Stress Analysis of Connector Pin Produced by Reverse Stamping Process with LS-DYNA Numerical Simulation and Comparison to Experiments

Authors:

Won Yong-Hee*, Kim Jeong-Ho**, Lee Young-Jun***
*Research engineer, CAE Group Production Engineering Center, LG Cable Ltd
** Research engineer, CAE Group Production Engineering Center, LG Cable Ltd.,
*** Connector Team Component Group, LG Cable Ltd

Correspondence:

555, Hogye-dong, Dongang-gu,
Anyang-shi, Kyungki-do
431-080
South Korea

Tel: +82-31-450-8406
Fax: +82-31-450-8331
e-mail: yhwon@cable.lg.co.kr

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ABSTRACT

The conventional progressive stamping process used in producing connector pin makes the pin-shift from side to side due to elastic recovery reffered to springback phenomenon. As the solution of this problem, the reverse stamping process was introduced to the production process of connector pin in LG Cable. In this study, we performed research on the feasibility of reverse stamping process to support a design guide of which process. For this research, we tested specimens made of the connector pin materials, and built up the finite element model to simulate the failure mode of the section of the connector pin. The nonlinear analysis for these stamping process was performed using LS-DYNA. Through these nonlinear finite element analysis, we suggest the level of lifter force letting the section shape of the connector pin better and we used LS-DYNA for the practical approach than theoritical appoach.

1. INTRODUCTION

Recently, Development trend is that the pitch between the connector pin becomes narrow fewer than 0.5 mm by minimization and integration of product that the connector of connector pin has built-in.
The typical section shape of connector pin produced by a progressive stamping process is asymmetric. Connector pin could make a behavior for a direction of pin's width and cause problems of interference with each connector pin by the phenomena of spring back induced by the residual stress.
Also, there are some cases of the escape of the design specifications such as an under or over angle in bending and the interferences between the connector pins more severe by the section of asymmetric shape when do bending process after the stamping process in the case of connector pin producted.

The connector team in LG cable did a technological examination about the simultaneous stamping process, we called, the reverse progressive stamping process for the improvement of the above mentioned problems. For this research, we compared and examined the section of the connector pin produced by the progressive stamping process and that of produced by the reverse stamping process in this research, and proposed a force on the lifter to produce connector pin with a fine section that there is few burrs and the shape of section is symmetric etc .. through the nonlinear analysis using LS-DYNA. The material tests were performed, and the suitable fracture strain by the inspection of the section of connector pin was applied in FE model

2. Technical basement

2.1 Material test

The tensile tests of connector pin's materials were performed based on ASTM E8, E646 to evaluate the connector pin's materials in the direction of 0˚, 45˚, 90˚ of the rolling direction as shown in fig.1. Also,the thickness of connector pin was 0.12 ~ 0.2 mm and width of that was 0.2 ~ 0.4 mm. For this reason, the tensile tests of small size specimens which represented the real size of the connector pin were performed to confirm the change availability about original material properties, and the material properties were tabled in table 1.

It was performed to count the number of the grains of the connector pin' materials through the thickness referred ASTM E112 as shown in figure 2. The number of grains was observed about average 20 ~ 25 for the thickness direction as shown in figure 2. In general, this number is a sufficient number to maintain original material properties.

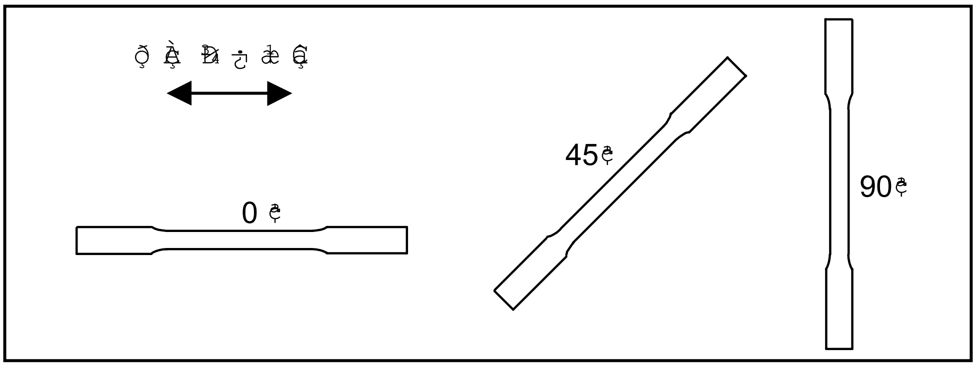


Fig 1. Specimen for tensile test.

material	thickness (mm)	direction	Young's Modulus (GPa)	Yield stress (MPa)	Ultimate stess (MPa)
C5210 H	0.1	0deg	113	624	648
		45deg	112	598	649
		90deg	109	598	666
C5210 H	0.12	0deg	112	593	632
		45deg	112	580	639
		90deg	110	558	651
C5210 H	0.2	0deg	112	622	660
		45deg	106	594	667
		90deg	110	599	687
C5210 1/2H	0.15	0deg	97	482	566
		45deg	96	450	537
		90deg	94	465	571

Table.1 Material properties

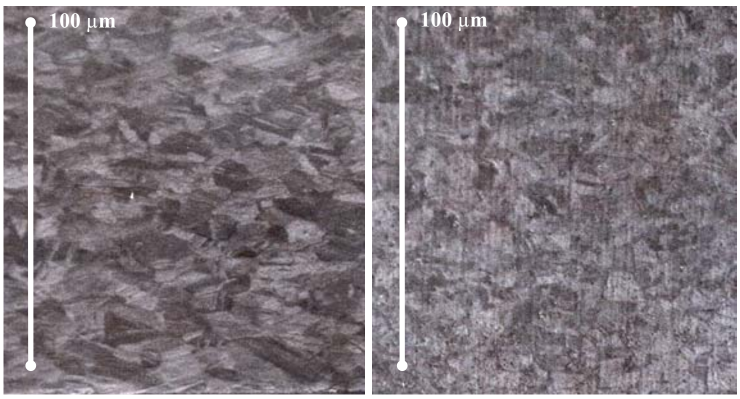


Fig. 2 SEM of C5210H

1.1 Fracture mechanism

The typical section of ductile fracture was consisted of rollover, shear, fracture, burr as shown in figure 3. It could be seen in figure 4 that the the phenomena 'fracture', occured from 45% of thickness in C5210H that the connector pin was made of. Therefore, the fracture strain was defined so that the fracture in the sheet(blank)was able to happen after 45% of thickness in this research.

