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Research on the Process of Flexible Blank-holder in Multi-point Forming for Box-shaped Parts

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Abstract. A new forming method using flexible blank holder with multi-point which can restrain wrinkles was discussed. Better forming results were obtained by changing the number of layers of blank holder. The wrinkling phenomenon of sheet metal parts in the course of multi-point forming is studied by finite element numerical simulation. The distribution of stress and strain and sheet thinning of the formed parts in the course of the non blank holder and flexible blank holder were analyzed. It proved that the flexible blank holder with multi-point forming method can effectively restrain the wrinkle of the sheet. In order to verify the feasibility of the new forming method using flexible blank holder with multi-point, series of relevant forming experiments were carried out by multi-point forming equipment.

1. Introduction

The box shaped part has always been a typical example in the research of sheet metal forming process. Through the geometric analysis of the box-shaped part, the different forming regions are divided and the stress and strain state of each region is theoretically analyzed. Schematic diagram of each area of the box is shown in Figure 1.

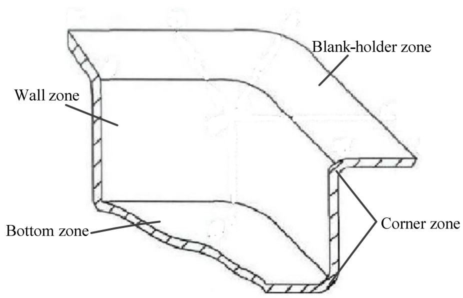

Figure 1. Diagram of each zone of box-shaped part.

Because the box is a typical non-axisymmetric part,during the stamping process,due to local plastic instability of the sheet material, bifurcation deformation occurs from the in-plane to out-of-plane direction, resulting in partial wrinkling.[1] In order to constrain the wrinkling of the flange area of the box-shaped part, the blank holder device is usually applied to impose enough constraints on the sheet to improve the quality of the parts. A group of scholars at home and abroad have conducted related research and achieved certain results. Yossifon et al. [2] conducted a series of different blank-holder experiments to obtain an acceptable blank holder force range. Siegert et al.[3] proposed that controlling the flow of the blank by controlling the blank holder force by means of segmented connection and blanking method ,which plays an important role in the process of sheet metal repetitive forming. Sun Chengzhi et al[4] of Shanghai Jiaotong University deduced a new optimization algorithm to determine the optimal blank holder force, and verified the accuracy of the algorithm through the box-shaped deep drawing experiment, and the best consequence of the box-shaped part depth was given. Li Mingzhe et al [5,6] of Jilin University studied the effect of flexible blank holder(FBH) method on multi-point forming(MPF) results. Gao Guijie et al[7] studied the deep drawing process of rectangular box-shaped parts.

Based on the theory of FBH, this paper studies the effect of the method on the form result of the box-shaped parts studied by changing the number of blank holder layers to improve the flexible of the blank holder. Simulation calculations were performed using display dynamics software and the results of stress, strain, and thinning were compared and analyzed. The simulation results were verified by relevant experiments.

2. Introduction of MPF method for FBH

Multi-point forming uses discrete ideas to replace the traditional three-dimensional curved surface with the regular arrangement and height-adjustable element punches, which is fast, digital, and reconfigurable. Figure 2 shows the sheet forming schematic diagram.

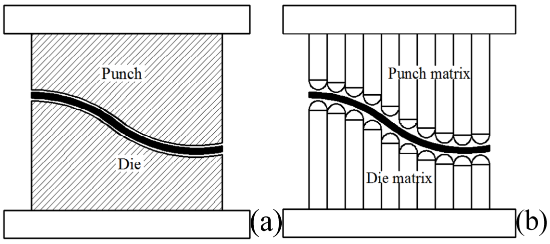

Figure 2. Diagram of sheet metal forming: (a)Traditional forming process. (b)Multi-point forming process.

