Research on Resistance to External Pressure of Automobile Cover

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Abstract. The forming process of automobile covers is relatively complicated, various defects often appear. Insufficient resistance to external pressure is one of them. To solve this problem, this paper proposes to increase a pre-stretching process before the stamping process. Through building a series of finite element models for an automobile cover forming process, the influence of different pre-stretching amounts on the thickness and resistance to external pressure are compared. Finally determine the appropriate pre-stretching amount.

1. Introduction
The automobile cover is often affected by external factors during use, such as artificial pressure, accumulated water or snow[1]. Therefore, the automobile cover must have the characteristics of good rigidity, which is an important concern in automobile manufacturing[2]. However, insufficient resistance to external pressure often occurs, causing problems such as restlessness and abnormal noise when the car is running, which affects the performance of the entire vehicle. Therefore, corresponding measures must be taken to avoid insufficient resistance to external pressure[3]. This paper uses finite element simulation to analyze the forming process of a company’s automobile cover, adds a pre-stretching process before the forming process, analyzes the influence of the pre-stretching parameters, and looks for the best value to improve the ability of the resistance to external pressure of automobile cover.

2. Experiment design
Taking an automobile cover from a car company for example, use numerical simulation to analyze its forming process.

The geometric model of the automobile cover is shown in Figure 1. It can be seen that the part has a large area and a relatively flat shape, which is prone to insufficient rigidity after forming. To solve this problem, a pre-stretching step is added before the stamping process. Compare the directly stamped parts with the pre-stretched parts to determine the appropriate pre-stretching amount.

Experimental procedure:(1) Pre-stretching: Fix the clamps on both sides of the sheet to pre-stretch the sheet in the horizontal direction to the degree of 0%, 0.5%, 1%, 1.5%, 2%, and 2.5%. (2) Stamping: The binder presses the stretched sheet, and the punch presses down to completely shape the sheet. (3) Unloading: Lift the punch and the binder to return to the initial position, and the sheet metal springs back. (4) The resistance to external pressure test: Fix the parts around completely, then apply a
certain pressure to the center of the part, control the deformation within the elastic range, and observe the degree of sag.

**Figure 1.** CATIA model of the automobile cover.

### 2.1. Material model

In the mechanical properties of materials described by the elastic-plastic model, the elasticity is isotropic and the plasticity is anisotropic. Hill '48 The yield criterion may be written as [4]:

\[
\varphi(\sigma_{ij}) = F(\sigma_{22} - \sigma_{33})^2 + G(\sigma_{33} - \sigma_{11})^2 + (\sigma_{11} - \sigma_{22})^2 + 2La^2_{31} + 2Na^2 - \ddot{\sigma}^2 = 0
\]

(1)

\(F, G, H, L, M, N\) are anisotropic coefficients, \(\sigma_{ij}\) is plane stress. Combined with Hill's 48 yield criterion, Hollomon hardening curve can be expressed as:

\[
\sigma = K\varepsilon^n
\]

(2)

\(\sigma, \varepsilon, K, n\) represent the true stress, true strain, strain hardening coefficient and strain hardening index. The study sheet is made of St14 steel plate with a thickness of 0.7mm, and its main material parameters are shown in Table 1[5].

**Table 1.** St14 material mechanical properties model parameters.

| Material | Density [g/cm³] | Elasticity modulus [GPa] | Yield strength [MPa] | Poisson’s ratio | Strain hardening exponent | Plastic strain ratio |
|----------|-----------------|--------------------------|----------------------|----------------|---------------------------|---------------------|
| St14     | 7.85            | 207                      | 176.3                | 0.28           | 0.247                     | r0 1.88 r45 1.40 r90 2.23 |

### 2.2. Finite element model of forming process

Figure 2 shows the automobile cover forming process model. Use the 3D modeling software to generate the mold parts, and then import into the finite element simulation software. The dynamic
Figure 2. (a) FE model of pre-stretching and stamping process (1/2 symmetry) (b) distinct zones of sheet metal (1/2 symmetry).

The explicit method is adopted to simulate the forming process of the automobile cover. Select dynamic explicit method for springback process, which is closer to the real unloading process [6]. In pre-stretching process, apply displacement control conditions on both sides of the Y-axis direction of the sheet to stretch the sheet to make the sheet close to the yield limit. In stamping process, fully constrained die; binder and punch can only move in the Z-axis. The pressing of the binder is controlled by pressure, the loading curve type is smooth step; punch punching with displacement control, running distance is 300 mm, running time is general contact, and the friction coefficient is 0.1.