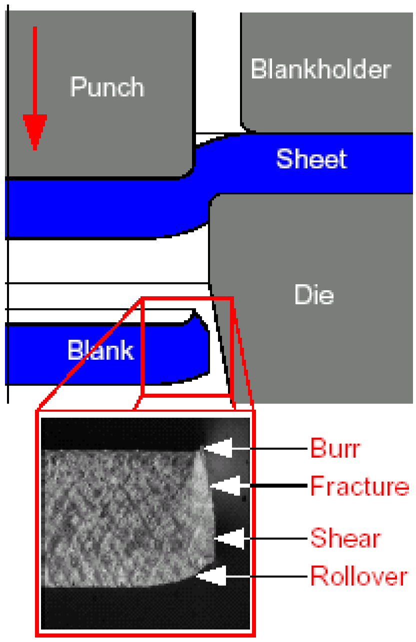


Fig 3. Typical section of ductile fracture

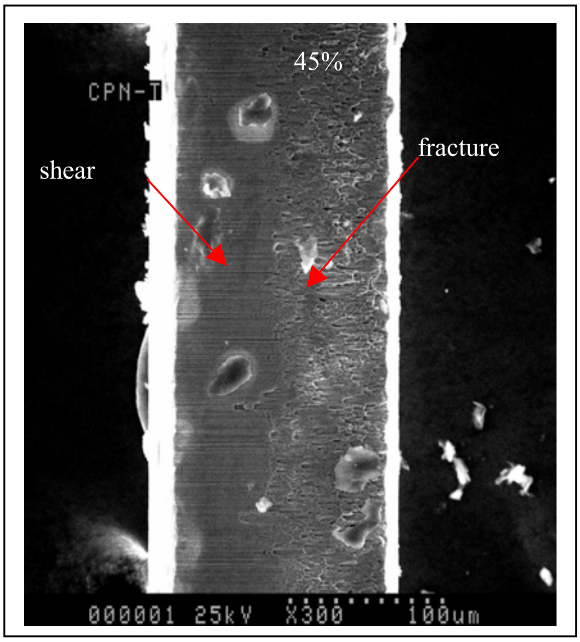


Fig 4. Section view of connector pin made of C5210H

2. Building up FE model

3.1 Modeling of Conventional Progressive stamping process

Fig 5a~5b expressed the the convential progressive stmping process. In the progressive stamping process, the sufficient force on PGB(Punch Guide Block, blankholder) was needed to perform the efficient stamping process, in which the connector pin had few burrs and the section shape of that was symmetric.

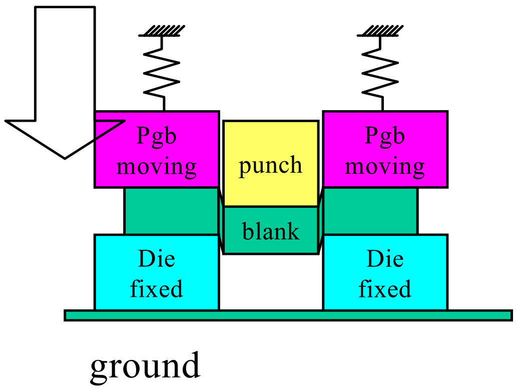


Fig 5a. Schematic drawing of conventional stamping

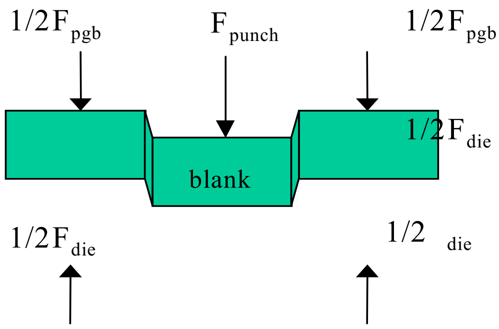


Fig 5b. Schematic drawing of conventional stamping

$$\frac{1}{2}F_{pgb} + \frac{1}{2}F_{pgb} + F_{punch} = 2(\frac{1}{2}F_{die})$$

$$where, F_{pgb} = k(d_{initial} + d_{stroke})$$

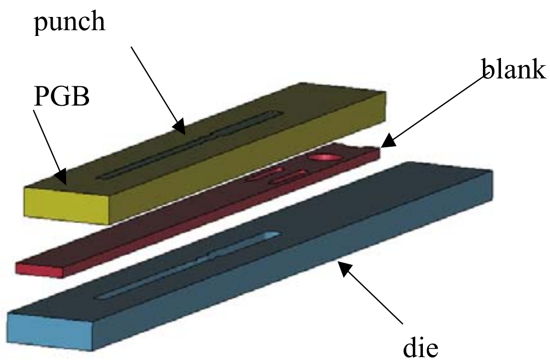
$$F_{pgb} = k(d_{initial} + d_{stroke}) = F_{die} - F_{punch}$$

$$F_{die} = F_{pgb} + F_{punch} = k(d_{initial} + d_{stroke}) + F_{punch} \quad \text{Equation .1*}$$

