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Optimum blank shape design in sheet metal forming by boundary projection method

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ABSTRACT: The optimum blank shape is the minimization of the difference between the target contour of the part and the outer contour of the deformed blank. The main objective of this paper is to introduce a new blank design method based on iterative finite element (FE) sheet metal forming simulations. The algorithm is based on the projection of the target contour on the deformed blank and modifying the blank shape accordingly. The developed algorithm is applied a square cup drawing in order to confirm its validity.

Keywords: Optimum blank design-sheet metal forming-FE simulation

1 INTRODUCTION

A problem that has attracted some attention in the recent past years is optimum blank shape design for the sheet metal forming. Optimum blank shape has many evident advantages. The optimum blank not only improves formability and product quality but also reduces material cost, number of trials in the try-out stage and product development period. Moreover, the optimum blank shape leads to the prevention of tearing, the uniform thickness distribution and the reduction of the press load during drawing. However, it is not easy to find optimum blank shapes because of the complexity of material behavior especially in the actual stamping dies described with 3D CAD data.

Designing of blank shape have been widely studied by many researchers. Hazek and Lange [1] and Karima [2] used the slip-line method to design the initial blank. Chung and Richmond [3, 4] proposed a direct design method and its theoretical basis to get an initial blank shape of the sheet metal component. These studies did not consider the real forming conditions, such as blank holding forces, friction and tool geometry. Barlet et al. [5] and Lee et al. [6] proposed an inverse design approach using a mathematical technique to obtain blank shapes, considering contact conditions between the tool and metal sheet. Analytical methods using the FE analysis code were also developed [7, 8]. However, expensive computational time is required in order to obtain a precise blank shape.

In this paper, an effective algorithm called boundary projection method based on finite element simulation is presented for arriving at the optimum blank shape. This technique approximately develops the component shape onto a 2D plane. FE analysis is used to simulate the forming process with real processing parameters and a shape of the formed part is obtained, which is compared with the shape of the initial CAD design.

The FE forming simulation is carried out by using the commercial FE code, Ls-Dyna. The material properties, the friction between the material and the tools and the blank holding force affect the deformation of the material and thus affect the blank dimension. The effects of these parameters on blank shape can be rationalized via FE simulation. Two examples are used to evaluate the proposed algorithm. The results show that the optimum blank shape can be obtained in a few iterations compared to other methods.

2 BOUNDARY PROJECTION METHOD

Figure 1 shows a detailed algorithm of the proposed method. In the process of the blank design, an interface program is developed to connecting the FE analysis package, the blank design module, and the re-meshing module. All parts including die, punch, blank holder, and initial blank are first modeled. The process parameters such as punch movement, blank holder force, friction coefficient, and contact conditions are determined. The initial blank is deformed using FE analysis.

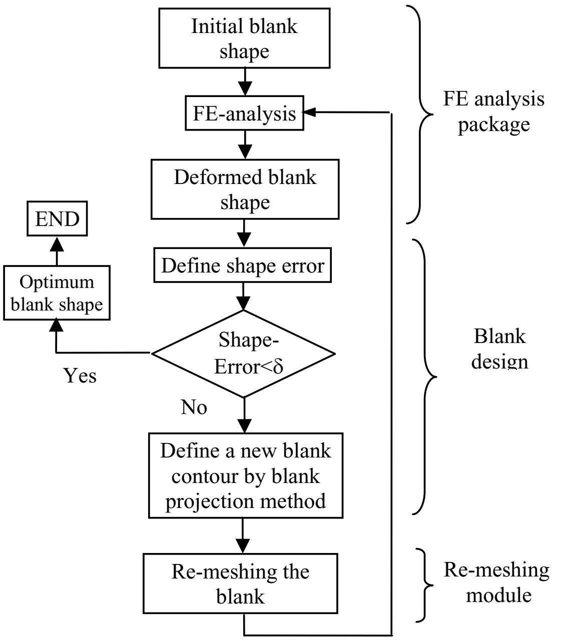

Fig. 1: Schematic diagram of boundary projection method

If the shape error becomes greater than specified value, the boundary projection method is used to minimize the shape error. The geometrical shape error is defined as the difference between the deformed blank contour and the target contour. The target contour is generated from outer contour of the product. In this stage, the procedure to define the new blank shape is started from the projection of the target contour to the deformed blank. Knowing the elements that the boundary is projected on, the position of the projected boundary is defined on the initial blank. In this way, a new blank contour is defined and the re-meshing module is used to define a new blank shape model.

The new blank is deformed using the FE analysis again and its boundary is compared with the target shape. If any shape error is remaining, the whole procedure is repeated until the error becomes smaller than the given error bound.

