent portion of specimen, two-time forming are investigated. Numerical simulation was applied for investigating mechanism regarding springback.

2. Experimental apparatus

A hydraulic V-bending apparatus (100kN) was developed for this experiment as shown Fig.1. SKD11 (alloy tool steel) was used for the material of the dies. The hardness of the dies was HRC60-61. Fig.2 shows the dimensions of the dies. The distance blocks were used for controlling of the lower dead point position of the upper punch by inserting them between dies. The range of the height of the distance blocks was from 15.75 to 16.00mm with 0.05mm intervals. In order to observe the movement of the dies around the lower dead point, the inductive displacement sensors with 4μm

resolution (EX-210/422 : Keyence Co.) were attached to the dies. Three sensors were installed in both sides (total six sensors) of the dies as shown in Fig.3.

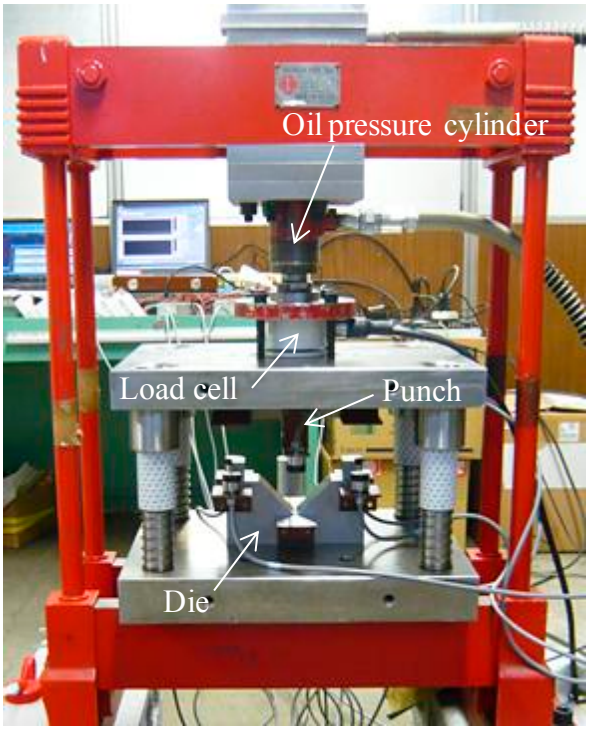


Fig. 1 V-bending apparatus

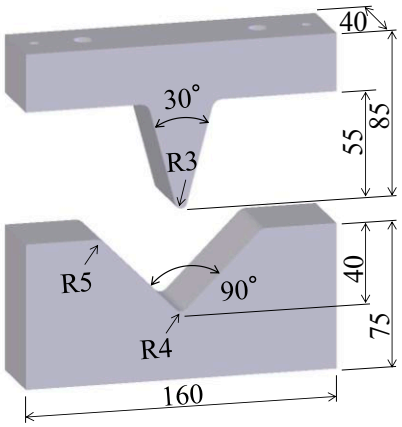


Fig. 2 V-bending die and punch

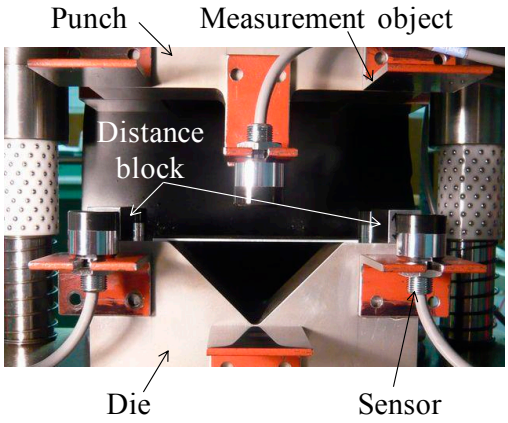


Fig. 3 Installation of sensors on dies

3. Specimen

5000 series aluminum alloy sheets (GC45-O: Sumitomo Light Metal Industries, Ltd.) with 1mm in thickness were applied for the specimen. The material is used for the parts of automobiles. The dimensions of the specimens are 100mm x 30mm x 1mm. They were produced by machining. The longitudinal direction of the specimen is coincide with the rolling direction Mechanical properties of the specimen are shown in Table 1.

