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Optimizing Process and Design of Die with CAE on the Car

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Abstract

The traditional mould design method mainly relies on the experience, it needs repeated debugging and processing which prolongs the mould development time and increases the mould manufacturing cost. The modern advanced mold design uses the finite element analysis software to do numerical simulation on the forming process of the die and optimizes the parameters of the mould which is very helpful for improving the precision of mould design.Take the rear quarter panel of car as an example, using the DYNAFORM finite element software to do simulation on blank forming process to control the springback after unloading on the shallow and deep parts and design the mould of rear quarter panel based on optimization results, so as to improve the accuracy of the mold and reduce the mold development time and the mould cost [1].

Keywords*: mould design, CAE, variable blank holder force, springback*

1. Introduction

In the process of forming parts, the traditional method of mould design mainly relying on the experience. In order to avoid cracks, wrinkles and springback, etc, it needs repeatedly tests and mould repair. This method greatly prolongs the mould development time and increase the cost of the mould.With the continuous development of elastic-plastic finite element simulation technology, the modern mould design industry that based on Computer Aided Engineering (CAE) has a considerable development. Compared with the traditional manufacturing method of die design, modern mould manufacturing technology has obvious advantages. It may predict forming problems by using CAE technology, and may obtain the optimal process parameters, thereby reducing the test cycle, improving the mold quality and reducing the cost of mould.Take the rear quarter panel of car as an example, this paper analyzes the process by using DYNAFORM and design mould based on the the simulation results.

2. Analysis the Process of Rear Quarter Panel

Lead the model of rear quarter panel of car into the DYNAFORM. As is shown in Figure 1. The rear quarter panel of car is space free curved surface structure with large size, complex shape and the material is thin. The stamping process involves geometric nonlinear, material nonlinear and complex contact friction problem, forming the characteristics of a high surface quality with higher coordination.

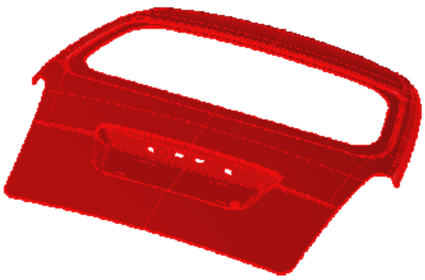

Figure 1. Part Drawing of Rear Quarter Panel

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Making process analysis in the following three aspects of the rear quarter panel: In tailboard body part, the workpiece needs to fill the empty and added borderline along the outer edge portion of the process of contour surface; Automobile tailboard belongs to shallow drawing part, if the selection of the stamping direction is reasonable,pressing negative angle will not appear, but the rebound has become a common and difficult problem in the process of forming, especially in the automobile tailboard field using shallow drawing forming process. The rebound of automobile panels can be predicted by DYNAFORM, so according to the simulation results, we could modify the process parameters and make compensation in the process of forming; Making binder should reduce the depth of draw, it should be a flat or smooth surface with no local bump, setting short rib locally in fragile sites to increase the feeding resistance to prevent the blank wrinkling [2]. According to the shape of the blank after boarding, it need first drawing cut edge and punching, this paper only analyzes the process of drawing.

Get the numerical simulation on the forming process and optimization of process parameters by using DYNAFORM software, then use the analysis results to guide the tailboard of mold design and manufacturing.

3. Component Finite Element Analysis and Process Optimization

In order to make stamping forming simulation of back panel, lead the rear coaming model into DYNAFORM, as is shown in Figure 1. The accuracy of simulation results is largely related to the quality of blank mesh.The element mesh sizes of die is not more than die minimum radius of 1/2 that will contact with blank [3, 4].

