Analysis on Effect of Process Parameters on Performance of Rectangle Box in Deep Drawing

Guoying Ma[1, a], Binbing Huang[1, b] and Chenyu Du[2, c]

[1]College of Mechanical & Electronic Engineering, Shandong University of Science & Technology, Qingdao 266590, China;

[2]School of Mechanical & Automotive Engineering, Anhui Polytechnic University, Wuhu 241000, China

[a]mguoying@126.com, [b]kinghuang1990@163.com, [c]740229851@qq.com

Abstract. The mechanism of the deep drawing of rectangle box was researched, and the forming process was simulated by using the finite element analysis software Dynaform. On this basis, the influences of process parameters including stamping velocity, blank holder force, and friction coefficient on performance of rectangle box were deeply analyzed. The analysis results show that small blank holder force and friction coefficients are benefit to the shaping of sheet metal in a certain range, and usually lead to wrinkling at the same time; on the contrary, overlarge blank holder force and friction coefficients may result in cracking of rectangle box; and overlarge stamping velocity also reduce the stamping property. With the aid of finite element simulation, using repeated comparison and analysis, and selecting the most reasonable process parameters can greatly improve the efficiency of stamping production before the actual product put into production, and reduce the production costs at the same time.

Keywords: Rectangle box, Process parameters, deep drawing.

1. Introduction

Rectangular box as a typical representative of non-axisymmetric parts, its forming process is different from a simple bending and cylindrical cup drawing, the stress and strain is relatively complex, and forming is more difficult in deep drawing process. The straight edge part forming of rectangular box is similar to bending, while the corner forming is similar to cylindrical cup drawing. However, because of mutual restriction in deformation region, the overall deformation becomes more complex, the defects such as cracking and wrinkling often occur in the actual drawing process. In order to obtain a better forming quality of the work piece, process optimization method is usually used to select reasonable parameters to avoid such defects. Therefore, it has important significance of studying the influence of process parameters on the deep drawing performance.

In recent years, with the development of sheet metal forming simulation technology, many scholars have researched the forming of rectangular box with the help of computer simulation. Xiaoping Jie et al. [1] investigated drawing and springback process of rectangular box by means of finite element simulation, and summed up the change law of thickness in the deformation process. Qingfeng Zhang et al. [2] simulated the process of rectangular box incremental deep drawing by using Deform 3D software. Xi Xie et al. [3] examined the effect of material parameters and process parameters on the formability of rectangular box through orthogonal experiment and computer simulation methods. Lingjiang Cui et al. [4] researched the effect of local convex cylindrical blank-hold surface on square box part forming by applying numerical simulation. This paper will start form the rectangular box drawing forming mechanism, then simulate drawing process with Dynaform simulation, and focus on analyzing the effects of stamping velocity, blank holder force (BHF) and friction coefficient on the deep drawing performance.

2. Forming mechanism of the rectangular box

The forming characteristics of rectangular box are more complex, which mainly include cylindrical drawing in rounded edges and bending and drawing in the straight edge part. At the same time, because of the interaction among the deformation zones, the stress and strain distribution of rectangular box is not uniform during the deep drawing deformation [5].

In the drawing process, rectangular box elongated in the radial direction, shortened in the tangential direction, and had larger deformation in the rounded portion, which resulted in the value of σ_1 and σ_3 reaching maximum in rounded corner symmetric line, as shown in Fig. 1, meanwhile decreasing toward the straight edge direction until the value of σ_1 and σ_3 achieved the minimum at the straight edge midline. As the stress is the maximum at the midpoint of rounded corner and easy to reach the limit, the cracking is most likely to occur in the rounded part. Since the connection between the straight edge and corner part, the straight edge part not only produced bending deformation, but also drawing deformation of radial elongation and tangential compression in the actual deformation process.