Table 1 Mechanical properties of specimen

Tensile strength /MPa	Yield stress /MPa	Elongation /%	n value	r value
280	140	32	0.31	0.70

4. Numerical simulation

In order to investigate the process of v-bending, FEM simulation was applied. The sheet metal forming simulation software Stampack ver. 6.2.4 was used. The bending process was performed by dynamic explicit and the springback was performed bay static implicit. In order to reduce computing and modeling time, 1/4 models were applied with consideration of symmetry. Rigid shell elements were used to the models of dies. Elasto-plastic eight node hexahedron elements were applied to the models of specimens. Because forming in the thickness direction of the specimen was applied in some forming conditions in this study. The number of elements was 1800 and 7500, respectively. The friction coefficient between dies and specimen was 0.1. The simulation model is shown in Fig.4

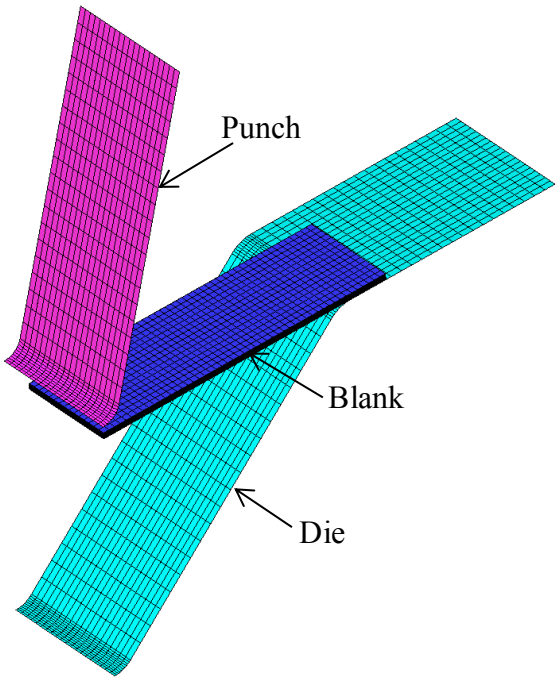


Fig. 4 Simulation model

5. Forming conditions

The following three kinds of experiments were performed. Because of the experimental ability of the developed apparatus, the maximum punch load was set to 70kN. Moreover, the number of experiment for each experimental condition was three times. Numerical simulations were performed before experiments cited below for finding the angle of the punch. The shortest edge of the specimen did not touch the dies. Therefore the phenomena of bending-unbending during forming process did not occur in the any experimental conditions.

5.1 Forming in the thickness direction of specimen (One-time forming)

The clearance between the punch and the die at the center (symmetry) line of the dies was reduced less than the thickness of the specimen by using distance blocks. The clearance was changed from 1mm to 0.75mm with interval of 0.05mm. Therefore six conditions were performed.

The punch was kept at the lower dead point of each forming condition for 10sec.

