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Formability Study on Weld Line Location and Movement of Laser-Tailor Welded Blanks

Joo-Pyo Hong*, Heon-Young Kim**, Soo-Ik Oh***

* Graduate School, Seoul National University
** Dep't of Mechanical Engineering, Kangwon National University
*** Dep't of Mech. Design and Prod. Engng., Seoul National University

Abstract

The weld line location and the weld line movement in stamping with laser-tailor welded blanks(TWB) were investigated through square cup deep drawing tests. The step blank holder was introduced to form TWB of different thicknesses without wrinkling, and the non-uniform blank holding force(BHF) was enforced to control weld line movement. Test results of the blanks with shifted weld lines showed that the large portion of the thinner area could result in a large weld line movement. Careful selection of the weld line location and the BHF control should be adapted in TWB design to avoid failures and to ensure its formability.

Keywords : Tailor Welded Blanks(TWB), Square Cup Deep Drawing Test, Blank Holding Force(BHF)

1. Introduction

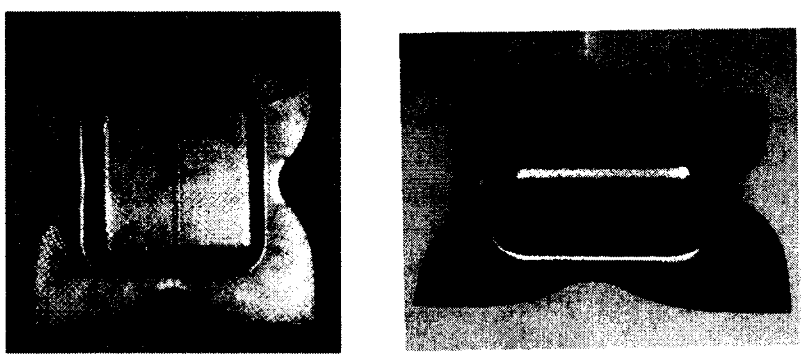
The concepts of metal forming technology related with laser welding are prevailing in the hope of synergistic effects from using laser-tailor welded blanks(TWB)[1]. Some applications of TWB are for automobile part production and the usage of TWB is expected to become more popular in industry[2]. Shi *et al.*[3] obtained limit strains by Marciniack cup tests and considered the limiting thickness/strength ratio. Saunders and Wagoner[4] carried out tests for formability evaluation of TWB such as OSU Formability Test and the scale fender forming. Ahmetoglu *et al.*[5] adjusted the variable blank holding force(BHF) to control the movements of weld line during cylindrical cup deep drawing. Van der Hoeven *et al.*[6,7] investigated the forming behaviors in stretch flanged areas with FE analysis for various parameters. Nakagawa *et al.*[8] performed simulations using commercial codes for stretch flanging conditions and for shrink flanging conditions based on the experimental data. And Joshi *et al.*[9] conducted simulations of hydroforming, press forming of fiber reinforced thermoplastic sheets, and stamping of TWB.

In this study, the square cup deep drawing was chosen as a test method to investigate the effects of the weld line location and how to control the weld line movements in TWB stamping. Weld line movements and failures due to the initial weld line location were discussed. And the BHF control was introduced to control the weld line movements and the failures.

2. Forming of Laser-Tailor Welded Blanks

2.1 Weld Line Direction and Forming Direction

Formed shapes were similar to those of non-welded blanks, in cases of the centrally-welded blanks and the diagonally-welded blanks of the same thickness of 0.7 mm(Fig. 1). However, the failures occurred at the corner wall across the weld line in cases of the diagonally-welded blanks, which had been studied in the previous work[10]. Generally, the corner wall areas are highly strained during the square cup drawing, and the elongation of the weld beads is much lower than those of base materials.



(a) Centrally-welded blanks (b) Diagonally-welded blanks

Fig. 1 TWB of the same thickness

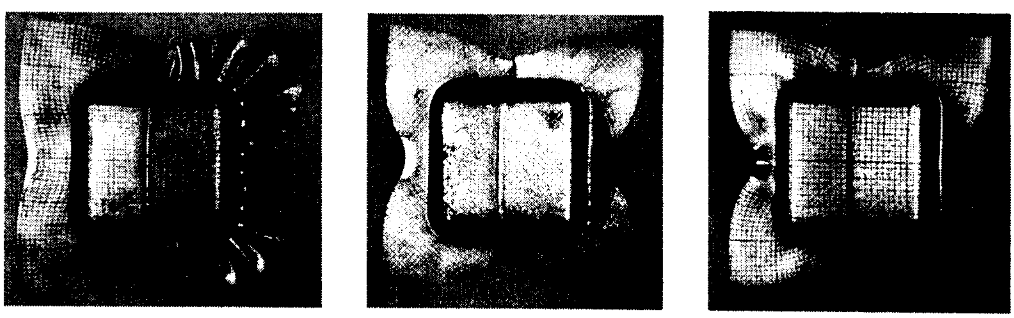
The punch face could be contacted with the step or the flat surface of the blanks while drawing(Fig. 2). The cost and the ease of the die modification could be decisive in choosing forming direction. For the visual parts, flat surface should be outside[6].

