Development of Forming Technique with Real-Time Control of Blank Holding Force

by

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Synopsis

In the conventional press forming process, Blank Holding Force (BHF) is fixed appropriately to suppress the press forming defects such as wrinkle and breakage within the formable range. However, it is difficult to suppress some kinds of defects in the conventional press forming process. Therefore, it is need to suppress these defects for stamping the complicated-shape-panels and using the high strength sheet steel. In order to solve these problems, a new press forming technique has been developed. The main feature of new technique is the real-time control of BHF through a stroke. By optimizing the controlled BHF it has been proved that the new technique is much useful to prevent the forming defects with the experimental and the actual stamping machines.

1. Introduction

Recently the demand for stamping the complicated shaped panels or using a high strength sheet steel increases for light weight or a safety vehicle body[1]. It becomes more difficult to suppress the press forming defects, such as breakages, wrinkles, and surface deflections. However it is impossible to prevent the defects without the change of the panel design or the improvement of the formability of sheet steel.

In response to these demand a press forming technique has been improved in the "intelligent" stage. In the conventional press forming process, blank holding force (BHF) is fixed appropriately within the formable range to suppress the press forming defects. Although in the new press forming process, BHF is controlled suitably for a change of forming mode or punch force[2),3),4)].

In this paper, this new forming technique with the controlling of BHF is proposed and proved to suppress the body wrinkle and the surface deflection using the model dies[5)]. Then this developed method was applied to the actual products for automobile and proved the effects[6)].

2. Experimental Procedure

Material and die — For the examination of the effect of the developed method on the body wrinkle, a 0.8 mm thick high strength sheet steel, as shown in **Table 1** and the model fender die modeled on the front fender of automobile, as shown in **Fig. 1** were prepared. The body wrinkle always occurs in the

Table 1 Tensile properties of material

YS (MPa)	TS (MPa)	El (%)	n-value	r-value
267	415	37.9	0.210	1.59

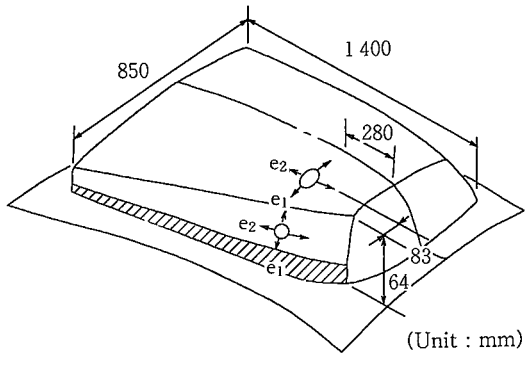

Fig. 1 Schematic illustration of model panel

side portion of the panel with the conventional method.

Forming condition — A double-action hydraulic press machine was used. The capacities of the inner and outer presses were 3 000 kN and 2 000 kN respectively. The average forming speed was 15.5 mm/sec. BHF was changed rapidly at the preset punch position, as shown in **Fig. 2**. During the forming BHF can be changed twice maximally.

Body wrinkle and strain — The profile of body wrinkle was measured in the side portion of the panel. The strain in the punch face was measured by using the scribed circle with the stamped panel, as shown in **Fig. 3**. and the change of the strain was measured after 30 mm to the bottom using the strain gages, because the sheet was fitted to the punch face and therefore not bended after this position. On the other hand, the strain in the side portion was measured from the start of the stroke using the strain gages in both sides of the sheet to exclude the bending strain.

