Simulation of Stamping Process of Automotive Panel Considering Die Deformation


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Abstract. In order to see the effect of die deformation on the forming of sheet metals, the draw-ins, strains, and spring-backs of an automotive fender panels are numerically simulated considering the die deformation, which is found by the simultaneous structural analysis of press and dies. By coupling the forming analysis and the structural analysis, the die deformation is simultaneously taken into account in the forming process. Furthermore, for the consideration of load difference transferred among the upper die, punch, and blank holder due to the changes in sheet thickness, the gap elements are employed instead of the blank sheet in the structural analysis. The numerical simulation results of an automotive fender draw panel are compared with the measurements. The comparison of the forming and spring-back analysis results between the rigid die and the deformed die shows that the deformed tool provides more accurate forming and spring-back prediction.

1. INTRODUCTION

In order to develop the stamping dies, the trial-and-error method still prevails by the die makers. One of the main reasons why the trial-and-error method can not vanish in die making industries may be the consideration of die deformation. In addition, for the success of stampings, the clearance between upper and lower dies should be kept in a constant gap. However, the changes in the clearance are invoked by the local die deformation happened when the forming loads such as blank holding force, press pressure, etc. are imposed to the dies. The changes in die clearance unevenly provide high forming pressures at the contact surfaces between blank and tools so that not only the sheet is not uniformly formed but also the spring-backs are inaccurately predicted. Moreover, the forming simulation in which the die, punch, and blank holder are assumed to be rigid ignores the elastic deformation. Therefore, as the elastically deformed die surface affects the simulation results like draw-ins, strains and spring-backs, the consideration of the changes in die profiles may be needed for improving the accuracy of the virtual prediction for forming variables and spring-backs.

In this study, in order to accurately simulate the forming process of automotive panels, the simultaneous structural analysis and coupled forming analysis are employed. Then the structural, forming and spring-back analyses of an automotive fender draw panel are carried out and the spring-backs, strains, and draw-ins between the simulations using rigid tools and deformable tools are compared.

2. PRESS/DIE STRUCTURAL ANALYSIS

The structural analysis for evaluating die deformation has been mainly carried out for each die member [1], and the stress analysis for finding press deformation has been individually carried out for each press member. Since the die deformation is influenced greatly by press deformation, a consideration of these mutual interactions is essential. In order to see the effect of mutual interactions, the structural analyses considering the interaction between the press and the die are performed and the deformation and strength of the press and dies are examined.
2.1 Modeling

Figure 1 shows the finite element model for the structural analysis of the press/die, which is consisted of upper die, punch, holder, press slider, and cushion pad. The finite element model employs 133,618 quadratic tetrahedron solid elements and 3,118 quadratic 4-node shell elements.

The upper die fixed to the press slider descends together and the punch fixed on the bolster is stationary. The blank holder, which is supported by the cushion pad, holds the blank sheet and controls the drawing between the upper die and the punch. The 1300 ton press/die model shown in Fig. 1 has 875 tons of forming force by the punch and 75 tons of blank holding force deliverable to the blank holder by the action of cushion pad.

The press slider transfers the forming load to the upper die via 7 hydraulic cylinders and the cushion pad delivers the holding load to the blank holder via 1 hydraulic cylinder. The rigid elements are used for connecting the press slider and the upper die. The contact boundary conditions are imposed at other contact area between the press slider and the upper die, where the rigid elements are not employed. Using the spring elements, furthermore, the cushion pad and the blank holder are connected. 4 corners of both press slider and cushion pad are constrained to move in the vertical direction only.

As the forming process proceeds, the blank thickness varies. Therefore, in order to count for the load differences transferred among upper die, punch, and blank holder by the changes in sheet thickness, the contact boundary conditions, which the changes in blank thickness are considered, are needed. To consider the changes in the blank thickness more accurately and simply, the thinned sheet obtained from the forming analysis is replaced by the gap element.

2.2 Results

Figure 2 shows the deformation distributions of the upper die, punch, blank holder after the panel is completely formed. Due to the load of press slider, large deformations are caused and big stress are concentrated in the upper die. In the distance blocks, and bottom blocks, the high stresses are found. The maximum deformation in the dieface contacting with the blank sheet is 0.14mm. Diefaces of upper die, punch, and blank holder deformed are utilized for the forming analysis as tool profiles.
3. FORMING ANALYSIS

3.1 Procedure

Figure 3 shows the procedure of the forming analysis based upon deformed dies. For the die structural analysis, gap elements are generated instead of blank elements using the blank thickness information obtained from the initial forming analysis based upon the die shapes in the current time step. Then, the shapes of deformed die faces generated in the press/die coupled structural analysis are employed as tool profiles in the forming analysis. When the draw-ins, strains, and spring-backs obtained from the forming analysis, which uses the deformed die shapes, are compared with those of the previous iteration, if the forming analysis results of the previous iteration are the same as those of the current iteration, the forming analysis based on deformed dies in the present time step is completed. Otherwise, the forming analysis is repeated until the forming analysis and the structural analysis are compatible.