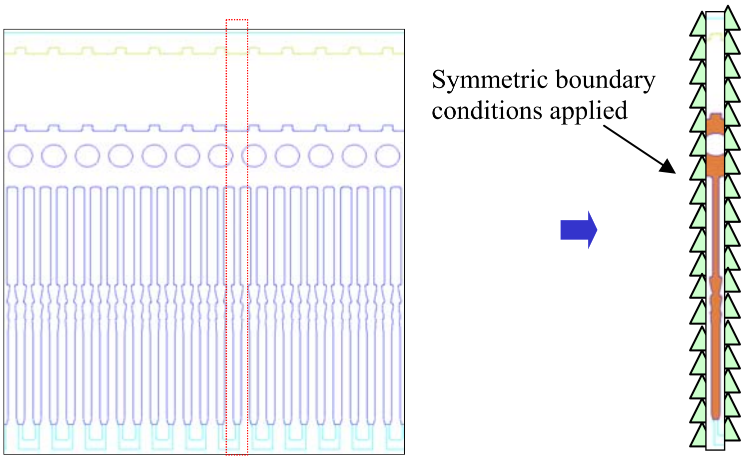
*Friction force is ignored.

The force on PGB could be calculated with equation.1 and the punch velocity was set to 0.2m/sec. The FE model was built up as the basis of the above mentioned conditions, as shown in fig.6a.

The FE model represents some processes of making single connector pin to reduce the solving time. Symmetric conditions on left side and right side of blank were applied .(Fig.6b) FE model illustrated to Fig. 6c has been consisted of two times of stamping process and one time of end-cut process. It was carried out review on the section shape of connector pin by progressive stamping process each section A-A ', B-B' and C-C ' using FE model.



□□ 6a. FE model of conventional stamping process



Fig, 6b Concern Domain

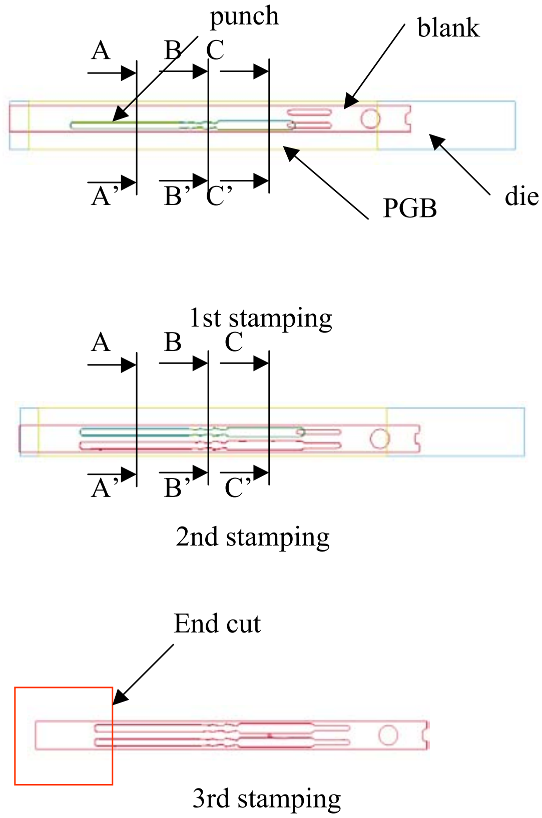


Fig. 6c. FE model of conventional stamping

2.2 Modeling of Reverse Stamping Process

In progressive stamping process or conevential stamping process, the connector pin was the remained part of blank and the chip was wasted by punch' stroke toward the ground by press mechine. Therefore two stampig process were needed to make the connector pin from the blank. But in the reverse stamping process, the punch was fixed at the ground and the blankholder(PGB) was moved by pressing mechine. The connector pin was stamped from the part of blank, so only one stamping process was needed. Fig. 7a~7b expresses the reverse stamping process. The sufficient force on lifter is needed for efficient stamping in reverse stamping process because the lifter play a role as blankholer(PGB) in the progressive stamping process.

$$
\begin{aligned}
&2(\tfrac{1}{2}F_{pgb}+\tfrac{1}{2}F_{pgb})=2(\tfrac{1}{2}F_{lifter})+F_{punch}\\
&where,\\
&F_{pgb}=k^{pgb}(d_{init}^{pgb}+d_{stroke}),\\
&F_{lifter}=k^{pgb}(d_{init}^{lifter}+d_{stroke})\\
&F_{pgb}=k^{pgb}(d_{init}^{pgb}+d_{stroke})=k^{lifter}(d_{init}^{lifter}+d_{stroke})+F_{punch}\\
&F_{punch}=F_{pgb}-F_{lifter}\\
&\qquad=k^{pgb}(d_{init}^{pgb}+d_{stroke})-k^{lifter}(d_{init}^{lifter}+d_{stroke})\\
&\qquad=k^{pgb}d_{init}^{pgb}-k^{lifter}d_{init}^{lifter}+d_{stroke}(k^{pgb}-k^{lifter})\\
&and\\
&F_{lifter}=F_{pgb}-F_{punch}\\
&\qquad=k^{pgb}(d_{init}^{pgb}+d_{stroke})-F_{punch}
\end{aligned}
\qquad \text{Equation. 2}
$$

If the friction force is ignored, the force on lifter(lifter force) can be calculated by Equation 2. This research applied the value of lifter force as much as knowing PGB's 40% empirically in the progressive stamping process.

On the method of the above mentioned, FE Model was bulited as shown in Fig.8. As shown in Fig.8, the symmetirc boundary conditions on the blank were applied by the same pattern in the progessive stamping process.

Observed each head, middle and section of tail part as see in Fig 9 to observe the quality of product by this reverse stamping. Head,middle and section of tail were observed to review the section shape of the connector pin(Fig.9). To access the suitable level of force on lifter, it was performed the case study that impose the force on lifter that corresponds to 2 times of lifter force as given.