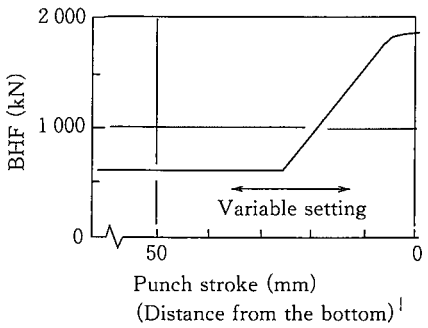

Fig. 2 Schema of the controlled BHF

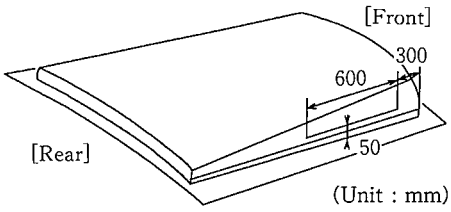

Fig. 3 Measuring portion of the body wrinkle

3. Results

3.1 BHF and Body Wrinkle

Body wrinkle by the conventional method — **Fig. 4** shows the profile of the body wrinkle by the conventional method. The body wrinkle could not be eliminated even at the upper limit BHF according to the breakage. It is clear that the increase of BHF is not effective on the suppression of the body wrinkle in this panel with the conventional method.

Body wrinkle by the developed method — **Fig. 5**(a) shows the profile of the body wrinkle by two different control patterns of BHF. It is clear that the body wrinkle was suppressed by the type-②, which was consist of the low BHF in the early stage of the forming process and the high BHF in the later stage, but the type-①, which was the monotonously decreased BHF, was not effective to suppress the body wrinkle.

As shown in **Fig. 5**(b), the body wrinkle was prevented perfectly with the high BHF in the later stage, if BHF in the early stage (BHF-E) was constant. On the other hand, as shown in **Fig. 5**(c), if BHF in the later stage (BHF-L) was constant, the body wrinkle was suppressed with the low BHF-E. However in both cases the breakage occurred as the punch position to change BHF was too early. Therefore it is necessary that BHF is changed at the appropriate punch position with the pattern of BHF changing.

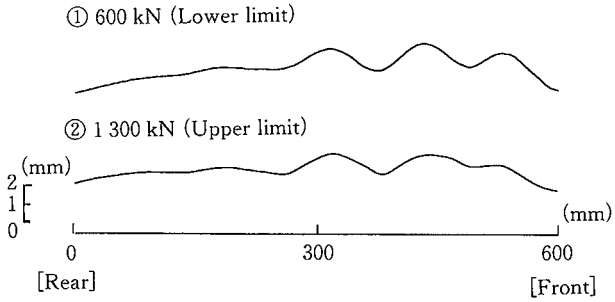

Fig. 4 Profile of the body wrinkle in the conventional method

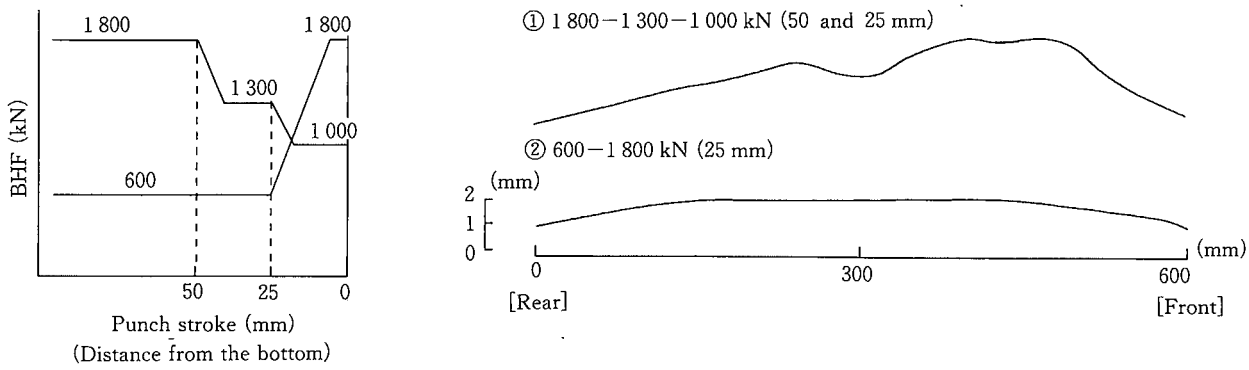

Fig. 5 Profile of the body wrinkle in the conventional method
(a) Difference between the typical two types of controlled BHF