3.2 Modeling

Since the blank sheet contacts with the upper die and the punch in some areas at the initial forming stage, the dies deform a little. Therefore, in this study, the die deformation is assumed to exist after the forming process 90%.

Rigid tool analyses are performed by using the upper die, blank holder and punch which are rigid and not deformable (see Figure 4), and the deformed tool analyses are carried out after the rigid tool analyses are performed drawing process. For the forming analysis of the remaining 10%, the deformed upper die, punch, blank holder obtained from the structural analysis are to the blank sheet formed up to 90% drawing process.

For the forming analyses, the minimum size of the blank element is 2mm x 2mm, and 4-node shell elements are employed. For the description of the dies, linear 3-node shell elements are used. The number of finite elements for the upper die, blank holder, and punch are 5678, 1226, 4897, respectively. The punch speed, holding speed, and the blank holding force are 5m/s, 2m/s, and 75 tons, respectively. Figure 5 shows the tooling layout, which uses in the deformed tool analysis.

FIGURE 3. Flow chart for considering the die deformation in a forming analysis step.

FIGURE 4. Layout of draw dies for the forming analysis based on rigid tools.

FIGURE 5. Layout of draw dies for the forming analysis based on deformed tools.
3.3 Result

As described in the previous paragraph, the forming analysis based on the deformed tools has the character that the forming analysis and the structural analysis are compatible because, as the forming proceeds, they are performed several times until satisfied solutions are observed. The differences in draw-ins, thickness strains, and spring-backs are decreased as both analyses are repeated and a few iterations are needed for the compatibility. Followings are comparison of the draw-ins, strains, and spring-backs between the forming analyses using deformed tools and rigid tools.

3.3.1 Draw-in

Figure 6 shows the comparison of draw-ins between the rigid tool analysis and the deformed tool analysis. Because of the gap distance occurred due to the elastic deformation of the die, the maximum difference in the draw-in between both analyses was 10 mm, and comparing with the actual die and panel, the draw-ins obtained from the deformed tools were closer to actual tryout measurement. From this observation, it is clear that that the deformation of dies affects greatly on panel's draw-in and the forming analyses considering die deformation are needed for the accurate simulation.

![FIGURE 6. Comparison of draw-ins between rigid and deformed tool analyses.](image)

3.3.2 Strain

Figure 7 and Figure 8 show the distribution of thickness strain obtained using rigid tools and deformed tools in the draw forming process. The overall strain distributions show similar tendency and the maximum strain computed using deformed tools appears to be 7% lower.

![FIGURE 7. Strain distribution obtained from rigid tool analysis.](image)

![FIGURE 8. Strain distribution obtained from deformed tool analysis.](image)

3.3.3 Spring-back

Figure 9 and Figure 10 show the distributions of the spring-back in normal direction obtained from the rigid and deformed tools, respectively. In the special areas where the spring-back occurred, the result of the forming analysis which uses the deformed tool is bigger than that of the forming analysis which uses the rigid tool. It indicates that there are big difference in the spring-back due to the differences in the thickness, strain, and draw-in of the panel which uses the deformed tool.
Figure 11 shows the automotive fender section lines to compare the spring-backs between the deformed tool analysis results and the rigid tool analysis. Figure 12 shows the comparison of spring-backs between two analyses. There are little discrepancy between both analyses, but the deformed tool analysis generally bigger spring-back than the rigid tool analysis.

**FIGURE 9.** Spring-back distribution obtained from the rigid tool analysis.

**FIGURE 10.** Spring-back distribution obtained from the deformed tool analysis.

**FIGURE 11.** Sections to compare spring-backs between rigid and deformed tool analyses.
4. CONCLUSION

In this study, the forming and the spring-back analyses of an automotive fender panel were carried out coupling the forming analysis and the structural analysis for considering die deformation. Through this research, the followings are summarized and pointed out.

1. The distributions of stress and deformation of the dies are obtained by introducing the simultaneous dies-press analysis.
2. By adopting deformed tools found by the structural analysis in the forming analysis, the draw-ins, strains, and spring-backs in the draw panel were accurately predicted.
3. The spring-back predicted by the deformed tool is bigger than that of the rigid tool and is closer to the measurements than the rigid tool.

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