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FINTE ELEMNT ANALYSIS OF DRAW-WALL WRINKLING IN A STAMPING DIE DESIGN

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Summary. *The 3-D finite element simulations were employed to analyze the draw-wall wrinkling in a stamping process. The major cause for the occurrence of wrinkles was identified and an optimum die design was developed according to the investigation of the material flow obtained from the finite element simulation results. The validity of the finite element analysis was confirmed by the sound production part.*

1 INTRODUCTION

Wrinkling is one of the major defects that occur in the sheet-metal forming process. For both functional and visual reasons, wrinkles are usually not acceptable in a finished part. In the present study, a wrinkling problem occurred in a stamping part used for a motorcycle oil tank was examined using the 3-D finite element analysis. In order to perform an accurate finite element analysis, the actual stress-strain relationship of the sheet metal was obtained from tensile tests. The sheet-metal flow due to the original die design was first examined and the possible reasons causing the wrinkling problem were then identified based on the finite element analysis. A detailed investigation on the material flow during the wrinkle formation process helps in the determination of the major cause for the occurrence of wrinkles and in the development of an optimum die design. Both the original and the optimum die designs are briefly described in the following.

2 ANALYSIS OF ORIGINAL DIE DESIGN

The finite element meshes for the original die design are shown in Fig. 1. It is seen that a feature shape is added to the die addendum in addition to drawbead around the periphery of the die cavity that are supposed to control the material flow into the part shape. However, the finite element simulation result reveals that both wrinkles and fracture are observed in the deformed shape, as indicated in Fig.2. The fracture occurred at location B, as shown in Fig. 2, may be attributed to a small corner radius at B or a larger blank-holder force applied, which is easy to cope with. But the wrinkles appeared in the C-D area, as shown in Fig. 2, are not expected. In order to determine the possible reasons that cause wrinkles, the strain history of elements in the C-D area was examined. Figure 3 shows the plot of major and minor principal strains of an element in the C-D area during the stamping process. It is noted in Fig. 3 that the difference of the major and minor principal strains increases abruptly when the punch contacts the blank at point B, which implies that wrinkles may start to form at this point. A detailed examination of the deforming shape during the stamping process confirms that wrinkles are formed when the punch contacts the blank at point B. In order to eliminate the wrinkles, the effects of the process parameters such as blank-holder force, blank size and draw-bead restraining force on the formation of wrinkling were studied and possible solutions were tried. However, the finite element simulations results indicate that wrinkles could not be completely eliminated by adjusting the above process parameters, on the contrary, the fracture problem becoming more serious. In addition, the corner radius at location B was also enlarged to help the material flow, but the fracture problem could not be eased.

3 AN OPTIMUM DIE DESIGN

A detailed investigation on the material flow during the wrinkle formation process revealed that the uneven stretch between the highest portion of the part, point A, and the draw-wall at the part edge, point B, as shown in Fig. 2, might be the critical reason causing the wrinkling problem. The finite element analysis was then employed to examine the effect of the die geometry on the formation of wrinkles. The trim line on the die shape was first identified and modifications on the die shape outside the trim line were then made according to the finite element simulation results. It is inferred that wrinkles could be eliminated if the punch-blank contact at location B is delayed and the contact area is increased. That means the vertical distance between point A and point B, as shown in Fig.4, should be increased and the corner radius at point B needs to be more generous to enlarge the contact area. The finite element simulations were performed for various corner radii in a selected increment at point B. The simulation results show a significant improvement on the elimination of wrinkles with the increase of the corner radius. However, wrinkles still could not be completely disappeared. A further investigation on the material flow for various corner radii found that a replacement of the sharp corner by an inclined flat surface could increase the vertical distance between point A and point B, also the contact area at point B to the most. The finite element simulation results revealed that both wrinkles and fracture were eliminated with the above design. To complete the die design, the blank shape was modified as well to a suitable shape with smaller dimensions. An optimum die design was then achieved by the finite element analysis.

A production die set was manufactured according to the optimum design and a sound part without wrinkles and fracture was produced, as shown in Fig. 5. The thickness distribution along C-D was measured from the production part and compared with that obtained from the finite element simulation, as shown in Fig. 6. The good agreement between the simulation results and those measured in the drawn production part demonstrates the accuracy of the finite element analysis.

4 CONCLUSIONS

The finite element analysis indicates that an uneven stretch between two unleveled portions in a stamped part is apt to inducing wrinkles. A detailed investigation on the material flow during the wrinkle formation process reveals that an increase of the vertical distance between the two unleveled portions, and an enlargement of the contact areas are found to be very effective in eliminating wrinkles due to the uneven stretch. The sound production part and the good agreement between the simulation results and measured data confirms the effectiveness of using the finite element simulations as a substitute for the expensive method of actual die try-outs is thereby confirmed.

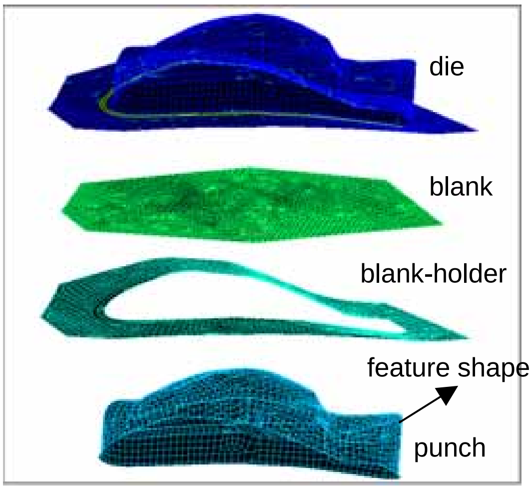

Fig.1 Finite element meshes for the original die design.

