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A study on the hinge bracket forming by thickening of a sheet

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Abstract. A hinge bracket is usually produced by bending of a sheet panel or welding of a hollow bar into a sheet panel. The hinge bracket that is made by bending or welding, however, does not have sufficient durability due to the stress concentration on the bended region or low corrosion resistance of the welded region. In order to make hinge bracket with high durability, a bracket is needed to be produced by forming process. In this study, a thickening process of a sheet panel for the hinge bracket is investigated. The maximum thickening limit in one stage was determined for various aspect ratios of specimen. Finally, the optimum multi-stage forming process was designed for hinge bracket forming and the process was verified by numerical experiment.

Introduction

With the increasing of world cargo volume, the development of a foldable container is needed. The foldable container can be folded when the container is empty and transportation efficiency increases. A hinge is an important part in foldable container and has to have sufficient durability. Most of hinges are made by folding of a sheet metal or welding of a hollow pipe into a sheet metal as shown in Fig. 1. However, the hinge that is produced by folding or welding process has not sufficient durability due to the stress concentration (point 'A' in Fig. 1(a)) and low corrosion resistivity for saltwater (welded region of point 'B' in Fig. 1(b)).

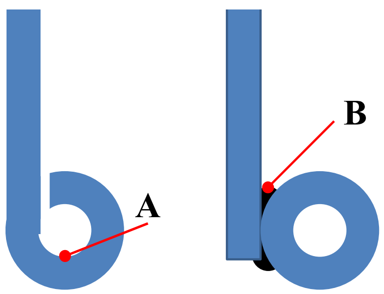

Fig. 1 Conventional hinge production processes by folding of a sheet and welding of a pipe into a sheet metal.

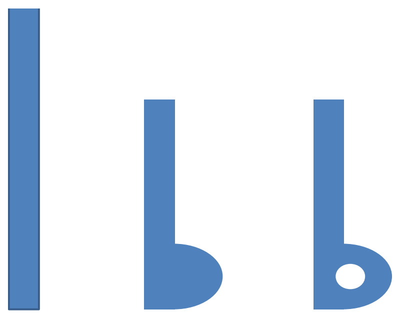

Fig. 2 Proposed hinge production processes

In order to overcome this weakness, the hinge is needed to be produced by forming process without welding as shown in Fig. 2. To form a hinge as shown in Fig. 2, the thickening process of a sheet is needed. However, the thickening of sheet is difficult due to buckling. Merklein and Opel [1] proposed a sheet-bulk metal forming process to produce tailored blanks of different thickness. Mori [2] and Merklein et al. [3] proposed many bulk forming processes of sheet metals in which local thickening and local thinning take place. By the proposed processes, they produced wheel disk, tailored blank, and gear. However, the thickening of sheet metals was limited to about 10 % in one stage [2]. When the thickening was greater than 10%, i.e., the gap was greater than 10% of the sheet thickness, buckling occurred and finally lap defects were caused [2]. In addition to these studies, there are many studies on sheet-bulk forming to produce very complex parts [4-6]. In most of the processes, the sheet forming and thickening take place simultaneously. However, the thickening is not so high.

In the hinge bracket forming shown in Fig. 2, the thickness should be increased more than twice. Therefore, multi-stage forming is used to manufacture the hinge bracket. In order to minimize the number of forming stages, the maximum thickness increase in one stage of forming without a lap defect was determined for various values of aspect ratio of specimen. Then, the optimum multi-stage forming process was designed based on the maximum thickness increase for given aspect ratio. The designed process was verified by finite element analysis.

Determination of the Maximum Thickness Increase

For the design of the hinge bracket forming process, finite element analysis (FEA) using ABAQUAS/Explicit [7] was carried out. For the verification of the lap defect prediction capability of the finite element analysis, experiments and finite element analysis were carried out. Fig. 3 shows the buckling shapes obtained by experiments and analysis. It was shown that the deformed shape is almost the same and the analysis can be used to design of the forming process.

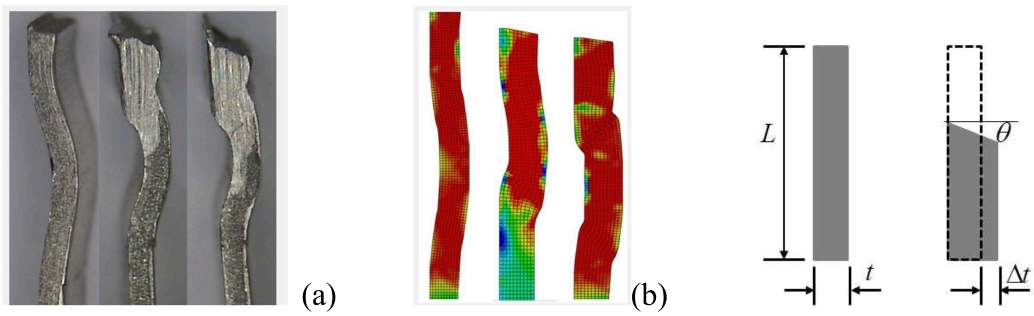

Fig. 3 Comparison of deformed shapes obtained in the (a) experiment and (b) FEA, and (c) explanation of punch angle

As shown in Fig. 3, buckling takes place when the thickness increase in one step is too large and this buckling cannot be recovered. This kind of buckling problem may be severe in the case of long specimen. For the design of multi-stage thickening forming, the maximum thickness increase was determined for various aspect ratios of specimen. The thickness of initial specimen was set in 1.0 mm. To retard the right movement of the top region, a punch with slope is used. For the specimen material, aluminum 1100 is used.