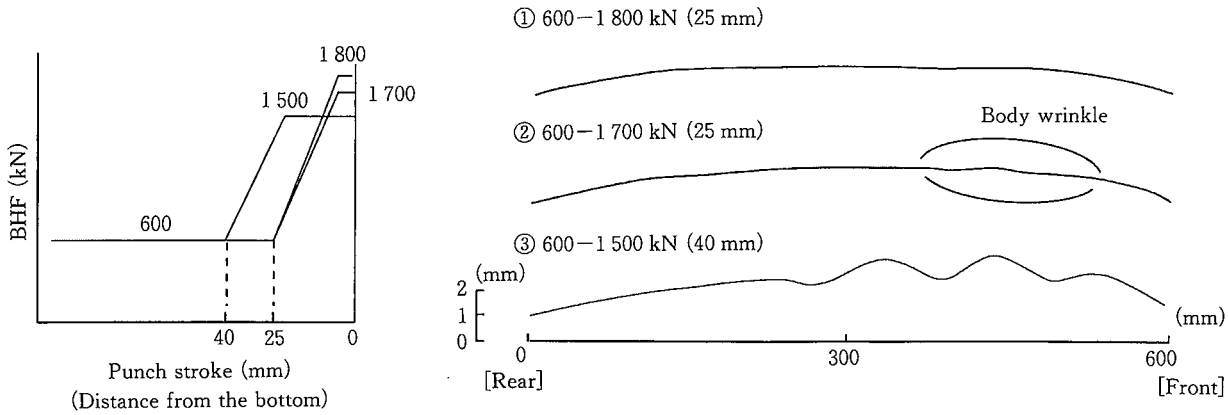

Fig. 5 Profile of the body wrinkle in the conventional method
(b) BHF is constant in the early stage

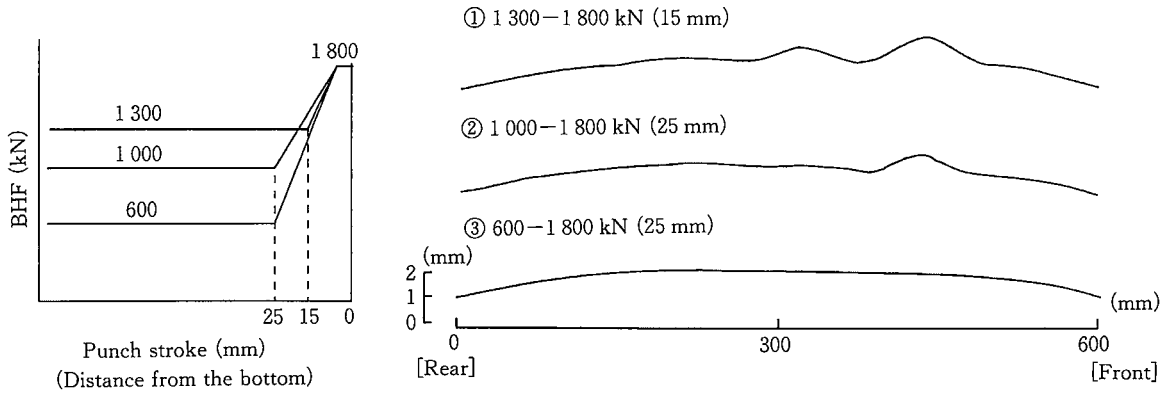

Fig. 5 Profile of the body wrinkle in the conventional method
(c) BHF is constant in the later stage

3.2 Difference of the Growth of the Body Wrinkle

Figure 6 shows the difference of the growth of the body wrinkle between the conventional method and the developed method. In the case of the conventional method, the body wrinkle grew with the descent of the punch stroke. Especially after 20 mm to the bottom, the body wrinkle grew large, and it was left after finished. On the other hand, in the case of the developed method (BHF-E was 600 kN and BHF-L was 1 800 kN, and punch position to change BHF was 25 mm to the bottom), it is recognized that the body wrinkle was suppressed after 20 mm to the bottom, although it occurred slightly at the 27 mm to the bottom. Therefore the body wrinkle is eliminated with the increased BHF.