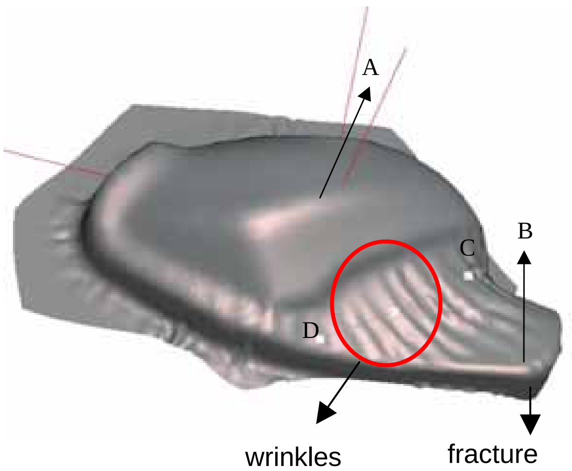

Fig.2 Appearance of wrinkles and fracture.

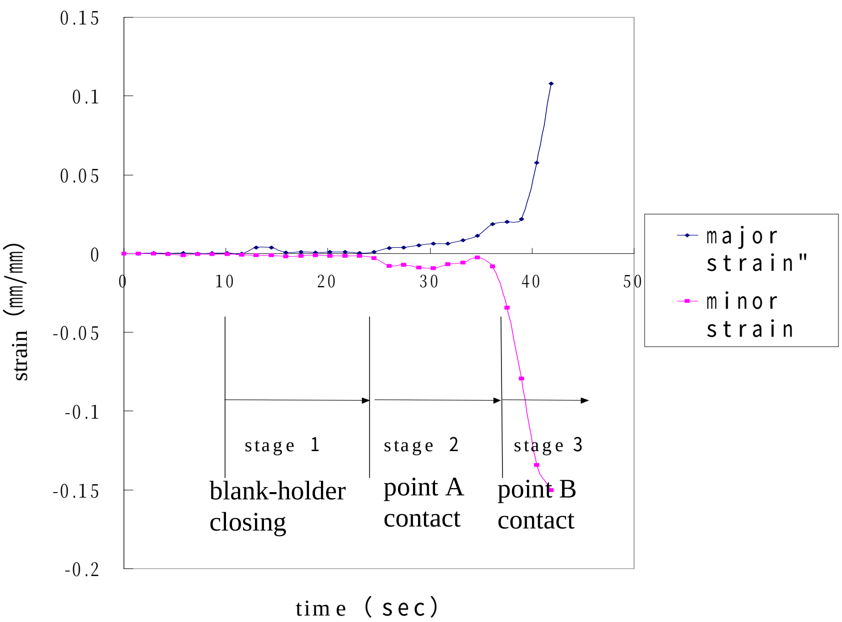

Fig.3 Strain history of an element in the wrinkling zone.

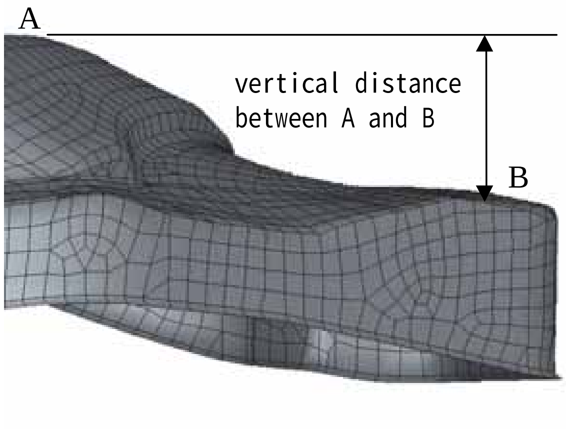

Fig.4 The vertical distance between point A and point B.

Fig. 5 A sound production part without wrinkles and fracture.

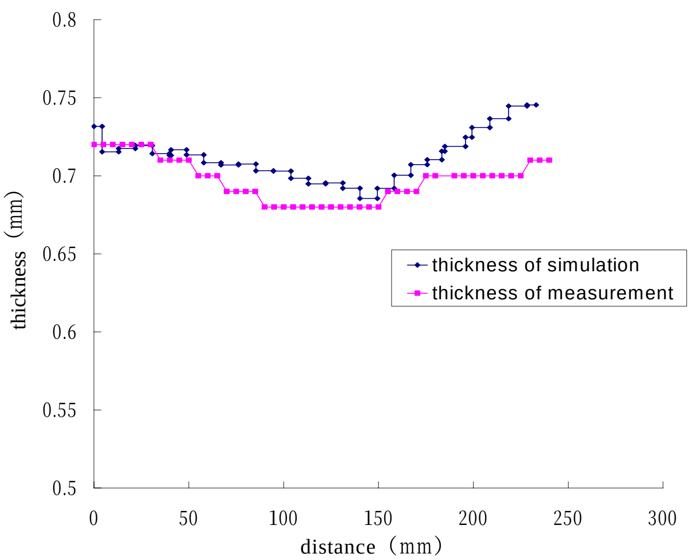

Fig. 6 Thickness distribution along the wrinkling area.