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Stress analysis of cylindrical parts during deep drawing based on Dynaform

Dong Weiping*, Wang Qichao, Wang Xiaoming and Wang bin

College of Engineering, Zhejiang Normal University, Jinhua, 321004

dwp@zjnu.cn

Abstract. In this paper, the Dynaform numerical method was used to simulate the deep drawing process of the cylindrical parts. The distribution of the thickness, stress and strain of the cylindrical part during multi-stage deep drawing, as well as the possible defects of the cylindrical parts at this time, were compared without using blank holder, using the flat blank holder or using cone-shaped blank holder. The one-step drawing showed that the use of flat blank holder or cone-shaped blank holder didn't have too much difference in stress and strain distribution. Based on the one-step drawn part, the stress and strain under different conditions at the second-step drawing showed that the use of cone-shaped blank holder could prevent the wrinkling and crack of the work-piece. The numerical simulation technologies presented in this paper can be used in the early analysis of such a complex process during the mold design, so as to predict and control the possible defects in the process of material processing, which can be used as a reference to verify the reliability of mold design.

1. Introduction

With the development of computer aided engineering, numerical simulation has become more and more widely used in the field of metal plastic forming process. In predicting the distributions of stress and strain in the work-piece forming process and the change of the thickness of fold and fracture, etc. computer simulation has great achievements, and provides effective data flow analysis and optimization design [1-4]. Most of the traditional press production is deep drawing, during which wrinkling and crack are the main failure [5]. There are numerous experiments and analytical discussion has been done on deep drawing. If the geometry shape of the desirable is complex, it will be difficult to do theory calculation to estimate the deformation degree. At present, before the mold design and manufacture, the finite element analysis technology is usually used first, according to that the stamping size and shape of stamping parts can be modified timely [6-11]. The software we used to deal with stress and strain analysis is Dynaform, which is a simulation software used to solve metal sheet forming simulation problems [12-16].

2. Numerical simulation details

This section gives brief introduction about how to carry out numerical simulation. We choose AISI 304 stainless steel. The thickness of the metal plate is 1mm; according to that the size of the blank should be calculated as 175mm and we need three steps [17]. During the first step, the blank come to diameter 96.25mm and deep 58.61mm. During the second step, the blank come to diameter 75mm and deep 85.98mm. And during the finally step, the blank come to 65mm and 100mm (our product). Other parameters include the way of drawing and the size of the blank holder force, the radius of the round angle of the concave and convex mould, the condition of the lubrication and the condition of the die, the drawing speed and so on.

We build the 3d model of our mould using CAD software and import the IGES files into the workspace of Dynaform, setting the location of concave-convex part, blank, blank holder and punch, using green, red, blue and gray respectively.

In our case, deep drawing can be divided into two states. First state is closing, which blank holder or die moves with 2000m/s, until blank holder and die close. Second state is drawing, which punch or blank holder and dies moves with 5000m/s, until the work-piece reach desirable depth. And then we use postprocessor to analyze stress, strain, spring back, and so on. During the simulation, if there is any failure, we can figure out the reason and make a targeted improvement.

3. Results and Discussions

In deep drawing process, the deformation is concentrated at the corner of the blank holder and the side of the cup. There are a few possible defects might happen during deep drawing. Such as wrinkling, crack, tearing and surface scratches [5]. The stress and strain analyses are provided in this section including the first step and the second step drawing (the process of the third step is similar to the second step). Via these analyses, we could figure out if the blank will break during deep drawing.

With the help of Dynaform postprocessor, we could generate forming limit diagram of stress analysis for first step drawn part. In figure 1, two kinds of blank holder were shown (a) using flat blank holder and (b) using cone-shaped blank holder. We use local enlarged image processing in figure 1(c), (d) and (e) to show some part which is not clearing. In figure 1(c), gray, purple, pink, blue, green, yellow and red denotes insufficient stretch, severe wrinkle, wrinkle, wrinkle tendency, safe, risk of crack and crack respectively. And in figure 1(d) and (e), the x-axis and y-axis represent strain rate along two different direction and the colorful points represent different stress condition. We can see in figure 1(a) and (b) that both two work-pieces do not crack (no red color), although wrinkle may appear (few pink color). In a word, the work-pieces are safe which means we can choose any of blank holders because there is no obvious stress distribution difference between them.