$$L \leq 1/2 r_{die} \tag{1}$$

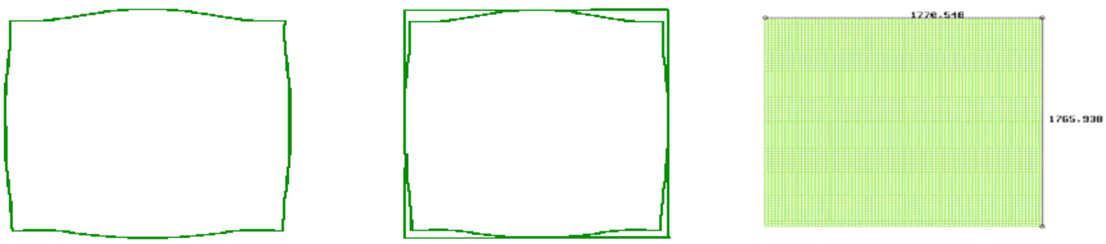
Dividing the rear coaming model with mesh surface in the finite element analysis software DYNAFORM, the grid size is set to 20mm after repeated simulation analysis, which can save time while achieving good simulation results.

3.1. Blank Size Estimation

According to the principle of constant volume: material thickness basically remain unchanged after drawing, the drawing surface area and the blank area are approximately equal. The blank diameter of simple cylindrical drawing parts can be calculated by used the formula:

$$D = \sqrt{(d-2R)^2 + 2\pi R(d-2R) + 8R^2 + 4d(H-R)} \tag{2}$$

Where *d*, *R* and *H* are cylinder diameter, fillet radius and wall height. Because the shape of the rear coaming is complex, it is difficult to accurately calculate the surface area of deep drawing parts with conventional method of calculation. This paper uses the blank of DYNAFORM software engineering (BSE) is special for calculate expansion blank's shape and area. In order to accurately reverse rough outline, we need to undergo a rigorous grid check, the unit overlapping check, normal direction check, unit size check and inner angle check, and make sure there is no holes inside. The reverse irregular sheet shape is shown in (a), the contour is not conducive to the sheet cutting. Using rectangular envelope with the reverse results, we get the shape shown in (b). Finally, measure the billet size shown in (c), the billet dimension is rounded as 1780mm*1780mm [5-8].



(a)The result of reverse on blank (b)Creating the rectangular enveloping (c) The size of blank

Figure 2. The Result of Reverse on Blank and its Enveloping

3.2. Determine the Drawing Direction

In this case, the stamping direction is shown in Figure 3. The advantages of taking the stamping direction is: Ensure all space drawing shapes (including ridge, the ribs and the drum kit) to draw out at one time. There is no " dead zone "that punch can not access to, namely the punch can enter the concave die; conducive to reducing the drawing depth; guarantee punch and blank has initial good contact state, reduce the relative sliding between the blank and punch, which is conducive to deformation and improve the surface quality of stamping parts.

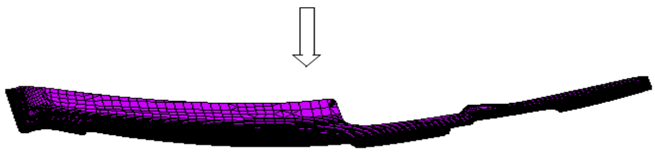


Figure 3. Stamping Direction

3.3. The Supplementary Part of the Design Process

When the stamping direction is determined, the shape and depth processing on the rear panel. Firstly close and supplement the pore so that the parts will not have inner holes. The complementary process to the outside parts should be conducive to the drawing structure and shape simplification. The closer the supplement is to the basic shape of the parts, and the easier the control material flow and plastic deformation is during the process of stamping. The distance between trimming line and draw bead is 25mm, the distance from radius of punch to trimming line is 5mm. This can ensure the use does not cause the round convex die to wear down which can affect the trimming line. According to the drawing depth and shape, punch radius is 6mm. Considering the factors above, the supplementary process is shown in Figure 4.