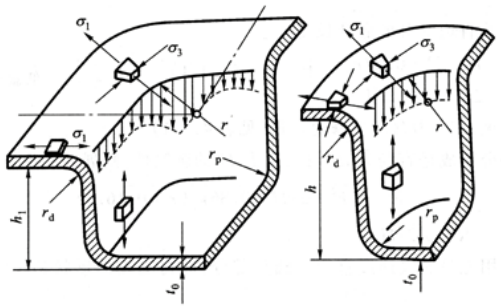


Fig.1 Stress pattern of rectangle box

3. Deep drawing process simulation of the rectangular box

As can be seen from the forming mechanism, the deformation process of deep drawing is complex. In order to study the complex forming process, finite element analysis software dynaform is used to simulate for intuitively observing the whole process. During the analysis, the aluminum alloy 2A12-O sheet metal is selected with thickness of 0.5mm and sheet size of 500mm ×500mm, the basic material properties and mechanical parameters are shown in Table 1.

Table 1 Material properties and mechanical parameters

Material	Density	Young's modulus	Poisson's ratio	Hardening exponent	Normal anisotropy exponent
2A12-O	2.7e-6kg/mm3	79000MPa	0.33	0.24	1.53

The specific operations of deep drawing process simulation analysis of rectangular box are as follows:

Solid modeling: create rectangular box drawing die in 3D modeling software Pro/Engineer, save it as .igs file for importing into dynaform to analyze;

Finite element modeling: import the solid model into dynaform to mesh and inspect the grid, meanwhile obtain the rectangular box blank by using die surface engineering, make the punch and the blank holder with offset and separation operation, then complete the finite element modeling for all models;

Automatically setting: using AutoSetup function in dynaform can conveniently simulate stamping process, respectively define die, punch and blank holder according to the requirements, set the sheet material parameters, define die stamping itinerary, then get the solving model under the open state after the above operations as shown in Fig. 2.

Solving and post-processing: after the completion of the automatic settings, submit ls-dyna solver to solve to gain the stress-strain cloud, thickness variation cloud, forming limit diagram, the deformation process animation, etc., which are used for evaluating formability.

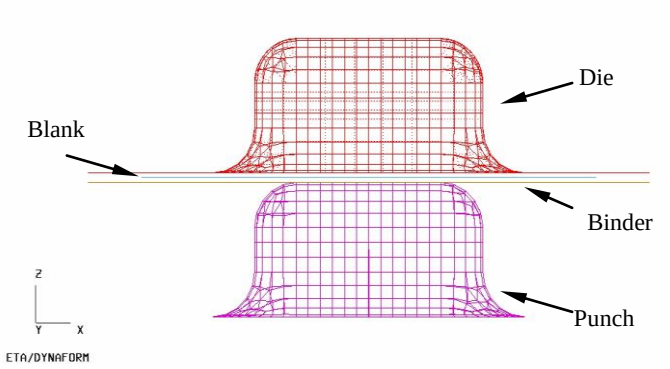


Fig.2 Solving model of rectangle box

4. Effect of process parameters

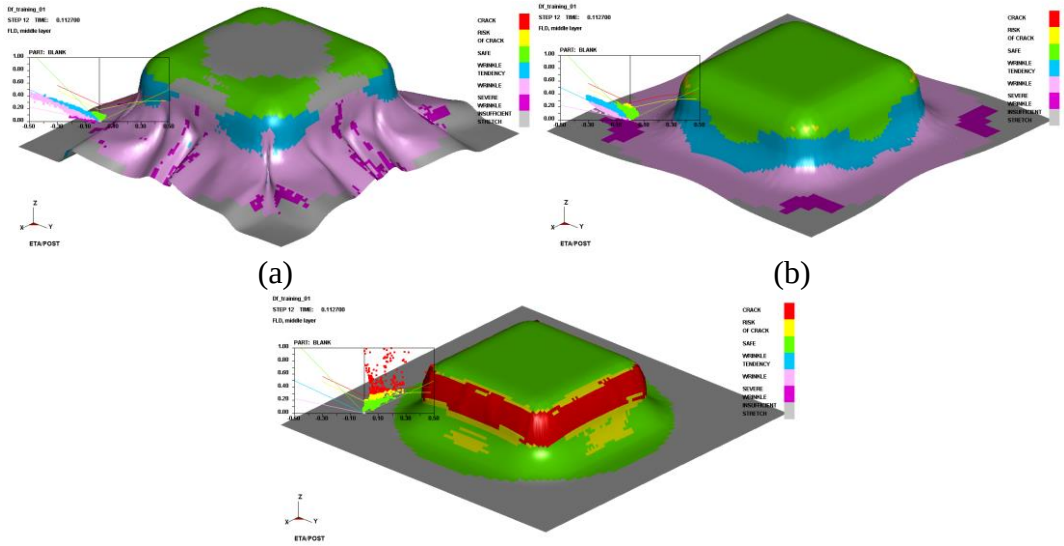
4.1. Effect of the BHF.