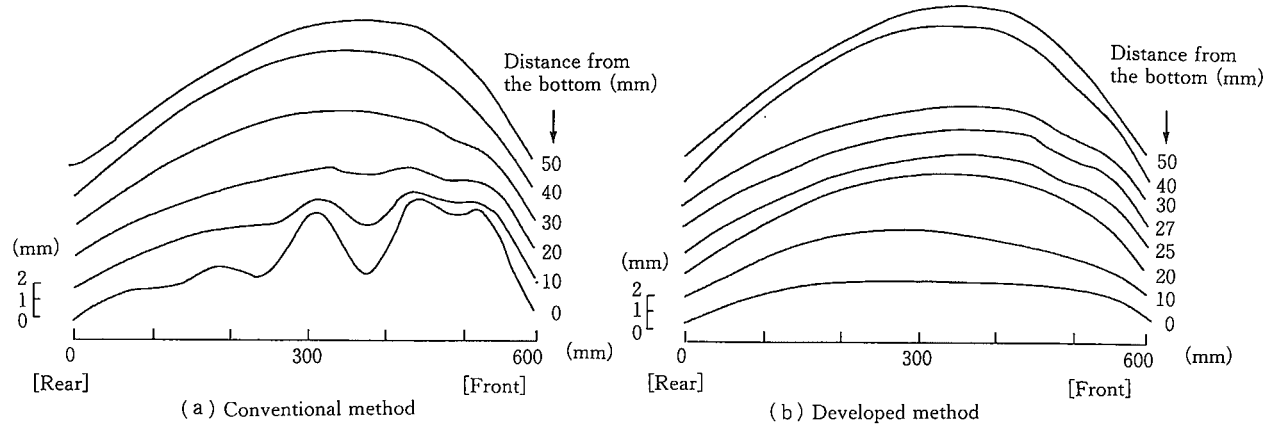

Fig. 6 Difference in the growth of the body wrinkle between the conventional method and the developed method

4. Discussion

4.1 Change of Strain with Punch Stroke

The strain-stroke diagram of the panel is compared the developed method with the conventional method in **Fig. 7**. In the side portion of the panel (**Fig. 7**(a)), the increment of the minimum principal strain, the longitudinal direction strain (e2) is changed from the negative to the positive immediately when BHF increases, although e2 decreases monotonously through the stroke with the conventional method. It is recognized that the strain state in the side portion is changed to the biaxial stretching with the developed method, and this change is effective to suppress the body wrinkle.

At the punch face (**Fig. 7**(b)), both e2 and the transverse direction strain (e1) increase rapidly with the increase of BHF, and e2 at the final punch position with the developed method are two times as large as that with the conventional method. However the ratio of the incremental strain ($\Delta e2/\Delta e1$) with the developed method is the same as that with the conventional method.

The feature of the developed method are as follows.

(1) The increment of the longitudinal strain in the side portion, in which body wrinkle occurred is changed from the negative to the positive immediately with the increase of BHF. As a result of this change, the strain state in the side portion is the biaxial stretching.

(2) The biaxial stretching of the punch face is promoted with the increase of BHF.

From both change of the incremental strain at the punch face and the side portion, it is considered that both e2 of the punch face and the side portion are connected with each other.