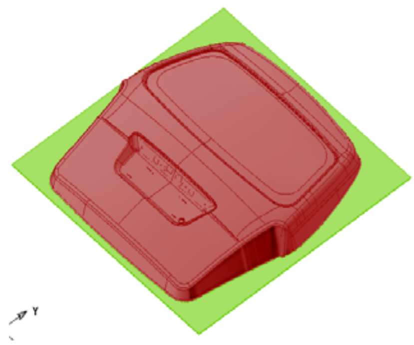


Figure 4. Supplement Process in the Part

3.4. CAE Simulations Results Analysis

The mold movement form is defined as Single action (inverted draw) and Lower Tool Available. The car panel material is stamping cold rolling ST13, and the thickness is 1.2mm. After the die parameters and material have been set, we should discuss the main effects that the blank-holder force has on the sheet metal forming in the simulation results. According to the formula estimate the blank-holder force value of P.

$$P=\pi\left(d_{1m}+t\right)t\left\{\frac{\sigma_b}{1-\psi_b}\left[\left(0.57-\frac{0.5m_1}{\sqrt{m_1^2-0.28}}\right)\frac{1}{\psi_b}\right]^{\frac{\sigma_b}{1-\psi_b}}\times 1.1\ln\frac{0.85}{m_1}+\frac{\mu Q}{m_1\pi R_0 t}+\frac{\sigma_b t}{2r_d+t}\right\}\times\left(1+1.6\mu\right) \quad (3)$$

But it's too complicated, so in the production commonly used empirical formula:

$$P = Lt\sigma_b K \tag{4}$$

Where L,t,σ_b and K are cross section surrounding length,sheet thickness,strength of extension and correction factor. The results when BHF is 160kN are shown in Figure 5. We can see clearly that the sheet metal forming is not sufficient and edge wrinkling is serious. In the plane stress, in the direction of plate thickness, due to the presence of compression force (the negative stress in σ τ), it may cause instability. This is because the blank-holder force is too small during the process of drawing that it cannot prevent the edge wrinkling due to metal flow. Therefore, we must increase the pressure properly.

When BHF is increased to 600KN, the simulation results are shown in Figure 6. We can see from the forming limit diagram that parts appeared crack phenomenon in the process of forming, but there are still not fully formed and wrinkling parts, and cracking phenomenon represents the fact that blank-holder force is too large.

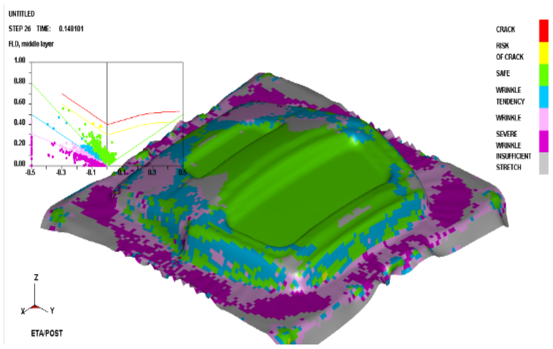


Figure 5. FLD on the Blank-holder Force is 160kN

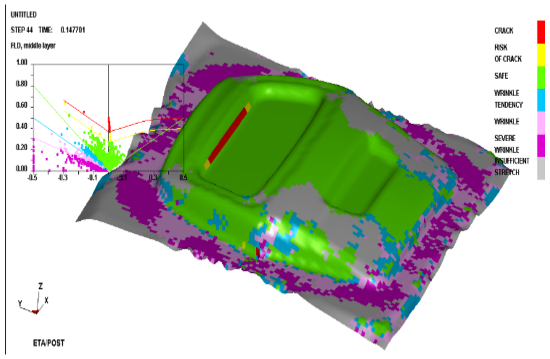


Figure 6. FLD on the Blank-holder Force is 600kN

From the animation of simulation results, it can be observed that the crack phenomenon appears in the forming process. So we should take the measure of changing the pressure in the forming process to improve the forming results. Combined with variable blank-holder force as shown in Figure 9 of curve 1 into DYNAFORM, in the forming limit diagram, there are still the wrinkles and cracks. Therefore, we cannot improve the quality of the parts only by adjusting BHF. The more complex the blank holder force changes, the higher requirements are needed for press machine.