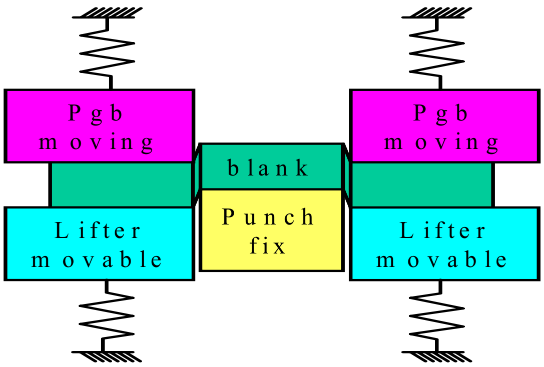


Fig 7a. Schematic drawing of reverse stamping

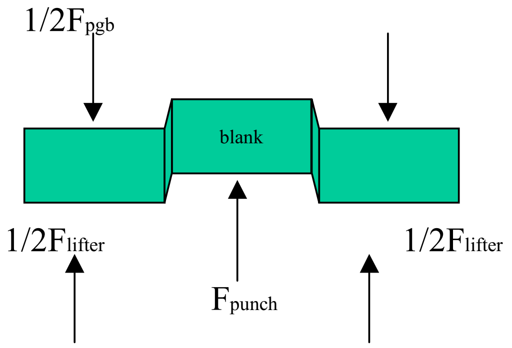


Fig 7b. Schematic drawing of reverse stamping

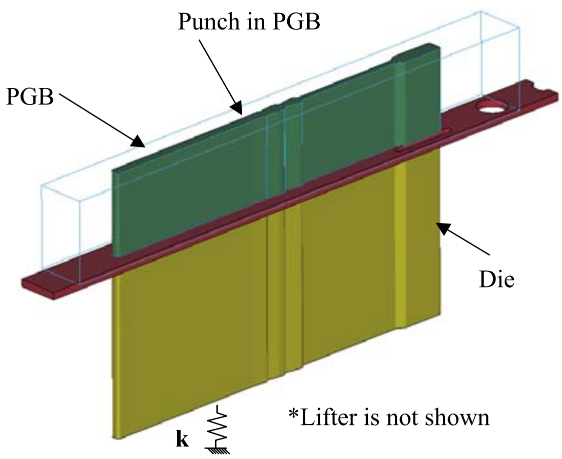


Fig 8. Reverse stamping layout(FE Model)

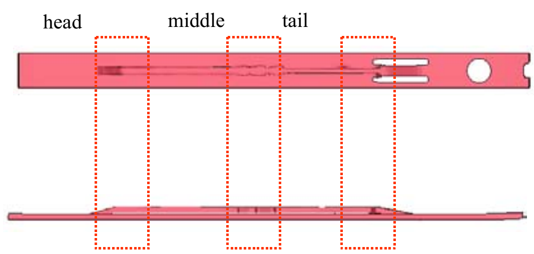


Fig 9. Connector pin made by reveres stamping process

3. Result

3.1 Result in the convention stamping process

4.1.1 Review of section shape

Deformation shape of section at the first stamping process and at the second stamping process were shown in Fig.10~ 11 at Section A-A‘ that is the width of section. A-A‘ is 1.2 times of the blank’s thickness.
At the first stamping process, the fracure of blank was occurred when the punch‘s stroke was reached at 45% of blank’s thickness(Fig.10) and ingeddients become fractured perfectly when the punch’s stroke reached at 75% of blank’s thickness. The section shape of blank maintained as symmetric. Otherwise at the second stamping process, although the fracture of blank was occurred at 45% of blank’s thickness, but the bottom of region was deformed in asymmetry shape by compression, and punch’s stroke at 75%, the rotation was observed .

Deformation shape of section at the first stamping process and the second stamping process were shown in Fig.12~ 13 at Section B-B‘, which the width of section A-A‘ is 1.5 times of the blank’s thickness.
At the first stamping process, the fracure of blank gets up when the punch‘ stroke reachs at the 45% of blank’s thickness.(Fig.12) and ingedients becomes perfectly when the punch’s stroke reached at 75%. The section shape of blank maintained as symmetric. At the second stamping process, although the rotation was observed but was not severe as compared of that of section A-A‘. Also, when the punch’s stroke reached at 75%, the rotation of the blank was observed in Fig.13.

Deformation shape of section at the first stamping process and the second stamping process were shown in Fig.14~ 15 at Section C-C‘, which the width of section A-A‘ is 1.0 times of the blank’s thickness. At the first stamping process, the fracure of the blank gets up when the punch‘ stroke reachs at the 45% of blank thickness. (Fig.14) and ingedients becomes perfectly when the punch’s stroke reached at 75%. The section shape of blank maintained as symmetric. At the second stamping process, when punch’s stroke reached at 45% as shown in Fig 15, the fracture of blank was begun and the bottom of region was deformed in asymmetry shape by compression and the amount of this deformation was observed much relatively severe comparing to that of A-A 'Section or B-B' section.
For reference, as shown in Fig 16, there is several facts that the behavoirs in FE model are not reflecting realastic deformations of part A and B, but the effects of the applied boundary conditions on the blank in this analysis is not severe, because the

parts which the boundary conditions were applied were excluded by stamping process.

More correct results would be gotten if the study about the boundray conditions problems was carried out after this research.