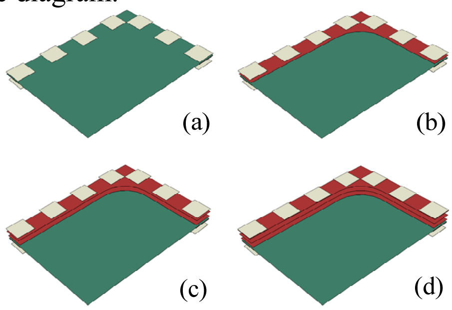

Figure 3. Diagram of flexible blank holder:(a)0mm(b)3mm(c)1mm+2mm (d)1mm+1mm+1mm.

In this paper, taking the non-blank holder（NBH） and the thickness is 3mm of blank holder as an example, this paper compares and analyzes the four kinds of edge-pressed methods of blank holder thickness of 0mm,3mm,1mm+2mm and 1mm+1mm+1mm, and the numerical simulation calculation is carried out to verify the influence of the different layers of the blank holder on the form result of the box-shaped parts. The four methods of blank holder are shown in Figure 3. In the Three types of stratification to the blank holder, the blank holder is divided into two layers of 1mm+2mm, because the average of blank holders into two layers are similar to that in which the holders are evenly divided into three layers.Therefore, the blank holder is divided into two layers with unequal 1mm+2mm. We will not discuss delamination of the blank holder.

3. The establishment of finite element model

This paper studied the target box-shaped part forming depth 20mm.Taking into account the characteristics of the box-shaped surface symmetry, in order to reduce the calculation time, the 1/4 of the whole model is used as the calculation model, and the calculation result are exactly the same as the whole model. The use of mechanical blank holder blocks instead of traditional hydraulic cylinders reduces manufacture costs.

3.1 Introduction of the model materials

Figure 4 shows the forming schematic diagram of the FBH. Figure 5 shows the finite element model, which consists of multi-point upper and lower die, steel pad, blank holders, sheet metal,blank holder blocks and steel gasket. Among them, 08AL was selected as sheet material, and the sheet size is 205mm×155mm×0.5mm. Table 1 shows the relevant mechanical parameters of 08AL. In the numerical simulation process, it is assumed that the sheet material is isotropic and conforms to the Levy-Mises flow criterion and the Prandtl-Reuss flow criterion.

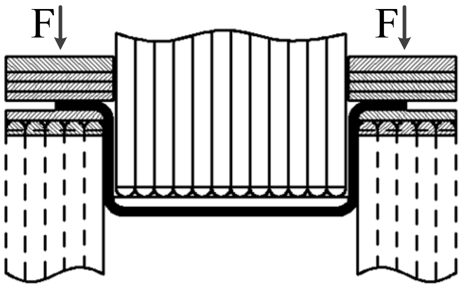

Figure 4. Diagram of box-shaped part under flexible blank holder with Multi-point forming.

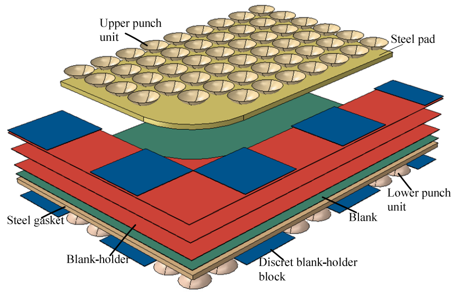

Figure 5. Finite element model.

Table 1. Mechanical parameter of 08AL.

Materia	Density ρ(Kg/m3)	Poisson ratio	Poisson ratio	Yield stress (MPa)
08AL	7850	0.3	205	270

Figure 6 shows the real stress-strain curves of 08AL. Since the force analysis is not performed on the multi-point upper and lower die, steel pad, steel gasket, and blank holder blocks which their material properties are set as non deformable rigid bodies. In order to better suppress wrinkles in the flange area of box-shaped parts, the 65Mn spring steel with tensile strength greater than 08AL is used as a blank holder material, in which the size and shape of the blank holder are shown in Figure 7.