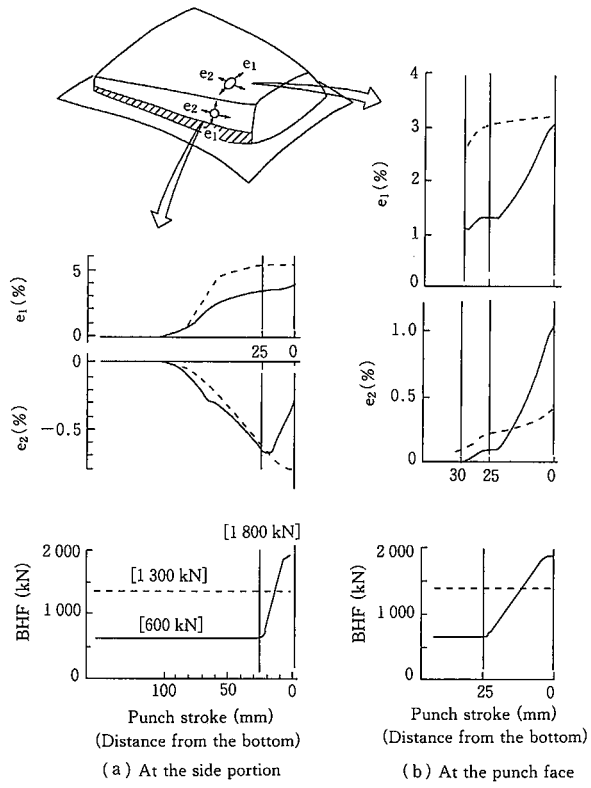

Fig. 7 Comparison in the change of the strain between the conventional method and the developed method

4.2 Best Controlled BHF

The stretching in the side portion suppresses the body wrinkle, and it is regarded that the stretching in the side portion is caused by the stretching in the punch face. As a result, the stretching in the punch

face is effective to prevent the body wrinkle in the side portion. To stretch the sheet at the punch face effectively, it is suitable that the flow stress of the sheet is low before BHF increases. According to this idea, the best controlled BHF is that the combination of the low BHF-E without the flange wrinkle and the high BHF-L without the breakage, and the appropriate punch position of BHF changed, because the low BHF suppresses the work-hardening of the sheet at the punch face and the high BHF stretches effectively the sheet.

5. Analysis of Stress History

5.1 The Assumptions for Analysis

It is considered that the reason to prevent the body wrinkle are the decrease of compressive stress for the wrinkle and the suppress of a buckling in a plain. The stress history in the side portion is estimated by stress increment and stress during forming using the in rigid plasticity based on experimental strain history. It is assumed that shear stress is too small to ignore and a material is an isotropy. The theory of strain increment and three assumptions as followed are used.

(1) The principal axis of plastic strain increment agree with the principal axis of stress increment at each moment.

(2) The deviatoric stress is estimated by the plastic deviatoric strain increment of each direction.

(3) The volumetric strain is not caused by the plastic strain increment.

5.2 Results of Analysis

The stress history in the side portion is compared the developed method with the conventional method in **Fig.** 8. The longitudinal direction stress (σx) is negative in later stage and the other stresses in plain are positive with the conventional method. This stress history agree to occurrence of the body wrinkle only in the side portion with the conventional method. On the other hand, with the developed method σx is changed from the negative to the positive immediately when BHF increase. This stress history explain the suppression of the body wrinkle.