(a) Punch toward flat surface (b) Punch toward stepped surface

Fig. 2 Forming direction

2.2 The Blank Holding Force Control

The square cup deep drawing tests with centrally-welded blanks of the different thickness were carried out with the maximum punch stroke of 40 mm. The TWB are composed of the same material of SCP3 with two thicknesses of 1.4 mm and 0.7 mm. Deep drawing tests under the flat blank holder showed severe wrinkles on the flange of the thinner sheet(Fig. 3(a)). Replacement of the flat blank holder by the step blank holder could efficiently suppress the wrinkles on the flange(Fig. 3(b)). The shims were placed to give effects of the step blank holder. However, the weld line moved during the forming of the TWB of the different thickness under the uniform BHF. The weld line moved toward the thicker area at the bottom of the cup, and flange edges of the thinner area near the weld line have taken the shapes of the enveloping flange edges of the thicker area due to the step blank holder. Prior to this study, the stamping press which can control BHF distribution was developed[10]. To minimize the weld line movement during the forming, the thinner area was exposed to higher pressure. When the BHF was distributed by the ratio of 4 : 6 on the thicker area to the thinner area(Fig. 3(c)), the weld line movement of the central point was reduced by about 50 %. The heights of outer surfaces of the bottom of the cup were measured along the transverse direction to the central weld line. The warping was observed, and the maximum variation of heights in cases under non-uniform BHF was reduced by 29 % compared with the results under uniform BHF(Table 1).



(a) Flat blank holder BHF ratio 5 : 5 (b) Step blank holder BHF ratio 5 : 5 (c) Step blank holder BHF ratio 4 : 6

Fig. 3 TWB square cup (1.4 mm / 0.7 mm)

Table 1 TWB square cup forming (1.4 mm / 0.7 mm)

BHF ratio	total BHF(kN)	initial BHP(MPa)	weld line movement(mm)	max. height variation(mm)
5 : 5	19.3	1.1	3	0.93
4 : 6	19.3	0.88 / 1.3	2	0.66
5 : 7	23.1	1.1 / 1.5	3	0.99