5.2 Two-time forming

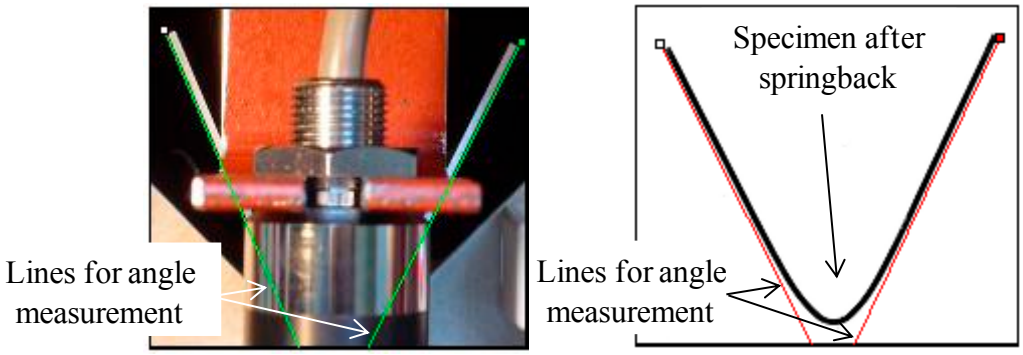
In the first forming, the position of the punch was maintained at the lower dead point for 10sec. In the next step, only the load on the punch was reduce to 0, In order to keep the specimen in the same position, the punch did not moved to upwards. The punch can hit the specimen at same portion in the first forming by this performance. After reducing the load of the punch, the load was increased again and maintained for 10sec and the punch removed from the specimen. The clearance between the punch and the die at the center line of the dies was set to from 1mm to 0.75mm with interval of 0.05mm. The six forming conditions were performed. In order to clarify the influence of the two-time forming to sprimgback after forming, the results were compared to the results of the one-time forming.

5.3 Holding forming die in certain period at lower dead point

The clearance between the punch and the die at the lower dead point was set to 1mm. It is the same as the thickness of the specimen. In his experiment, deformation in the thickness direction of the specimen did not performed. At this time, the punch holding time at the lower dead point for 0.2, 0.3, 0.5, 1, 5, 50 and 100sec. The punch holding time was calculated from the measurement value of the period of loading on the punch. Because the movement of the punch of V-bending apparatus was operated manually.

6. Method of evaluating springback angle

The springback was evaluated by the angle which was calculated from angular difference of the specimen between at the lower dead point of the punch and after forming. The digital pictures taken at both conditions were applied. Image analysis software ImageJ was used for the measurement of the angle of the specimen in the digital images as shown Fig.5.



a) Before springback b) After springback

Fig. 5 Measurement of the angle of the specimen in the digital images

7. Results and discussion

7.1 Forming in thickness direction at bent portion of specimen

The relationship between forming in the thickness direction the specimen and springback angle are shown in Fig.6. The stress distribution computed from the numerical sheet metal forming simulation is also shown in Fig.6. The springback angle decreases with increasing forming in thickness direction. The computed results indicate that the stress distribution in the thickness direction is more uniform with increasing forming in the thickness direction. The effect of the forming in the thickness direction more than 0.15mm is stable. It can be said that springback can be reduced drastically with this forming condition. However there is a limitation of reducing springback with this process.

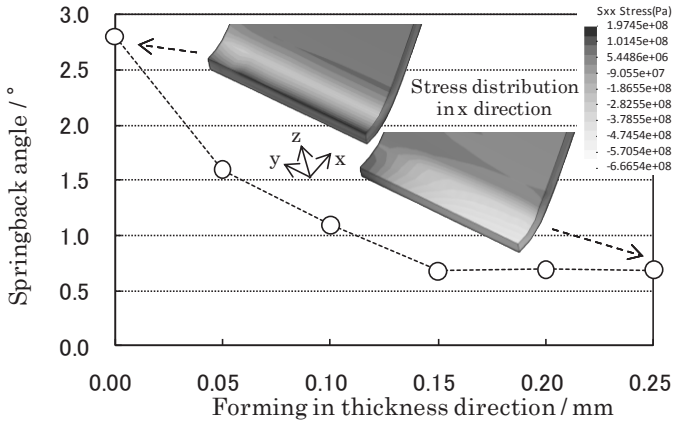


Fig. 6 Relationship between forming in thickness direction and springback angle

7.2 Two-time forming

Two-time forming was performed on the same conditions as the forming in thickness direction at bent portion of specimen. The relationship between forming in the thickness direction the specimen and springback angle from one-time forming (Forming in thickness direction at bent portion of specimen) and two-time forming are shown in Fig.7. The results from both forming conditions have same tendency. It can be said that the springback angle from two-time forming is smaller than that from one-time forming. It should be noted that there was no change in the measurement data regarding the position of the lower dead point of the punch in the one-time and the two-time forming. Moreover the specimens were hardly moved during forming. The only exception is the load between the one-time and two-time forming. As for the angle of specimens, the results of the measurement were almost the same while the specimens of one-time and two-time were formed. The clarification of the springback decreasing mechanism by two-time forming will be required the further research.