BHF is exerted on the blank holder in drawing process, it can be used to solve the wrinkling problem in the process of drawing, and it can be calculated by the following formula:

$$Q = Fq \tag{1}$$

Where, F is the area of the pressure side (mm^2); q is for unit BHF (MPa), and unit BHF of different materials is selected according to table 5.3 in the reference [6].

In order to study the effect of BHF on rectangular box forming, the material parameters and the process parameters must be ensured in the same values (stamping velocity of 500mm/s, the friction coefficient of 0.1) in the process of analysis, so the BHF of 1kN, 10kN and 100kN were respectively taken to analyze to obtain forming limit diagrams, as shown in Figure 3 (a), (b), (c).



(a) (b)

(c)

Fig.3 Forming limit diagram with different blank holder force

As seen from Fig. 3, when the BHF is too large to hinder the material flow, the material of sheet metal flange is unable to internal flow, and then produce cracking; when the BHF is too small to below normal counter-force of sheet metal flange, and thus can cause wrinkling.

4.2 Effect of stamping velocity.

As well, the material parameters and the process parameters are maintained in the same values (BHF of 10kN, the friction coefficient of 0.1) for researching the effect of stamping velocity, then respectively picking stamping velocity of 50mm/s, 500mm/s, 5000mm/s, 10000mm/s and 20000mm/s to simulate the forming process, and gain forming limit diagrams and thickness variation diagrams (due to limited space, this does not list all). The thinning rates under different stamping velocities are counted in Table 2.

Table 2 Thinning rate of sheet metal with different stamping velocity

Stamping velocity (mm/s)	50	500	5000	10000	20000
Thinning rate(%)	7.6	7.4	7.8	9.6	11.8

It can be known from the analysis results, when stamping velocity is small; it has little influence on the formability, while stamping velocity is too large (more than 5000mm/s), the stamping performance of sheet metal decrease significantly, then there will be cracking and larger thinning rate defects.

4.3 Effect of friction coefficient.

In order to discuss the effect of friction coefficient, the material parameters and the process parameters as well remain in the same values (BHF of 10kN, stamping velocity of 500mm/s), so respectively selecting friction coefficient of 0.05, 0.10, 0.20, 0.50 and 0.80 to analyze the forming parts. It can be drawn from the analysis, friction coefficient is smaller, the sheet metal flow is better, the thinnest thickness of stamping out parts will become thicker and the parts are not easily damaged; when friction coefficient is larger, the sheet flow is more unfavorable, the parts are easy to damage. If friction coefficient is so large that the friction force is very large, the sheet almost can not flow, and then the parts will produce cracking. Therefore, it is necessary to keep the friction coefficient under reasonable control in the forming process.

Through repeatedly adjusting the process parameters, the better forming process parameters were eventually obtained with BHF of 10kN, stamping velocity of 500mm/s, the friction coefficient of 0.1.

5. Conclusion

The rectangular box formability under different process parameters were compared through the simulation analysis of drawing process. The analysis results show that small BHF and friction coefficients are benefit to the sheet metal forming in a certain range, but usually lead to wrinkling at the same time; on the contrary, overlarge BHF and friction coefficients can cause cracking; and overlarge stamping velocity also reduce the stamping property. With the help of finite element simulation, through repeated comparison, it can be drawn that selecting the reasonable process parameters can greatly improve the stamping production efficiency, and reduce the production costs before the actual product into production.

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