3. Effects of Weld Line Location

3.1 Weld Line Movement

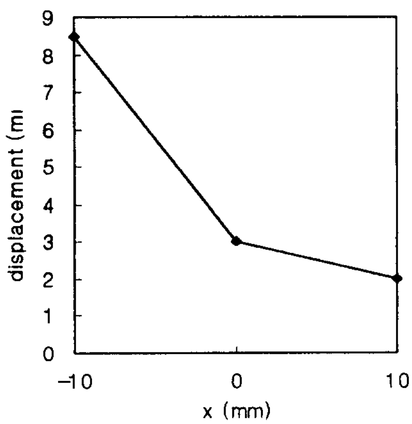


Fig. 4 Weld line movement due to initial weld line shift

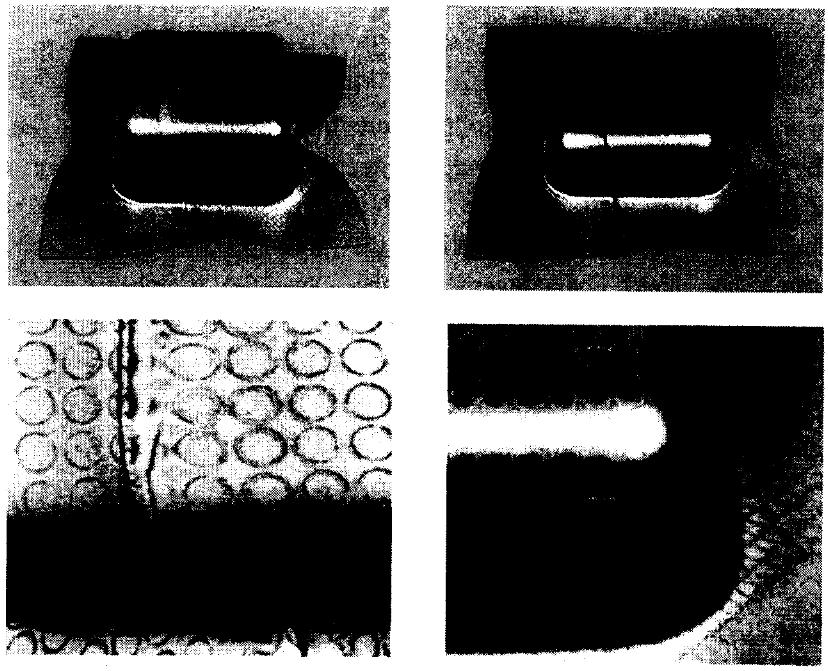
In the blank design, the weld line location is one of the major design factor to control the weld line movement in forming processes. The square cup deep drawing tests were conducted for 3 kinds of weld line locations. The central weld line and two lines shifted by ±10 mm from the center were chosen to study. After being exposed to a BHF of 19.3 kN, weld lines moved toward the thicker area. The 'x' denoted the distance to the thinner area from the center(Fig. 4). The weld line movement at the center of the weld line in case of x=-10 mm was about or 3 times more than those for x=0 mm and x=10 mm.

3.2 The Failures

For the specific case of x=-10 mm, the square cup deep drawing tests were conducted under uniform BHF and under nonuniform BHF(Table 2). There were failures in the thinner area for both cases, but at different points. When the cup was formed under uniform BHF of 19.3 kN, the failure was found along the weld line on the bottom near corner(Fig. 5(a)). The location of the failure showed that there had been excessive deformation near the interface of the two sheets. When the BHF on the thinner area was increased by 41 % to suppress the excessive inflow of materials, the failure occurred at the corner wall(Fig. 5(b)). These types of failures and forming conditions are frequently encountered in TWB applications to the automotive bodies.

Table 2 Failures noted on the specimens in case of x=-10 mm

BHF ratio	total BHF (kN)	weld line movement (mm)	punch stroke (mm)	failure
5 : 5	19.2	8.5	40	along weld on the bottom near corner
5 : 7	23.1	≤5	26	at the corner wall near the bottom of the cup



(a) BHF ratio 5 : 5 (b) BHF ratio 5 : 7

Fig. 5 Failures noted on the specimens

A forming limit diagram(FLD) for the thinner sheet was obtained from these experiments(Fig. 6). The safe points were mainly picked from the corner areas. The value of FLCo was calculated by Bethlehem Method and one of Hecker's curves were used as a standard forming limit curve[11]. The weld line locations and the BHF control must be carefully selected to avoid failures during forming of TWB. This FLD can be used as a criterion for TWB failure during forming in the numerical analysis.

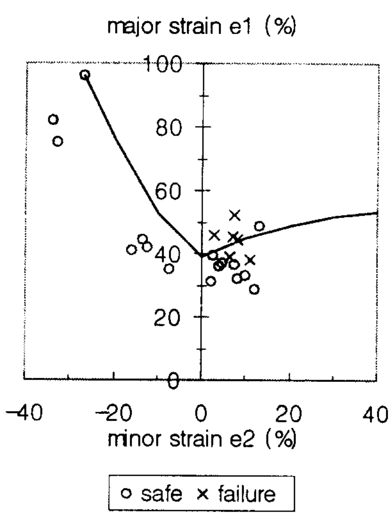


Fig. 6 FLD for SCP3(0.7 mm)

When the same tests were performed in cases of x=0 mm and x=10 mm, the resultant deformed shapes had no failures. Displacements of center points of the formed weld lines were reduced by 0~20 % compared with the test results under uniform BHF, when the BHF on the thinner area was increased by 41 %. In the case of x=0 mm, when we increased the BHF on the thinner area by 17.3 kN(BHF ratio 5 : 9), failures occurred at the corner wall in the thinner area.

4. Conclusions

Square cup deep drawing tests with TWB were carried out to study the effects of weld line location and to control the weld line movement. Wrinkles on the flange were suppressed by using the step blank holder. Adjusted BHF control reduced the weld line movement and the warping of the bottom surface of the cup. When the initial shifts of the weld line were considered, the area ratio affected the weld line movement. When the area portion of the thinner sheet became larger, the weld line movement was increased rapidly. And the failures occurred in case of x=-10mm, which is frequently encountered in the application of TWB to the automotive bodies. To avoid failures and to ensure the formability of TWB, the weld line locations and the BHF control should be considered in blank design.

5. References

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