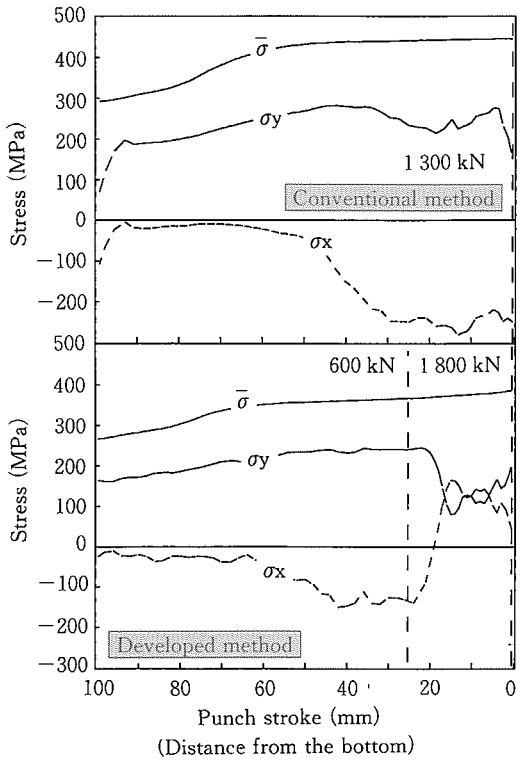

Fig. 8 Comparison in the defference in the stress path

6. Application to Actual Products

6.1 Experimental Procedure

At NISSAN MOTOR the 10/6 MN hydraulic press machine was improved for this experiment. It has the individually controlling system for 4 cylinders of outer press to change BHF. The developed method was applied to an actual high-roof panel of wagon, as shown in **Photo 1.** In forming the body wrinkle and the surface deflection occur at the front in the panel and the transition wrinkle at the rear. The growth of these wrinkles are different from each other, as shown in **Fig. 9.** Then the optimum controlled BHF is different between 2 cylinders at the front and 2 at the rear, as shown in **Fig. 10.**