In FE modeling, the blank is defined by triangular elements and the target contour is defined by a set of points. The first step to define the new blank contour is to project each point of the target contour on the deformed blank elements obtained by FE analysis. To define the elements close to each point, a search is done, and the element that the point has the perpendicular projection on it is selected.

To transfer the position of this point on the same element on the initial blank, the element is redefined by a rectangle bilinear parametric surface. After projection of the point on the selected element, the parameters (u, v) of this point are first determined (Figure 2). To allocate the location of this point on the initial blank, the same parameters (u,v) are used on the surface defined by the same elements on the initial blank. Therefore, the point is mapped back into the mesh system of the initial blank.

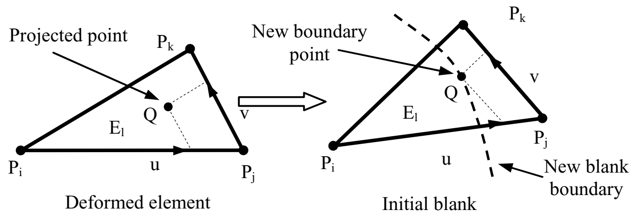

Fig. 2: Define the new blank boundary by point transformation

If the projection point falls out of deformed blank, the closest element to this point (ie. E_2 in Figure 3) is first determined. Then, the minimum distance d between the projected point and this element is calculated. Next, a point is generated with the same distance from the defined element (E_2) on the blank boundary. In this way, a new blank boundary is defined and a new blank mesh is accordingly generated. The new blank shape is used for the next iteration.

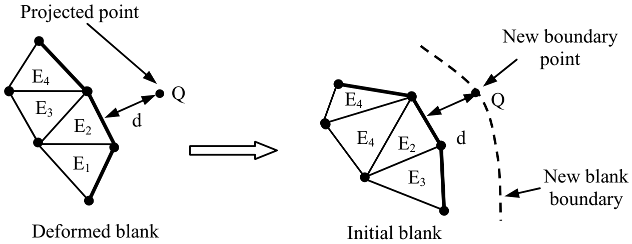

Fig. 3: Point transformation out of deformed blank

The geometrical shape error is defined as root mean square of the shape difference between the target shape and the deformed shape as:

$$Error = \sqrt{\frac{1}{N}\sum^{N} d_i^2} \qquad (1)$$

where d_i is the distance between the target shape and the deformed shape along the deformation paths, and N is the number of nodal points along the boundary of the blank.

3 EXAMPLES

To verify the validity of the boundary projection method, the algorithm is applied to the process of square cup deep drawing shown in Figure 4. In this work, the desired blank shape for a square cup has 31 mm height and 5 mm width of flange. The sheet metal is cold-rolled steel; sheet thickness, 1.0 mm; friction coefficient, 0.125; press stroke speed, 2000 mm/s; blanking holding force, 200 kN; Young's modulus, 210 GPa; Poisson's ratio, 0.3. When an 165 mm ×165 mm square blank is used for an initial blank, the results show that the shape error significant (Figure 5). The outer contour of deformed blank, the target contour, and the initial blank boundary are shown in Figure 6. The first modified blank shape can be calculated with the result of the initial square blank. The analysis result of this step is shown in Figure 7. The difference between the deformed shape and the target contour is remarkable. When the blank design process is repeated three times the difference decreases and converges to zero (Figure 8). Hence a square cup with a uniform flange at its periphery can be made. The final blank shape of square cup is shown in Figure 9. The FE analysis of the final stage is shown in Figure 10.