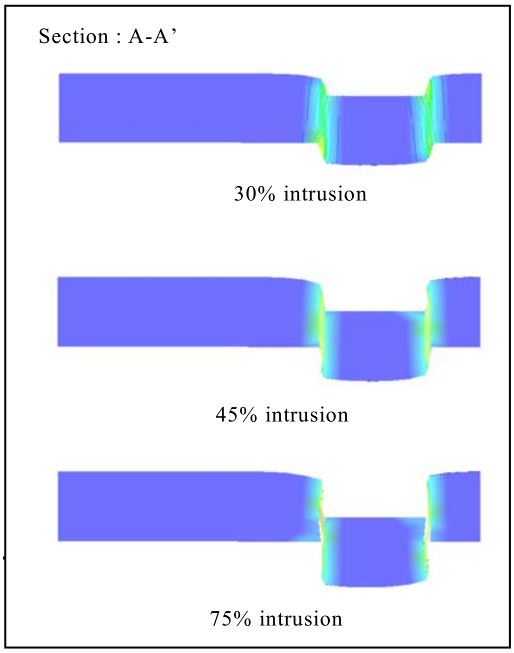


Fig 10. Deformation shape of section A-A' at first stamping process

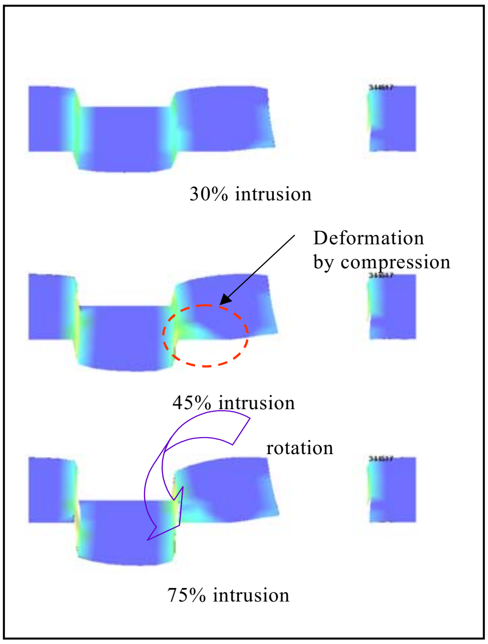


Fig 11. Deformation shape of section A-A' at second stamping process

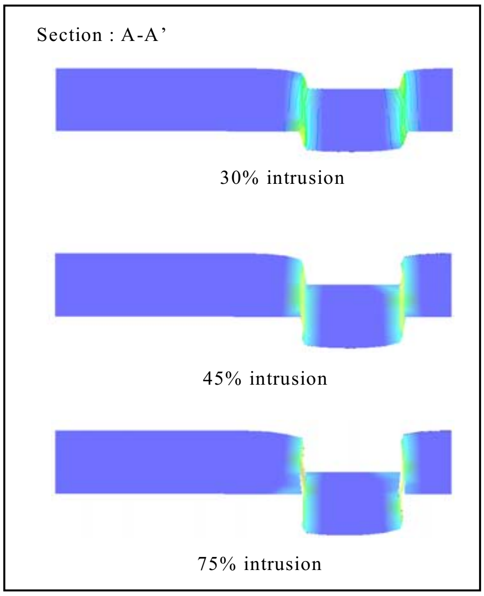


Fig. 12. Deformation shape of section B-B' at first stamping process

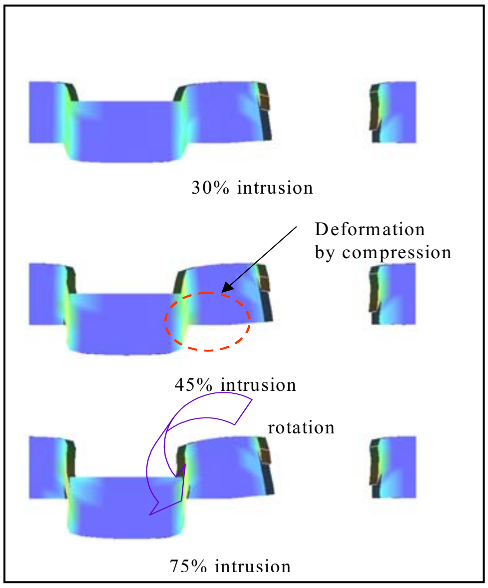
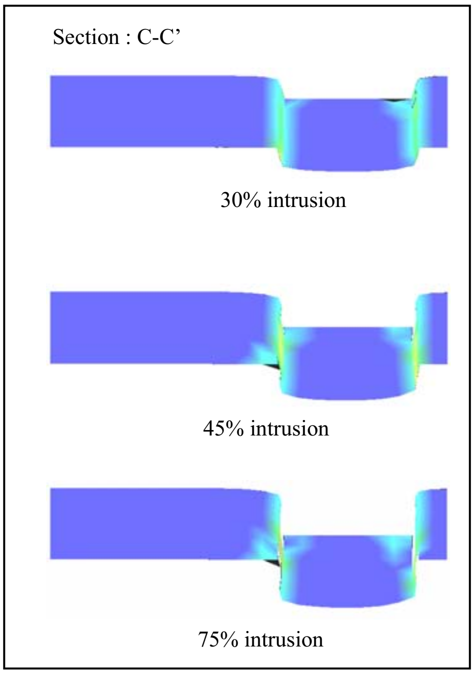