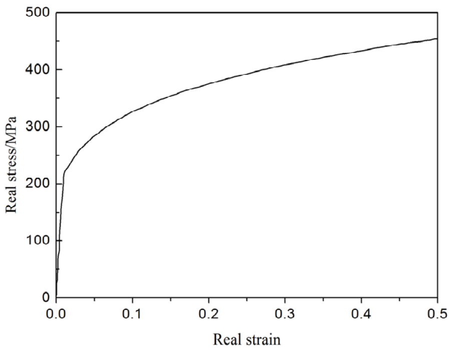

Figure 6. Real stress strain curve of 08AL.

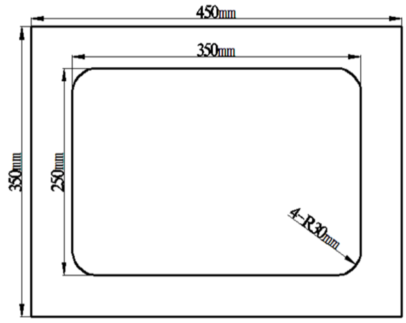

Figure 7. Diagram of blank holder size.

The multi-point upper punch die and lower punch die are both shell units and the material properties are set to rigid body. Steel pad is added between the multi-point upper die and the blank, and the size are 174.5mm×124.5mm×tmm, which auxiliary multi-point die punch forming box. The rigid gasket is added between the blank and the multi-point lower punch die and the rigid gasket is used in combination with steel pad to assist the MPF forming the corner arc of the box, in which the rigid gasket has the same size as the blank holder. In the numerical simulation calculation, replace the mechanical blank holder blocks with two rigid sheets symmetrically. The effective blanking area of a single blank holder block are 50mm×50mm, and the placement of the blank holder blocks are shown in the finite element model of Figure 5.

3.2 Defining boundary conditions and contact types

This paper takes the example of 1mm+1mm+1mm three-layers blank holder as the example to introduce the finite element model. Since the box-shaped part numerical simulation uses the 1/4 model and mainly studies the sheet metal form results, it is only necessary to impose symmetrical constraints

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on the sheet material. The motion of the multi-point upper punch die, steel pad and blank holders are controlled by applying only the translational degree of freedom in the direction of drawing, which limits the other rotational and translational degrees of freedom, and controls the motion of the multi-point upper punch die by the displacement-time curve. The only applied translational freedom in the deep drawing direction, restricting other rotation and freedom of movement.Limit all degrees of freedom for the lower blank holder block, rigid gasket, and the MPF lower punch die.The force of the blank holder block is achieved by the application of pressure, and the upper part of the blank holder blocks only applied the translational degree of freedom in the direction of drawing, and the 1MPa pressure is applied to the upper surface of the upper blank holder block. The 1MPa pressure is obtained through a lot of simulation analysis.

The coefficient of friction between blank holder blocks and blank holder, steel pad and blank, blank holder and blank, among the blank holders is set to 0.3. The friction between the other parts is static friction and the friction coefficient is set to 0.1. The 1mm assembly gap is reserved between the components of the finite element model in Figure 5 to prevent interference of various components during simulation. In the numerical simulation process, the contact between the various components is a universal contact by default, and the friction between them conforms to the Coulomb friction law. Its formula is:

$$f_t = \mu f_n \tag{1}$$

In the formula, f_t the friction force, μ the friction coefficient, and f_n the positive stress.