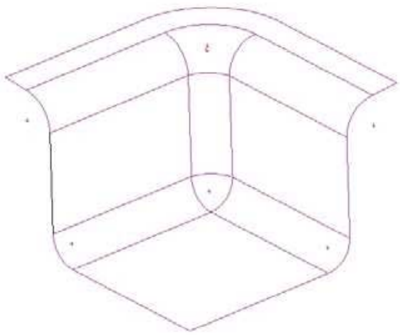

Fig 4: The square cup part

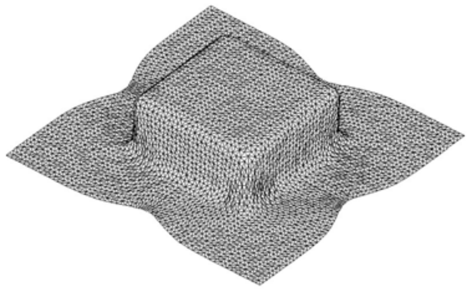

Fig 5: The FE analysis result of initial blank

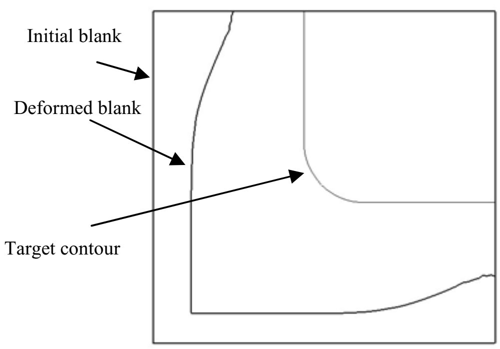

Fig 6: The result of first step

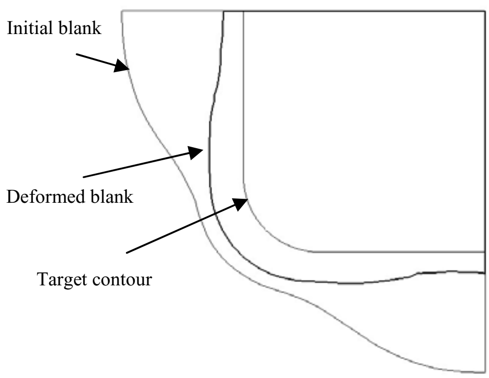

Fig 7: The result of second step

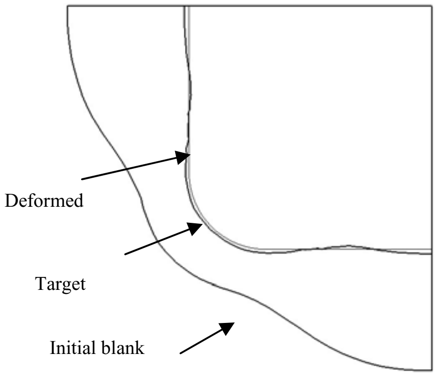

Fig 8: The result of third step

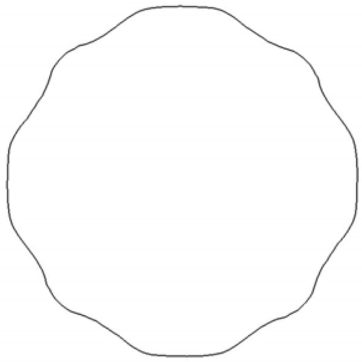

Fig 9: The optimum blank shape

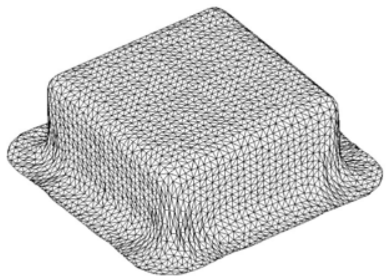

Fig 10: The FE analysis result of optimum blank

4 CONCLUSIONS

A new method of optimum blank design has been proposed by using the boundary projection method. The method was integrated in the finite element modeling of sheet metal-forming process. Deep drawings of an S rail and a square cup have been treated as examples. It has been found out that with a few iterations (three), the deformed contour shape becomes almost coincident with the target shape. The results show that the proposed method can reach the desired blank shape within a few iterations. The proposed method can be further applied to optimum blank design of other practical sheet metal-forming problems.

REFERENCES

1. V.V. Hazek, K. Lange, 'Use of slip line field method in deep drawing of large irregular shaped components', Proc. 7th NAMRC, 1979, pp. 65.
2. M. Karima, 'Blank development and tooling design drawn parts using a modified slip line field based approach', ASME Trans. J. Eng. Ind. 111 (1989), pp. 345.
3. Chung, K., Richmond, O., ' Ideal forming. I. Homogeneous deformation with minimum plastic work', Int. J. Mech. Sci. 34 (7), (1992), pp. 575–591.
4. Chung, K., Richmond, O., 'Ideal forming. II. Sheet forming with optimum deformation', Int. J. Mech. Sci. 34 (8), (1992), pp. 617–633.
5. Barlet , O., Batoz, J.L., Guo, Y.Q., Mercier, F., Naceur, H., Knopf-Lenoir, C., 'Optimum design of blank contour using the inverse approach and a mathematical programming technique', Numisheet'96, (1996), pp. 178–185.
6. Lee , C.H., Huh, H., 'Blank design and strain prediction of automobile stamping parts by an inverse finite element approach', J. Mater. Proc. Tech., 63, (1997), pp. 645-650.
7. Toh, CH., Kobayashi, S., 'Deformation analysis and blank design in square cup drawing', Int J Mach Tool Des Res, 25(1), (1985), pp. 15-32.
8. Iseki, H, Murota, T., 'On the determination of the optimum blank shape of nonaxisymmetric drawn cup by the finite element method', Bull JSME, 29(249), (1986), pp. 1033-40.