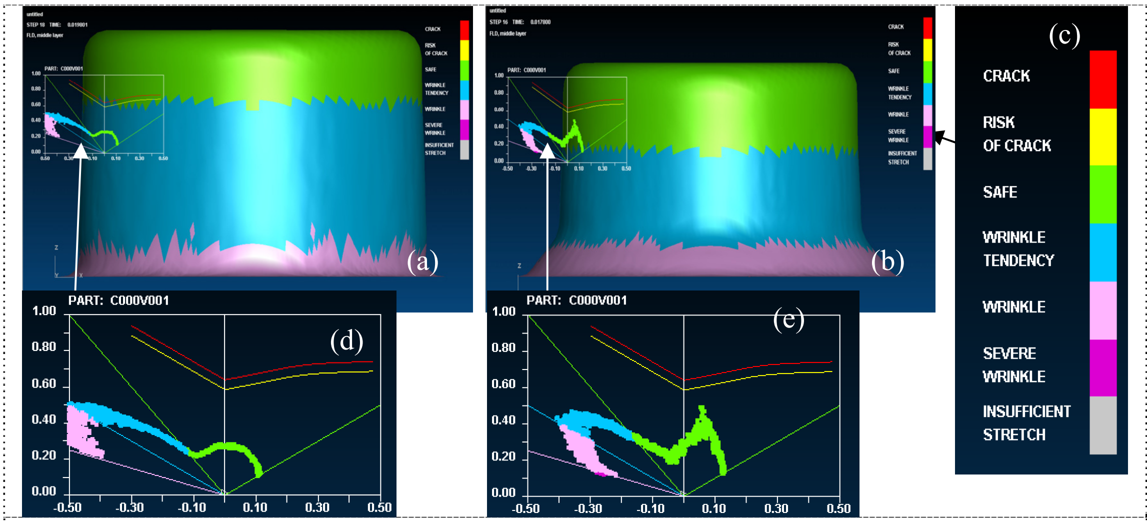

Figure 1. Forming limit diagram of stress analysis for first step drawing: (a) using flat blank holder; (b) using cone-shaped blank holder.

Materials under the action of tensile stress and compressive stress produce plastic deformation. With the move of the punch or die, metal sheet flows into the clearance between die and punch. In general, the area between punch and material has the largest strain. Strain distribution for the first step drawing shown in figure 2(a) and (b), we use different color to indicate different strain distribution, in which the color to red is the biggest strain and the blue color is the smallest strain. We can see the area between punch and blank holder using both two kinds' blank holders has the biggest strain for red color. But the work-piece suffers much a little bit higher strain by using flat blank holder.

Metal sheet thickness for the first step drawing shown in figure 2(c) and (d), in which the red color of the parts implies the thinnest parts and the blue color of the parts implies the thickest parts, we can see the thickness of the metal sheet gradually decreases from the flat surface to the corner of the punch. Compare figure 2(c) and (d), if we use cone-shaped blank holder, the minimum thickness of metal sheet drops to 0.804 mm. This value is greater than the minimum thickness under flat blank holder (0.728 mm). And the safe region which using cone-shaped blank holder is much larger than that using flat blank holder, so we also think it's better to using cone-shaped blank holder.

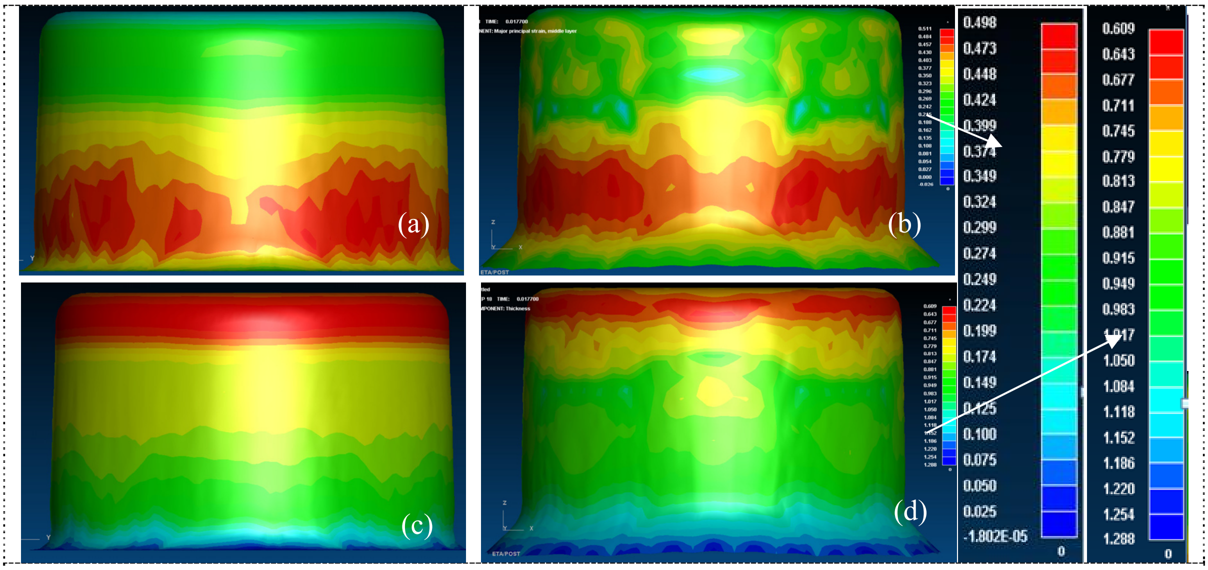

Figure 2. Strain distribution for first step drawing: (a) using flat blank holder; (b) using cone-shaped blank holder; Metal sheet thickness: (c) using flat blank holder; (d) using cone-shaped blank holder.

