Measurement of Aluminum Alloy Automotive Cover Parts Forming Parts Based on ARGUS System

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Abstract: This article takes the outer panel of an aluminum alloy engine hood as the research object, uses the finite element analysis software Dynaform for finite element analysis simulation, and uses the ARGUS mesh strain measurement system to conduct experimental analysis on the solid formed parts. This article mainly completes the experimental verification of parameters such as thinning rate measurement for a formed aluminum alloy automotive cover using the ARGUS grid strain measurement system. By comparing simulation results with experimental measurement results, check whether the formed part is feasible under this process parameter. To ensure the accuracy of the results, 21 points distributed in different parts of the formed part were taken and measured using the ARGUS grid strain measurement system to check whether the simulation results are close to the experimental results.

Keywords: Stamping forming, ARGUS mesh strain measurement system, simulation, aluminum alloy automotive panels.

1. Introduction

Mold surface compensation is an important technology to improve the level of automotive manufacturing. In the process of compensating for automotive mold surfaces, the main focus is to control some important mechanical process parameters that affect the quality of mold surface forming, such as edge pressure control, mold clearance, mold structure parameters, sheet thickness, friction factors, etc., in order to achieve the effect of compensating for mold surfaces [1,2]. The wrinkling or rupture of certain parts of the sheet metal during the stamping process is the main defect that occurs in the production of aluminum alloy engine hood outer panels. For formed parts, the rebound caused by metal memory is also one of the factors affecting the final quality of the formed parts [3,4]. In actual production and manufacturing, controlling the stamping parameters of the aluminum alloy engine hood outer plate can achieve the effect of compensating the mold surface, thereby ensuring that the formed parts do not wrinkle, crack, and have a large amount of rebound, which is an important issue in the field of mechanical stamping [5]. In order to detect the quality defects mentioned above in the formed parts, this article uses the ARGUS grid strain measurement system to measure and analyze the formed parts, check the forming status of the formed parts, and provide support for further production and manufacturing.

2. Process Analysis of Aluminum Alloy Engine Hood Outer Panel

The main research content of this article is to analyze the problems that may occur during the stamping process of the automotive hood outer panel (Figure 1), such as tensile cracks or wrinkles, which affect the forming quality. The part is symmetrical as a whole, with complex shapes and relatively large surface area, and the overall changes during stamping forming are relatively small. The surface of the part has two distinct edges, while the other areas are relatively flat,

The overall height difference of the parts is not large, and plastic deformation is not easy to occur during the forming process, which can easily cause rebound and cause changes in the overall shape of the parts. Due to the fact that the aluminum alloy outer panel is equivalent to a car facade, it has high requirements for forming quality. During the forming process, it is necessary to select the optimal forming parameters to ensure sufficient surface forming of the parts and reduce rebound. Therefore, it is necessary to ensure that the thinning rate of the formed parts is not higher than 25% and the thickening rate is less than 10%. In order to ensure the quality of the formed parts, it is necessary to carry out integrated design from material selection to optimization of stamping parameters.

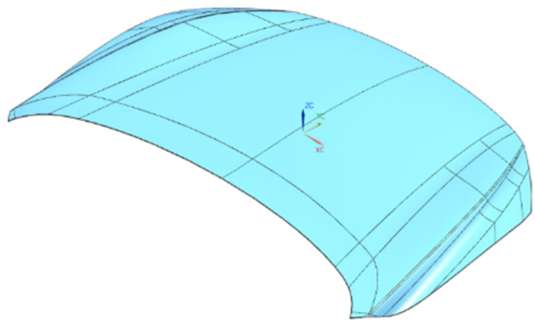

Figure 1. 3D model of the exterior panel of the car hood

2.1. The influence of material selection on sheet metal forming

(1) Hardening coefficient

The hardening coefficient is mainly used to describe the degree of hardening of the aluminum alloy engine hood outer panel during the plastic stage of the stamping process[6,7]. In the stamping process of aluminum alloy engine hood outer panels, which have complex shapes and generally larger individual workpieces, if the deformation of various parts during the stamping process is uneven or the bulging component in the middle of the part is large, the effect of the hardening coefficient is very obvious[8]. The larger the hardening coefficient, the more real stress is applied to the part under the same conditions, which can make the deformation of the part more uniform and reduce local thinning of the part[9].

(2) Thickness anisotropy coefficient

The magnitude of the thickness anisotropy coefficient expresses the difficulty of deformation of aluminum alloy sheets in that thickness direction, and their relationship is positively correlated[10,11]. That is, the larger the thickness anisotropy coefficient, the more difficult it is for the aluminum alloy material to deform in that thickness direction. During the stamping process, the resistance of this part of the aluminum alloy material gradually increases[12]. In order to comprehensively evaluate the overall anisotropy performance of aluminum alloy sheets, the average thickness anisotropy coefficient is generally selected[13];

(3) In-plane anisotropy coefficient of the board

Aluminum alloy sheets may have fiber orientation during rolling, resulting in certain differences in deformation forces in various directions during the forming process. By using the directional anisotropy coefficient within the plate surface to represent the differences in various directions, the larger the difference in performance in each direction, the more uneven the deformation of various parts of the sheet metal during the stamping process[14,15]. This phenomenon can cause uneven wall thickness of the final formed part, reducing the quality of the formed part. So for the selection of stamping formed sheet metal, materials with smaller in-plane anisotropy coefficients should be selected[16].