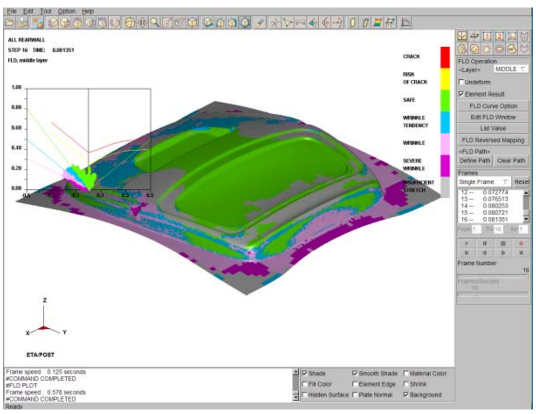


Figure 7. The Forming Limit Diagram After Added Drawbead

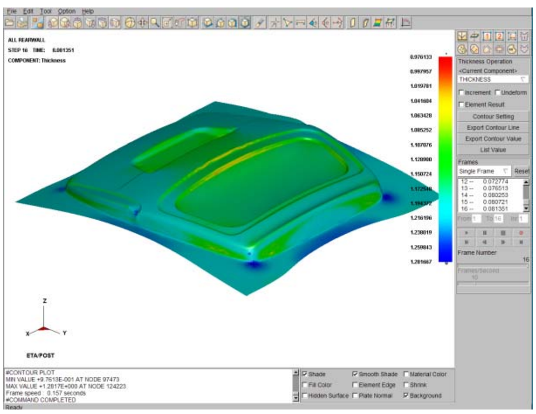


Figure 8. The Change in the Thickness

In conclusion, there is need to find another way to improve the forming results. We adopt local drawbead measures. On one hand, it can limit the wrinkled area (prevent the metal flowing), avoiding wrinkling in smaller pressure circumstances. On the other hand, it reduces the possibility of cracking. In order to simplify the operation steps, we generate drawbead curve through the data conversion in PRO/E software, and import it into DYNAFORM software to analyze. The results are shown in Figure 7, form which we can see that the forming results are improved: There is no cracks in components and no wrinkling in the main forming part. Although there are some wrinkling in the flange, but these do not affect the performance of components, and the flange will be removed in the following procedures.

As is shown in material thickness changes (Figure 8), the thinnest sheet is 0.976mm, and the thinning rate is 18.3%. The reduction is within 30%, so there will be not breaks, and the key part of forming region is secure. The thickness of thickest region is 1.28mm, where the wrinkling is not serious. The final deformation is acceptable. Therefore, after adjusting the blank holder force and set the parameters of drawbead forming, we can obtain good results. In the stamping process of loading the following kinds of blank-holder force change curve and get the thickness of the parts in the thickness change is the biggest place [9].

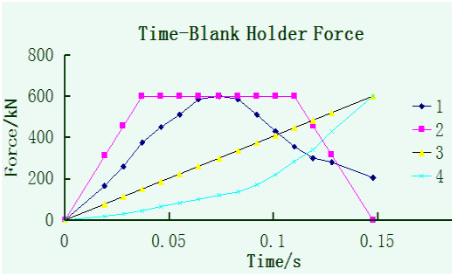


Figure 9. The Curve of Time-blank Holder Force

Table 1. The Thickness Changes in Different Blank-holder Force Form

The blank-holder force change form	1	2	3	4
The thickness of the parts in the thin place(mm)	0.976	0.927	0.884	0.936

The rear coaming of automobile is small shallow drawing which will produce springback after unloading, as is shown in figure 10. The springback quantity is largely related to the performance of the material itself and the stress conditions in the process of forming. Automobile rear cowl panel adopts stamping cold rolling ST13. If we want to control the springback, the only way is to change the mechanical properties. After many simulation analysis, the larger the blank holder force is, the smaller the springback amount is in flange region. However, it is not feasible only by simply adjust BHF to control springback of the integral parts. As an important way to control the material flow, drawbead can change the stress condition of the parts greatly, so it can be used to control the drawbead springback. Under the same loading path conditions, we gradually change the parameters of drawbead. After repeated simulation, we analyze the springback of components with different drawing rib height using cross section method, and find the bigger the drawbead height is, the greater the stress is, and springback is the minimum after unloading [10-12].