The down segment focuses on the stress analysis during second step deep drawing. In order to ensure our design is reliable. To approximate to the real facts, we export VRML file of the work-piece after first step drawing. Three situations (without blank holder, using flat blank holder and using cone-shaped blank holder) are used to compare the stress analysis.

Figure 3(a), (b) and (c) show the arrangement of each part without blank holder, with flat blank holder and with cone-shaped blank holder respectively. And the punch presses the work-piece into die cavity. Punch's travel distance is 86 mm. Figure 3(d), (e) and (f) show the geometry shape and stress distribution of the work-piece at the end of second step deep drawing process matching with the three situations mentioned before. Green, red, purple and blue denote die, blank, blank holder and punch respectively. Comparing figure 3(a), figure (b) and (c) have blank holders (purple color). Processing deep drawing without blank holder indicates that work-piece is safe (the color of work-piece in Figure 3(d) is blue and green full body), but wrinkling at root area is in serious condition (the pink color of work-piece in Figure 3(d) is crimping at root area). It does not meet our manufacturing requirement. Processing deep drawing with flat blank holder indicates that work-piece cracks (the color of work-piece in Figure 3(e) is red during corner and sidewall) and it also does not meet our requirement. Processing deep drawing with cone-shaped blank holder indicates that work-piece is safe (Figure 3(f)) and its wrinkling in root area is small. This work-piece meets our manufacturing requirement.

Clearly, from the previous comparison, there are a few advantages to use cone-shaped blank holder. For example, during first step deep drawing it will reduce strain condition of the work-piece during the process of deep drawing, although thickness of the metal sheet will become a little small. For second step deep drawing, using cone-shaped blank holder prevents the blank from wrinkling or cracking and the finished work-piece meets our requirement.

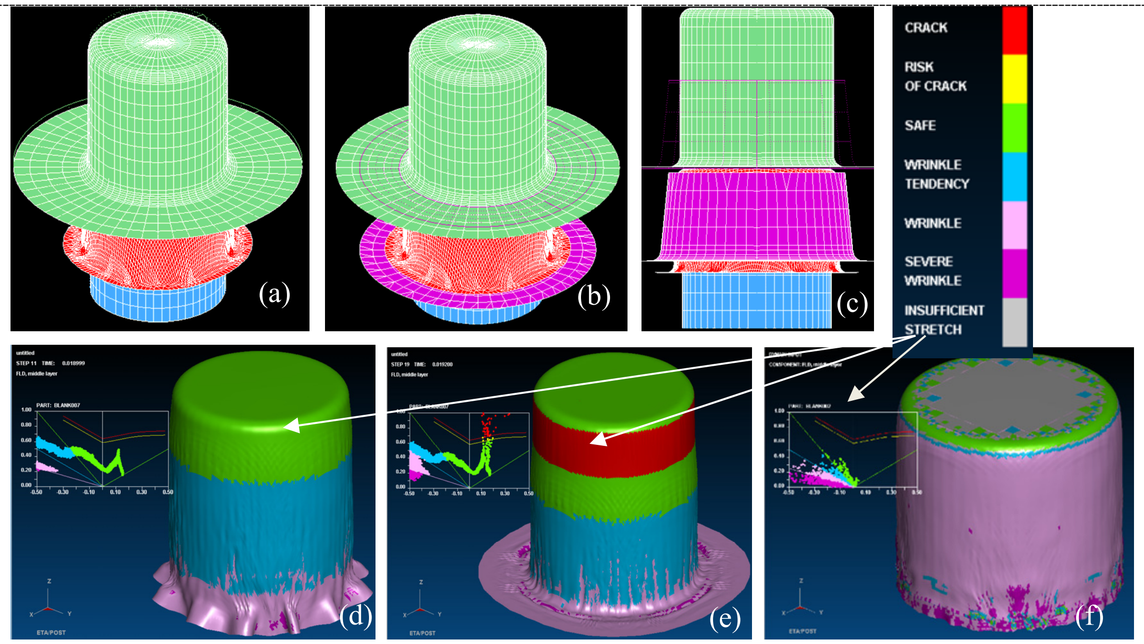

Figure 3. Stress distribution for the second step drawing. (Green, red, purple and blue denote die, blank, blank holder and punch respectively.) (a) Arrangement and (d) after drawing without blank holder; (b) Arrangement and (e) after drawing with flat blank holder; (c) Arrangement and (f) after drawing with cone-shaped blank holder.

4. Conclusions

It is seen from the above review that both flat blank holder and cone-shaped blank holder can meet our requirement during the first step deep drawing, but using cone-shaped blank holder can reduce strain condition of the work-piece and thin the thickness of metal sheet. For the second step deep drawing, we have to use cone-shaped blank holder, which can prevent work-piece from wrinkling or cracking. If we do not use blank holder, there are serious wrinkling. If we use flat blank holder, it increases the friction during metal flows and the material has cracks. The technologies presented are valuable for numerical simulation of such a complex process as multi-stage sheet metal forming.

Acknowledgment

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