Fig 13. Deformation shape of section B-B' at second stamping process



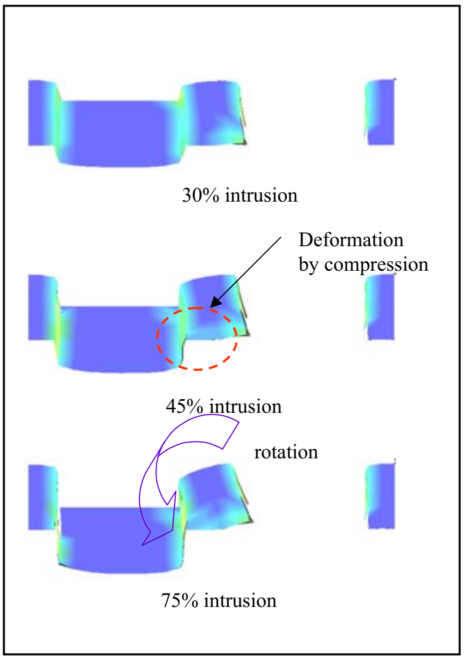


Fig 14. Deformation shape of section C-C' at first stamping process

Fig 15. Deformation shape of section C-C' at second stamping process

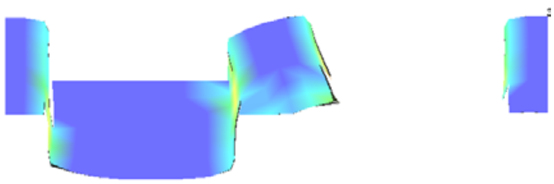


Fig 16. Deformation shape of section

4.1.2 Deformation shape after spring back

The spring back by the residual stress on the blank after stamping process causes the behavior that (in Fig 17 arrow direction), the connector pin is such to become shift for the second stamping process's direction. Fig. 17 shows the shape of connector pin deformed by springback.Red one is a shape before springback , and blue one is a shape after springback.Fig 17 ~ 18 is expressing well that connector pin becomes shift by showing image of each section.

Also, Fig 19 is a typical section of deformed connector pin. As see ,the section of connector pin is asymmetry structure when do via center-line.

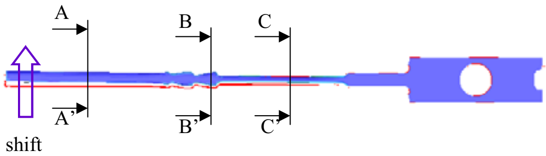


Fig 17. Comparison of deformation shape before springback & after springback

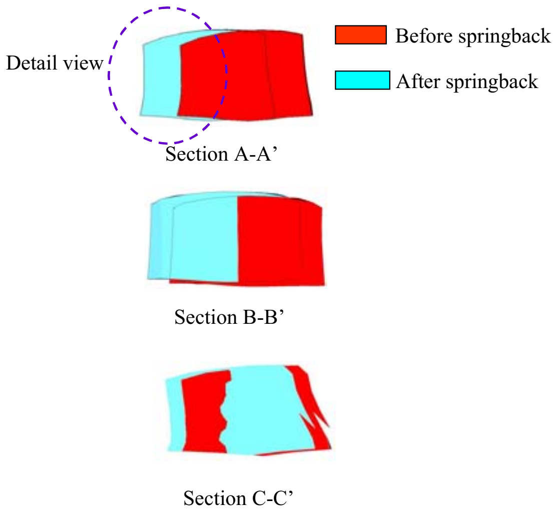


Fig 18. Section shape of connector pin

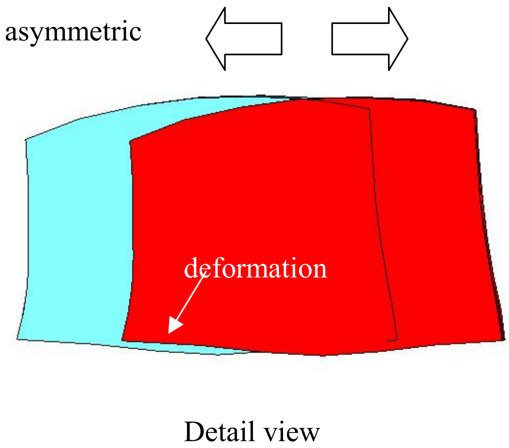


Fig 19. Detail view of section A-A'

4.1.3 Forces on tools

As shown in Fig 20a ~ Fig 20b, compared the punch force of first stamping process and of second stamping process, the punch force is higher in second stamping process. For this reason, the length of the fractured zone became short and the length of the shear zone became long by the effect of the rotation of blank.

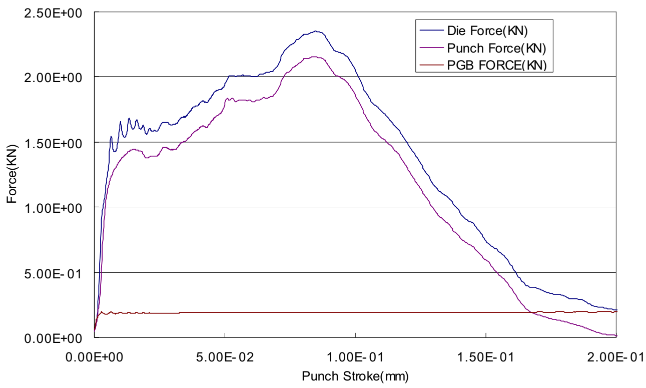


Fig 20a. Force curve of tools at first stamping process

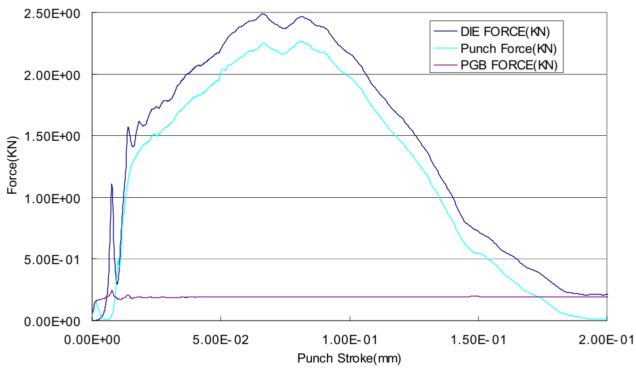


Fig 20b. Force curve of tools at second stamping process

4.2 Result of Reverse Stamping Process

4.2.1 Review of Section Shape

Two case studies were carried out to access the effect of the force on lifter in the reverse stamping process. Case1 was that the force on lifter is 40% of the force on PGB in the progressive stamping process, and Case 2 is that the force on lifter is increased to 2 times than value of case 1.