(4) yield strength

The yield strength represents whether a metal sheet is prone to deformation during the stamping process. If the value of yield strength is larger, it indicates that the material is less prone to deformation. If the value of yield strength is smaller, it indicates that the material is more prone to deformation[17,18].

(5) Flexural strength ratio

The yield strength ratio represents whether a material is more likely to enter the plastic deformation stage during the stamping process, thereby reducing the occurrence of wrinkling. The smaller the yield to strength ratio of a material, the easier it is for its flange surface to enter the plastic deformation stage when subjected to external pressure during the stamping process[19]. Therefore, reducing the value of the edge holding force can also reduce the plastic deformation force, resulting in a decrease in the ultimate drawing coefficient[20].

2.2. Material selection

Based on the aluminum alloy engine hood outer plate blank provided by a certain automotive mold company, it is determined to be E170 aluminum plate. The specific properties of this aluminum plate are as follows:

Table 1. E170 Aluminum Plate Performance

Sheet thickness/mm	zero point nine
Yield strength/MPa	one hundred and twenty-one
Tensile strength/MPa	two hundred and thirty-eight point two
Elongation rate/%	22.0-25.6
N-value	zero point two four nine
R-value	zero point five eight five

2.3. Process supplementary surface design

The process supplement surface is designed mainly to ensure the quality of the formed part is more sufficient. Its main method is to add some materials that can play a specific role in some positions on the original basis of the part. This part of the material is not necessary for the stamped product, and needs to be cut by the trimming die after the final stamping is completed. The rationality of the design of the process supplement surface has a significant impact on the subsequent forming quality, and the subsequent shaping, trimming, flipping and other processes will also have a significant impact [21,22]. Due to the crucial design of process supplementary surfaces, it directly affects the forming quality, process parameters, stamping deformation conditions, and other steps of subsequent aluminum alloy sheets. It also has a significant impact on the subsequent forming quality, such as wrinkling, cracking, and springback [23].

The process supplement for aluminum alloy automotive panels in this article is shown in Figure 2; The main ideas for designing supplementary surfaces in the process include:

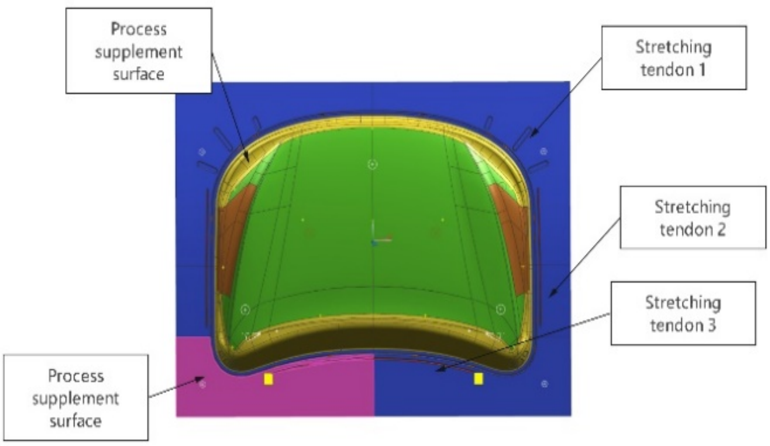

Figure 2. Process Supplementary Surface Design

(1) Fill some holes on the aluminum alloy car cover model, which should not be generated during the stamping and deep drawing process. Therefore, when making process supplements, it is necessary to fill them according to the shape of the holes. For smaller holes, direct filling measures are generally adopted. For larger holes, the drawing radius and draft surface need to be considered, and the process supplementary section method is used for design. But since there are no holes in the car cover, there is no need to fill the holes.

(2) By designing supplementary surfaces around the mold, aluminum alloy metal sheets can transition from elastic deformation to plastic deformation during the stamping process, thereby controlling the springback of the formed parts.

(3) The radius of the drawn fillet usually affects the fluidity of the sheet metal. In order to facilitate the flow of the sheet metal during the forming process and reduce the springback of the formed part. According to the characteristics of this stamping part, the radius of the drawn fillet is set to 20mm.

2.4. Principle of stretching reinforcement

Stretching ribs are a common component in stamping molds, whose main function is to provide flow resistance of the sheet metal during the stamping process, thereby controlling and adjusting material flow. The main functions of stretching bars are as follows:

(1) Increase feed resistance: Stretching ribs can effectively increase the resistance during feeding, preventing wrinkling caused by excessive material flow.

(2) Adjusting the distribution of feed resistance: By setting different shapes (such as square, semi-circular sections, etc.) and sizes of stretching ribs, the distribution of feed resistance can be adjusted to meet different process requirements.