2.3 Finite element model of the resistance to external pressure test
After the stamping and unloading process, import the calculated odb file into the finite element software, and give it the initial predefined field at the last moment of the odb file. Fully constrain the part around, set a small punch radius of 5 mm which type is rigid body in the center of the part, apply 20N pressure to it and observe its sag displacement as a test standard. Figure 3 is the schematic diagram of the resistance to external pressure test model and the front view of the small punch.

![Figure 3](image)

Figure 3. (a) FE model of the resistance to external pressure test (1/2 symmetry) (b) Front view of the punch.

3. Results and discussion
According to the pre-optimization test, 0.8 MPa is a more appropriate binder force. The following simulation test results are based on the binder force of 0.8 MPa.

3.1 Influence of pre-stretching on thickness
Figure 4 shows the cloud diagram of the thickness distribution which the pre-stretching amount from 0% to 2.5%.

It can be seen from figure 4 that wrinkle defects appear on the edge, where will be cut in subsequent trimming process, so the defects of this part will not affect the final forming. According to figure 4, when the pre-stretching amount is within 2%, the minimum thickness of the part is 0.4912 mm, and the maximum thinning rate is 29.8%; when the pre-stretching amount is 2.5%, the minimum thickness of the part is 0.4887 mm, and the thinning rate is 30.2%. The maximum thinning rate of the cover forming is not more than 30%, and the cracking defect will appear if it exceeds this range. It can be seen that the thickness of the formed part decreases with the increase of the pre-stretching amount, the maximum thinning of the part in the range of 0%-2% is within the allowable range, when the pre-stretching amount is more than 2.5%, The thickness of the formed part exceeds the allowable range of engineering acceptance, and the problem of poor forming quality will occur. Therefore, the calculation results are analyzed for stretching below 2%.
Figure 4. Thickness distribution contour plots under different pre-stretching amounts: (a) 0%, (b) 0.5%, (c) 1%, (d) 1.5%, (e) 2%, (f) 2.5%

Figure 5. (a) Thickness distributions under different pre-stretching amount along line BA (b) Trend of thickness difference of different pre-stretched parts.

Figure 5(a) shows the thickness distribution of the part in the BA direction which the pre-stretching amounts from 0% to 2%. Figure 5(b) is the trend diagram of the thickness difference of 0%-2% pre-stretched parts. It can be seen from Figures 5 that the uniformity of the thickness of the parts after pre-stretching has changed, the maximum thickness of the unpreshetred sheet center is 0.6887mm, the thickness difference from the edge of the part is 0.014mm; the maximum thickness of the center of the pre-stretched 2% sheet is 0.6827mm, the thickness difference from the edge of the sheet is 0.0096mm. In the range of 0% to 2%, the thickness uniformity becomes more uniform as the amount of stretching increases. The reason for that is during the stamping process of the parts, due to the flat center shape, the center thinning is small, and the edge thinning is large. But in the pre-stretching process, the middle part is stretched thinner than the edge. After pre-stretching and then punching, the thickness difference between the center and the edge is reduced, so the sheet is stretched more fully and the thickness is more uniform.
3.2. Influence of pre-stretching on stiffness
Constrain the parts around, apply external pressure in the Z-axis (u3) direction at the center of the part to test its resistance to external pressure. Figure 6(a) is the diagram showing the displacement of the part along the BA direction when 20N pressure is applied to the formed parts with different pre-stretching amounts in the Z-axis direction. Figure 6(b) is the trend diagram of the maximum sag displacement after external pressure is applied to the formed parts with different pre-stretching amounts.

It can be seen from Figures 6 that the maximum sag displacement of the part gradually decreases with the increase of the pre-stretching amount from 0% to 2%, so that the resistance to external pressure of the part increases as the pre-stretching amount increases. The reason for that is pre-stretching increases the yield strength of the sheet, and the tensile stress on the upper and lower surfaces of the sheet increases, resulting in a decrease in springback after forming. Therefore, the reduction of the arc height of the top cover will decrease and the resistance to external pressure will increase. In addition, the pre-stretching makes the forming thickness of the entire automobile cover more uniform, and also improves the resistance to external pressure. Within the allowable range of thickness reduction, when the stretching amount is 2%, the effect of improving the resistance to external pressure of the part is better.

4. Conclusion
Taking an automobile cover as the research object, this paper adds a pre-stretching step before the traditional stamping step. Studies have shown that this method can significantly improve the resistance to external pressure of the automobile cover. Within a certain range, the increase in pre-stretching caused the decrease in springback and the increase in deformation degree caused the improvement of the uniformity of the cover, which contributed more than the thickness reduction to the increase in resistance to external pressure. For the research object, the test results show that when the pre-stretching amount is 2% in the length direction of the sheet, the ability to resist external pressure is improved best.

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