Figure21 ~ 23 show about deformation shapes from Head, Middle, Tail of connector pin , burrs was shown little in connector pin in case of Case 1, but could be observed in the blank.

While, in the case of Case 2, burrs do not exist in all connector pin and the blank as compared with Case 1. From this result, concluded that the increment of force on the lifter reduced phenomenon that burrs were generated in the blank , and that the design of tool's layout was needed to get the well-stamped section shape of the connector pin, because an undesirable shape observed in Fig 23 was due to the design of tool's layout.

The section shape of connector pin in the reverse stamping process is symmetry referring to Fig 24.In the case of Case1 because the pressing force is not sufficient to press the blank down, the rollover on the blank was severe, but in the case of Case 2, because the tools were pressing the blank effectively than in the case of Case1, the rollover on the blank was less severe than that in the case1.

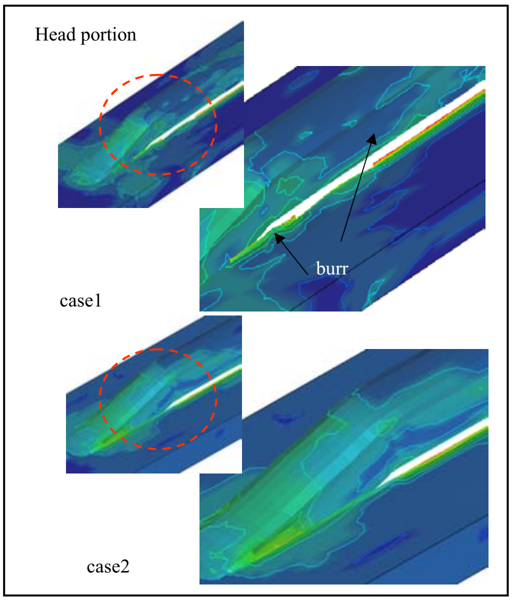


Fig 21. Comparison of head part of blank

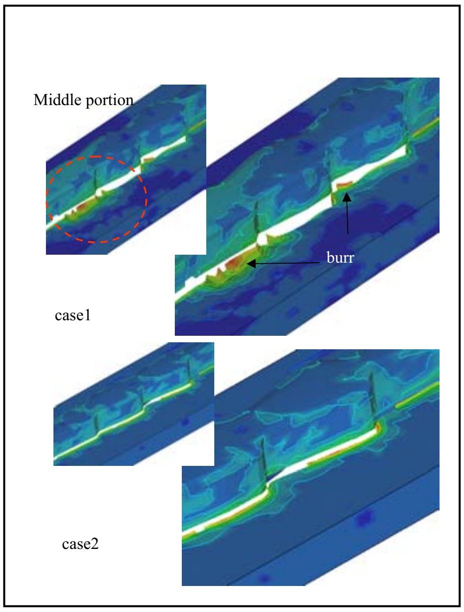
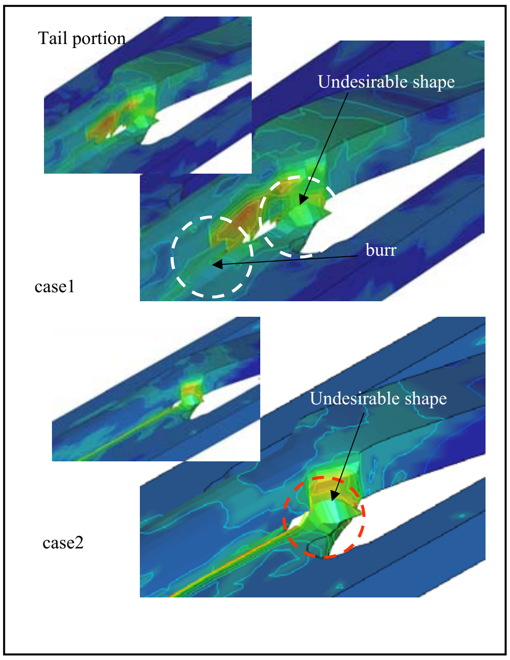


Fig.22. Comparison of middle part of blank



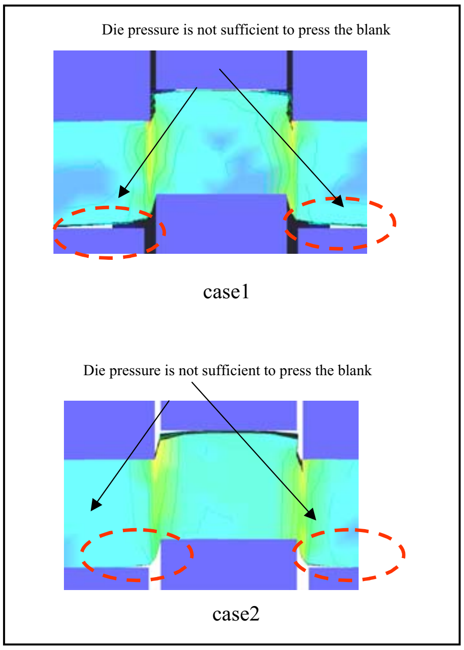


Fig 23. Comparison of tail part of blank

Fig 24 Comparison of section shape of blank at PGB' stroke 30% of thickness

4.2.2 Force curve on tools

Figure 25 is displaying forces that act on die in case1 and case2. Comparring to the die force of Case 1 and that of case 2, the level of the force on the case2's die is higher than that of case 1, is short relatively in PGB stroke. These reason is that the length of the fractured zone in Case 2 is shorten relatively by the well-pressed. Figure 26 shows the force and on lifter and on PGB of Case1 and Case2, the slant of the lifter force in Case2 is 2 times high as that in Case1.