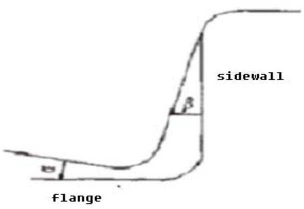
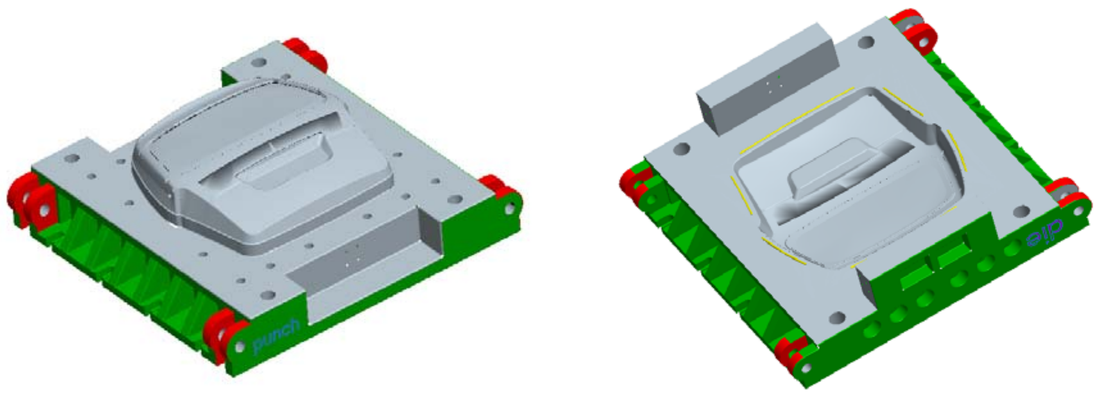


Figure 10. The Part's Springback

4. Process Optimization and Die Design Rear end Panel

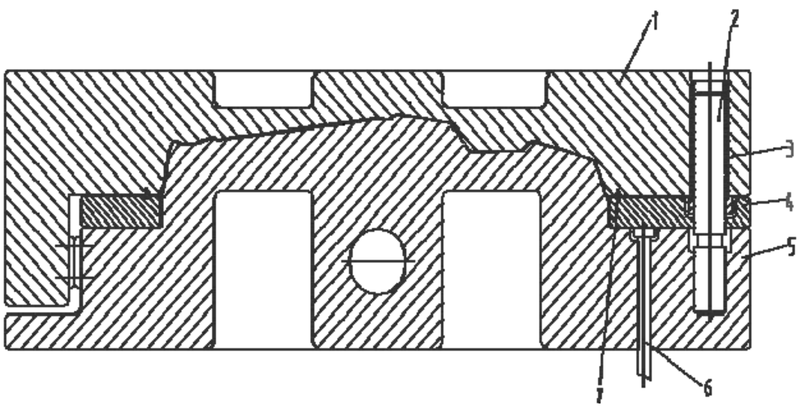
After repeated simulation and analysis of simulation results, we find out the reasonable stamping process parameters to achieve the objective of the forming process optimization. Then we use these parameters to solve the problems in back panel die design and manufacturing, so as to realize the optimization design of die.

Then we consider the binder surface, brake bead, press and a few other conditions. Mold design is shown in Figure 11, and its plane is shown in Figure 12.



(a) The stereogram of punch (b) The stereogram of die

Figure 11. Mold Drawing



1—Die; 2—Guide pillar; 3—Guide sleeve; 4—Blank holder; 5—Punch; 6—Ejector pins; 7—Material leading

Figure 12. The Planar Graph of Mould

5. Conclusion

This paper uses CAE software to make several finite element numerical simulation analysis of a certain automobile rear end panel stamping forming under constant blank-holder force and step-shaped and curve-shape change, and find the optimal BHF and its changes. At the same time, we analyze stamping forming to obtain the minimum rebound value under good forming results and achieve the purpose of optimizing sheet metal forming. This paper determines the suitable stamping process parameters for practical pressing covering parts,provides guidance for design of stamping process planning and die, so as to shorten the production cycle, reduce cost and improve body quality of a car.

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