3.3 Mesh Generation

Unit types commonly are used in numerical simulation are S4R shell elements and C3D8R solid elements. S4R shell elements are commonly used for meshing thin sheet type components, and C3D8R solid elements are commonly used for meshing large-strain components. In order to reduce the running time of the computer, the sheet blank is meshed into the S4R shell element which can be deformable, and the blank holder is meshed by the C3D8R entity unit, and the multi-point upper punch die, the multi-point lower punch die, the blank holder blocks, the sheet pad and the sheet gasket are all meshed by the rigid shell element S4R。

4. Results analysis of simulation

4.1 Wrinkle defect and thickness analysis of forming parts

Figure 8 shows the light pattern of the box-shaped form result when different edge-pressed methods are shown. Figure 9 shows the thickness distribution of sheet metal under different blank holder.As can be clearly seen from Figure 8, the wrinkles in the flange area of the box-shaped part are marked when the edge is pressed by the 0mm blank holder. It is known from Figure 8(b)-(d) that the wrinkle of flange corner of box is gradually decrease with the increase of the lamination number of blank holders. When the 1mm+1mm+1mm three layers blank holders were used to press the edge, the flange area of the box-shaped part is formed well without wrinkling. During the stamping process of the box-shaped parts, the force at bottom of box-shaped part is even and no wrinkle occurred.

It can be seen from Figure 9 that during the forming process of the box-shaped parts, the thinning of sheet metal mainly occurs in the fillet area at the bottom corner of the box-shaped part, and the thickening of the sheet metal occurs mainly in the straight edge area of the flange. From Figure 9(b) -(d), it can be seen that with the more number of blank holder layers, the thinner of the corner area is. When the three laminates are pressed, the thickness of the plate is most evenly distributed. With the number of blank holder layers increases, the thickness of the straight edge area of the flange gradually decreases. When the three layers blank holder are pressed, the thickness of sheet in the area tends to be uniform.

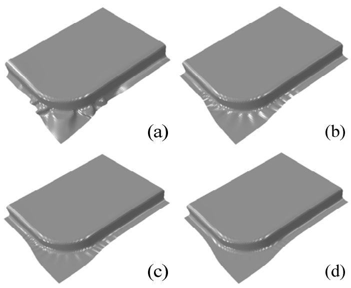

Figure 8. Illumination maps of the parts:(a)0mm(b)3mm(c)1mm+2mm (d)1mm+1mm+1mm.

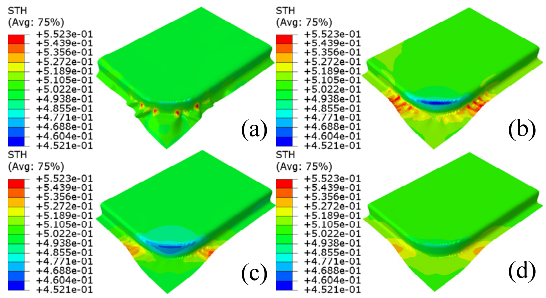

Figure 9. Comparison of blank thickness distribution cloud diagram with different blank holde:(a)0mm(b)3mm(c)1mm+2mm(d) 1mm+1mm+1mm.

4.2 Analysis stress and strain of NBH and FBH

Figure 10 shows the stress distribution cloud using different edge-pressed methods. Figure 11 shows the strain distribution cloud diagram using different blank holder methods.From the stress distribution cloud diagram in Figure 10, it can be seen that the maximum concentration of the stress in the flange fillet area is most obvious when the NBH is used to hold the edge.When the blank holder is used to press the edge, the stress in the flange fillet area gradually becomes uniform as the number of layers in the blank holder increases. When the 1mm+1mm+1mm three-layers blank holder are pressed, the stress distribution in the flange fillet area is the most uniform and the stress distribution of the entire box-shaped part is uniform. When the three layers blank holder are pressed, the maximum concentration of stress in the flanged area of the box-shaped member can be effectively solved, and the stress distribution is more uniform.

From the strain cloud diagram of Figure 11 (a), it can be seen that because of the blank holder was pressed, the deformation of the corner wall region of box parts are larger, but not the largest. As can be seen from Figure 11(b)-(d), when a 3mm single-layer blank holder is pressed, the amount of deformation in the wall portion of the molding corner is the largest; when the 1mm+2mm two-layers blank holder were pressed, the deformation of the corner wall area is slightly improved;when the 1mm+1mm+1mm three-layers blank holder were pressed, the deformation of the corner wall is the least, and the stress distribution of the forming part is the best.