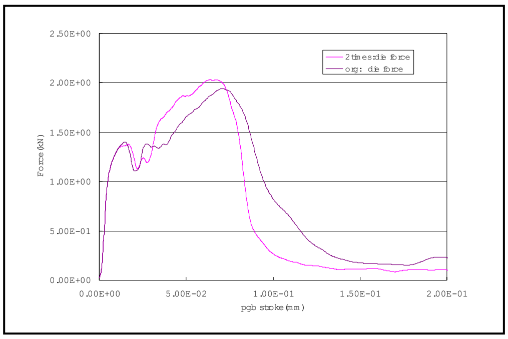


Fig 25. Die force (case1 vs case2)

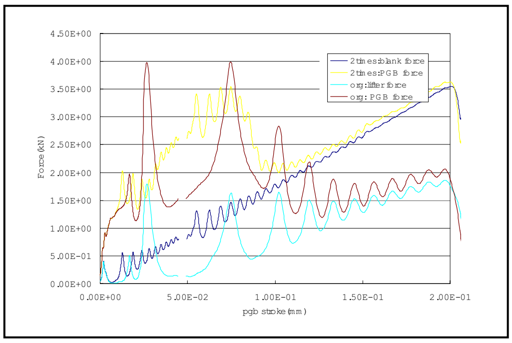


Fig 26. PGB force on tools(case1 vs. case2)

4.3 Production for test

The picture of the reverse stamping tool were shown in Fig. 27 ~ 28. Fig 29 is a picture of test product, and Fig.30 represents the section picture by SEM . As see in Figure, defects such as burr that happen in conventional stamping process in connector pin is not found. and the shape of the section is symmetric.

Fig 27. PGB for reverse stamping

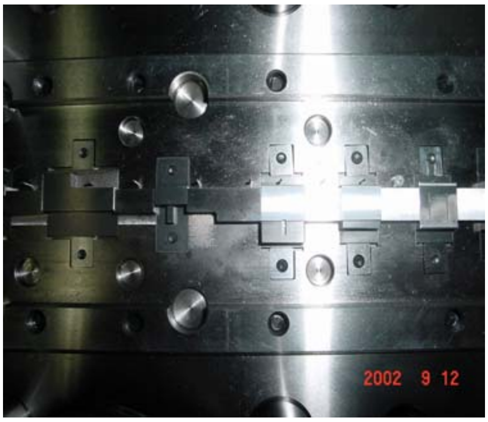


Fig 28 Lifter for reverse stamping

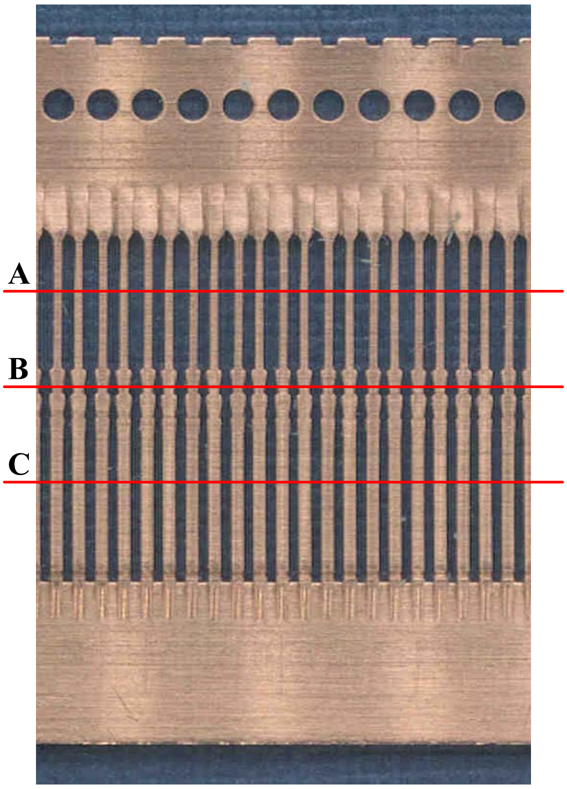


Fig 29. Connector pin of reverse stamping process

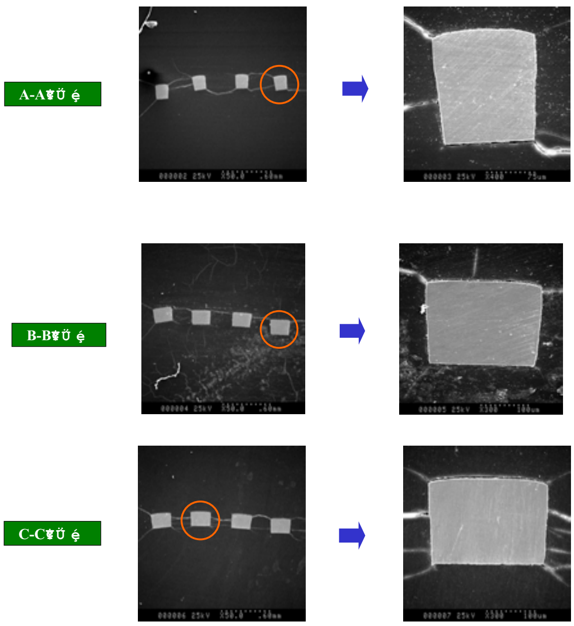


Fig 30. Section view of connector pin(SEM) in reverse stamping process

5. Summarys and Conclusions

We could get the following conclusions by this reasrch.

1. estiblish the baseline of analysis using FE in the stamping process
2. propose the forces on tools in the reverse stamping
3. produce the test-product by new stamping process(reverse stamaping)
4. reduce the trial-error for the design of the stamping tool.

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