Fig. 4 shows the analysis results for various lengths and thickness increases. When the length of specimen is less than 2.7 mm, the maximum thickness increase is 0.2 mm. As the length is less than or equal to 2.7 mm, the maximum thickness increase is increases. Fig. 5 shows the determined maximum thickness increase for various aspect ratios. When the punch angle (see Fig. 3(c)) is 0^o, the maximum thickness increase is 0.4 mm when $4.0 \leq t \leq 7.0$. However, the thickness increase of 0.4 mm is unstable. So, the maximum thickness increase is regarded as 0.2 mm. When the punch angle is 10°, the maximum thickness increase becomes greater than or equal to 1.0 mm as the ratio of length to thickness become less than or equal to 2.7.

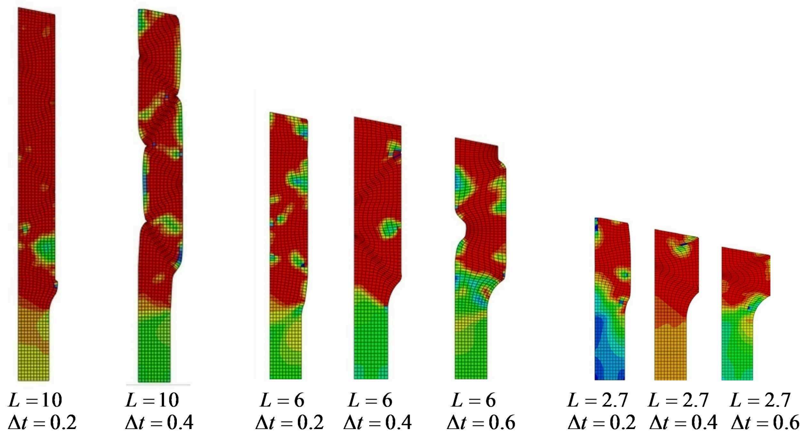

Fig. 4 Schematic illustration of thickening forming

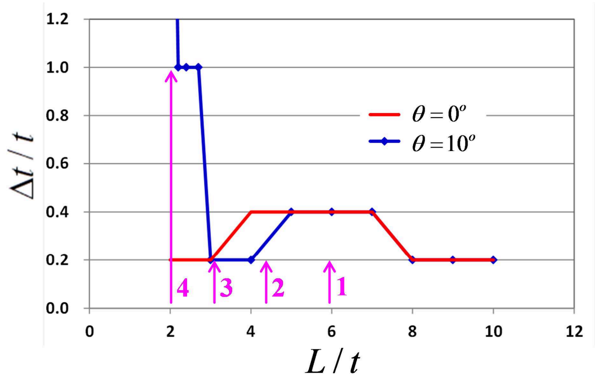

Fig. 5 Determined maximum thickness increase for various aspect ratios of specimen

Design of Multi-Stage Forming and Verification

Based on the maximum thickness increase for various aspect ratios (see Fig. 5), a multi-stage thickening forming was designed. The initial thickness and length is 1.0 and 6.0 mm, respectively. The finial thickness increase is 2.4 mm. To get the final thickness of 2.4 mm from 1.0 mm, intermediate forming stages were designed as marked in number in Fig. 5. The ratio of $\Delta t/t$ is 0.2 up to 3rd forming stage and final shape is formed in the 4th stage forming. Fig. 6 shows the deformed shape by designed multi-stage forming. It is shown that the final shape is obtained without lap defect.

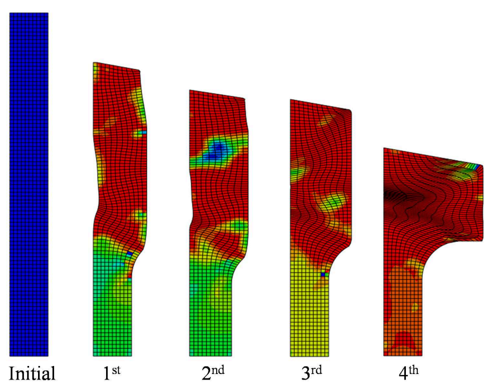

Fig. 6 Deformed shape at each stage of forming

Summary

The maximum thickness increase in one stage of forming was determined for various aspect ratios. Then, a multi-stage thickening process for hinge bracket was designed and the designed process was verified by FEA.

Acknowledgements

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