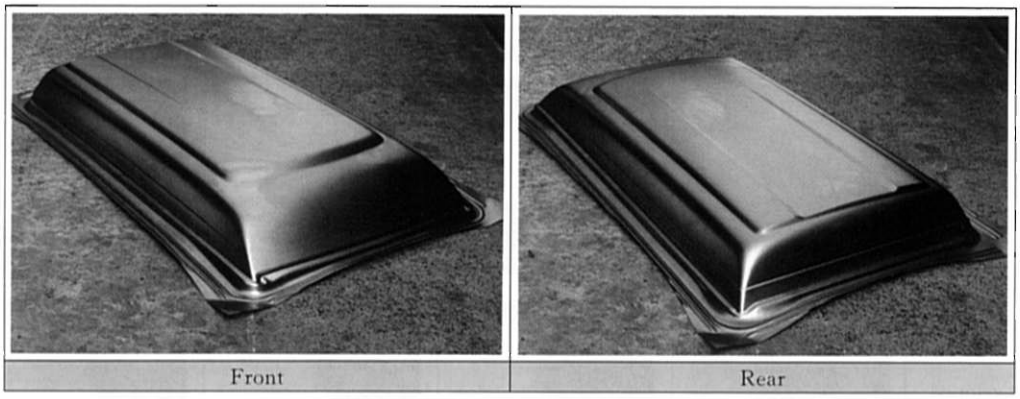

Photo 1 View of the actual panel

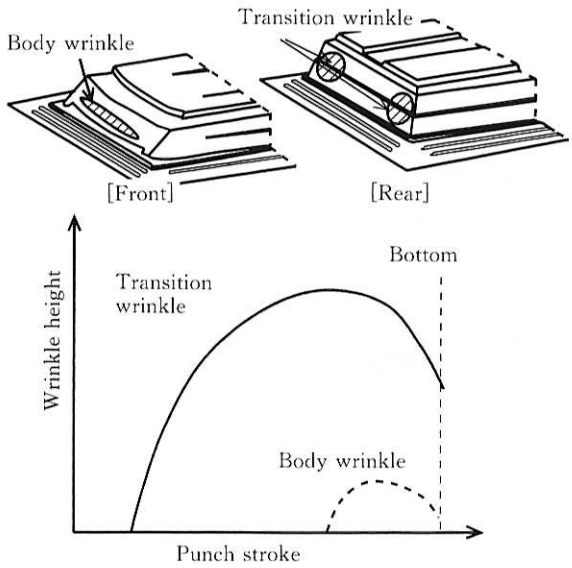

Fig. 9 Schema of the growth of wrinkle

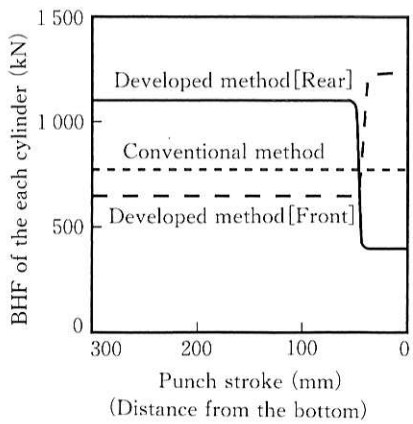

Fig. 10 Optimum controlled BHF for the actual product

6.2 Effect of the Developed Method

The change of the transition wrinkle in a stroke is shown in **Photo 2**. It is clear that with the developed method the transition wrinkle occurred more slightly and eliminated more rapidly. It is observed that the body wrinkle of the front side was prevented with the developed method even using the low grade sheet steel. Thus it is able to obtain the higher quality panel with the controlled BHF for each cylinder responding to the defects.

7. Conclusion

The effect of the new forming technique with real-time control of BHF was examined. The following results were obtained.

(1) The press defects, not to be suppressed in the conventional method, was prevented remarkably with the developed method.

(2) To prevent the body wrinkle and the surface deflection, the best controlled BHF is that the combination of the low BHF-E without the flange wrinkle and the high BHF-L without the breakage, and the appropriate punch position of BHF changed.

(3) The feature of the developed method is that the increment of the longitudinal strain of the panel is changed from the negative to the positive immediately with the increase of BHF.

(4) The effect of new method has been proved with the actual stamping.

Furthermore, other press defects, such as surface deflections and spring-back, are prevented remarkably with the developed method by the model forming. For the future it is considered that this new method will be practical use after checking an endurance of improved press machine in automobile company.

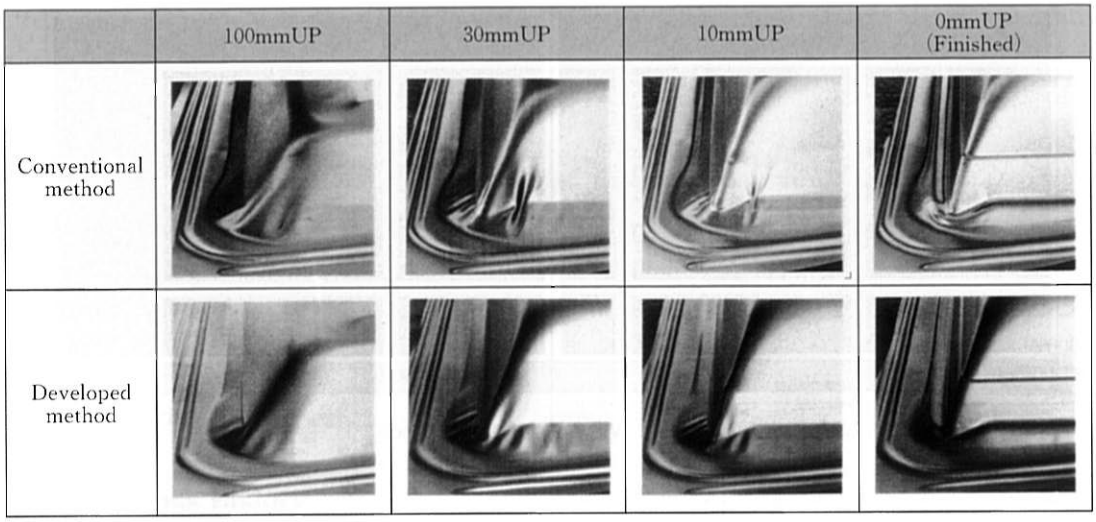

Photo 2 Effect of the developed method on the transition wrinkle

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