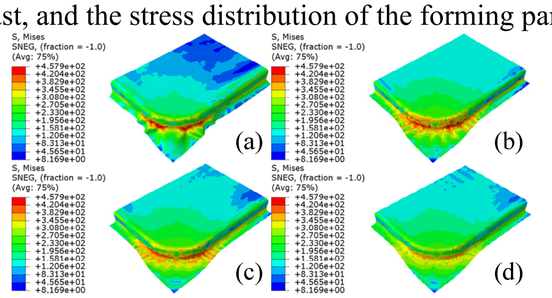

Figure 10. The stress distribution cloud diagram with different blank holder:(a)0mm(b)3mm (c)1mm+2mm(d)1mm+1mm+1mm.

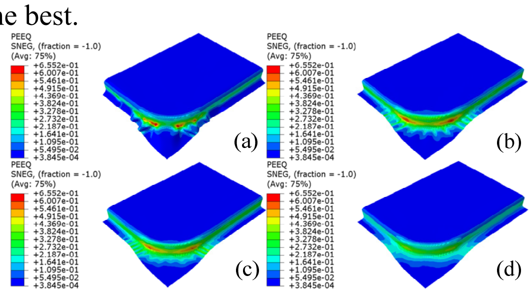

Figure 11. The strain distribution cloud diagram with different blank holder: (a)0mm (b)3mm(c)1mm+2mm(d)1mm+1mm+1mm.

5. Experimental verification of flexible blank holder

Through the analysis of the simulation results of the four blank holder methods, a series of relevant tests were carried out to verify the simulation results. The experimental equipment was selected by Jilin University YAM-200 Multi-point forming presses, as shown in Figure 12.The size of sheet metal, multi-point forming basic bodies, blank holder, steel gasket, sheet pad and blank holder blocks are the same as numerical simulation. Choosing punch pressure 25t; the depth of the forming target box is 20mm, and the 08AL sheet is used as the test material. Figure 13 shows the results of the experimental form parts. It can be clearly seen from Figure 13 that the more number of blank holder layers when the FBH is pressed, the better forming quality of the box-shaped part.

Figure 12. YAM-200 Multi-point forming presses.

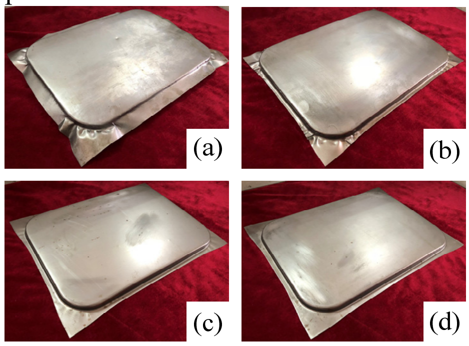

Figure 13. Comparison of test formed pieces:(a)0mm(b)3mm(c)1mm+2mm(d) 1mm+1mm+1mm.

6. Conclusions

(1) During the stamping process of the box-shaped part, the sheet material in the flange area is subjected to compressive stress in the tangential direction, resulting in the material destabilizing and wrinkling; the material in the wall area and the corner area is subjected to the tensile stress of the punch, and easily broken, which needs to be formed during the forming process. The BHF is applied to eliminate forming defects.

(2) The simulation analysis of the edge-pressed form results of the NBH and the different layers blank holder can be found that the wrinkle in the flange area of the box is effectively inhibited, and the stress-strain and the thickness of the sheet metal were distributed more evenly when the multi-layer blank holder were pressed.

(3) The reliability of the 08AL multi-point forming and the reliability of the numerical simulation were verified by experiments. The verification results have certain guiding significance for the actual forming of the box-shaped parts.

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