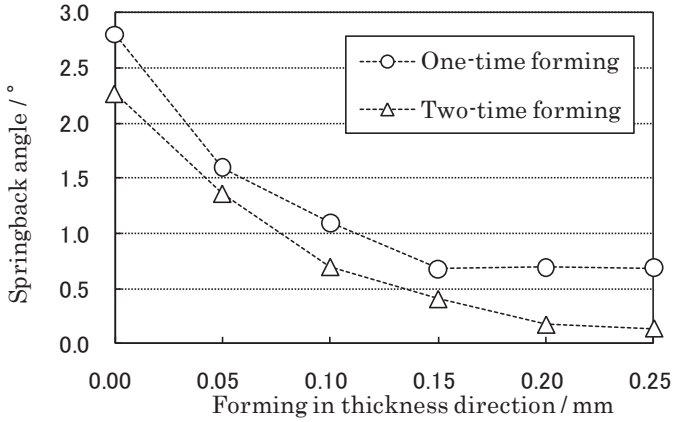


Fig. 7 Effect of two-time forming for springback angle

7.3 Holding the die in certain period at the lower dead point

The relationship between die holding time at the lower dead point and springback angle is shown in Fig.8. It indicates that there were not so many differences of the amount of the springback by changing hold time of the die. The uneven contact between the punch and the die was confirmed by measuring the movement of the dies around the lower dead point by inductive displacement sensors. Therefore, the oil pressure rose gradually after causing uneven contact between the dies and then the

surface of the punch contact to the distance block. About 2.2sec was required from the uneven contact to fully contact between the punch and the distance block. From this investigation, it is difficult to be mentioned that the holding time influence to sprimgback. The more accurate experiment by more controlled the punch position and the holding time of the punch will be performed by using servo controlled press etc.

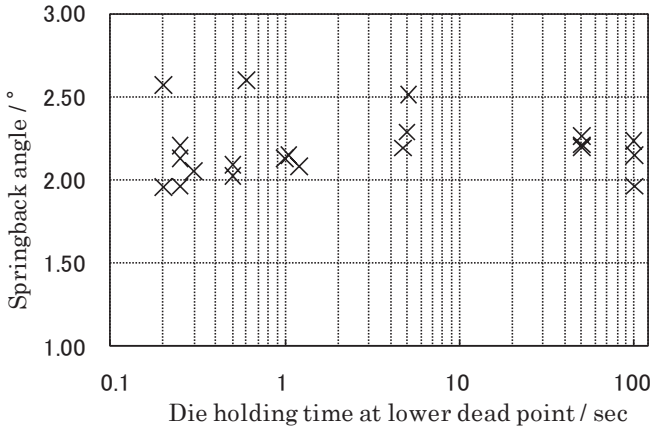


Fig. 8 Relationship between die holding time at lower dead point and springback angle

8. Conclusion

The following conclusions were obtained from the present study regarding springback of V-bending with aluminum alloy sheet.

1) Forming in thickness direction at bent portion of specimen (one-time forming). : The springback angle after forming was reduced drastically with increasing forming in thickness direction. The computed results indicate that the stress distribution in the thickness direction is more uniform with increasing forming in the thickness direction.
2) Two-time forming : The specimens were formed two times with the same conditions as one-time forming. This process also can reduce springback. Two-time forming is more effective on reducing springback than one-time forming.
3) Holding the die in certain period at the lower dead point : It did not affect to reducing springback using present apparatus. More accurate control of the movement of the punch is required for further investigation.

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