(3) Adjusting the inflow: The stretching rib can adjust the inflow to a certain extent to obtain the ideal stamped part.

(4) Reduce the requirements for the clearance of the pressing surface, grinding difficulty, and equipment tonnage: After using drawing ribs, the clearance of the pressing surface can be appropriately increased, and the surface accuracy can be reduced, thereby reducing wear and lowering the cost of mold manufacturing.

(5) Prevent wrinkling: By increasing the amount of thinning of the sheet metal, stretching ribs can help prevent wrinkling caused by the inflow of raw materials.

(6) Increase radial tensile stress and reduce tangential compressive stress: This helps prevent wrinkling caused by billet inflow.

(7) The deformation force of bending and anti bending is the main part of resistance: when the sheet metal passes through the drawing ribs, friction resistance is generated at the parts in contact with the ribs, causing an increase in the total drawing force.

(8) In addition to providing passive flow resistance, diagonal braces can also provide active guiding forces for material flow.

2.5. Setting of stretching bars

The final forming quality of aluminum alloy engine hood outer plate stamping largely depends on the reasonable setting of the stretching ribs, which means that the reasonable design of the stretching ribs plays a decisive role in the final quality of aluminum alloy engine hood outer plate stamping forming [10,11]. In the stamping process of aluminum alloy sheet metal, a certain size and uniformly distributed radial tensile stress is required around the aluminum alloy blank. This tensile stress mainly comes from the deformation resistance of the stamping equipment to the aluminum alloy sheet metal, as well as the friction force between the compression fabric or flange surface and the aluminum alloy sheet metal. However, if only these forces are relied on for stamping forming, aluminum alloy sheets are prone to quality problems such as cracking and wrinkling. So it is necessary to set reasonable stretching ribs for aluminum alloy sheets, increase the resistance of the stamping process, and meet the radial stretching force required for aluminum alloy stamping forming [12,13]. Reasonable setting of stretching ribs has a certain inhibitory effect on the possible wrinkling or cracking of aluminum alloy sheets during the forming process. In order to make the simulation results more accurate, solid stretching ribs were set up for the aluminum alloy engine hood outer panel, which directly drew grooves on the pressing surface, as shown in Figure 3. Compared with virtual stretching ribs, the resistance of solid stretching ribs is mainly adjusted by the depth of the stretching ribs and the size of each corner. Therefore, during forming, the higher deformation complexity of the sheet metal will lead to an increase in finite element simulation time [14,15].

Due to the high risk of wrinkling in the upper right corner of the stamping process, a stretching rib 1 is set to control the radial flow of the sheet metal and prevent excessive inflow of the sheet metal in that area, thus preventing wrinkling. At positions 2 and 3 of the drawing ribs in the mold, there is a large amount of deformation of the sheet metal at that position, which also requires controlling the excessive flow of sheet metal. Therefore, double drawing ribs are set at these two positions to make the sheet metal deform more fully during the forming process.

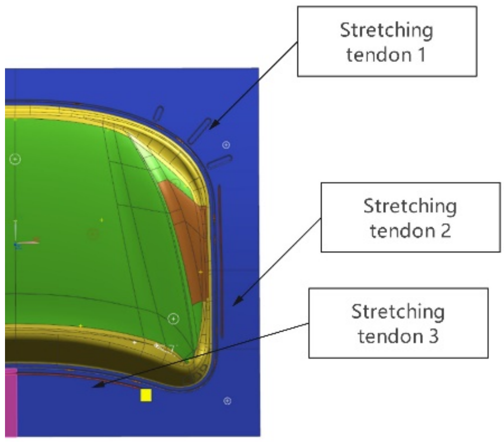

Figure 3. Design of Stretching Reinforcement

3. ARGUS System Measures Entity Results

The ARGUS grid strain measurement system is used to measure and analyze solid workpieces. The ARGUS grid strain measurement system mainly includes an electrochemical marking machine, an Argus measurement head, Argus digital reference points, and a workstation equipped with Argus software (as shown in Figures 4 and 5).

Its main purpose is to verify the CAE analysis results and provide guidance for optimizing stamping processes.

Figure 4. Grid Printing System

Before using this system for measurement and analysis, the sheet metal must be cleaned to remove surface impurities. Then, a certain shape of grid circles must be engraved on the surface of the metal sheet metal through electrochemical etching. During the stamping process of the aluminum alloy car hood outer plate, these grid circles will be stretched or compressed due to the flow of the sheet metal. Stamping the sheet metal with grid circles to obtain the formed specimen (as shown in Figure 5); Then, high-resolution cameras are used to take photos of the formed parts from different angles, and the three-dimensional coordinates and primary and secondary strains of these grid centers are calculated using the principle of "photogrammetry". Finally, the thinning rate and primary and secondary strains of each point were calculated using Argus software based on the assumption that the volume of metal plastic deformation remains unchanged. The results are shown in Figure 6.

Figure 5. ARGUS Software and Hardware System

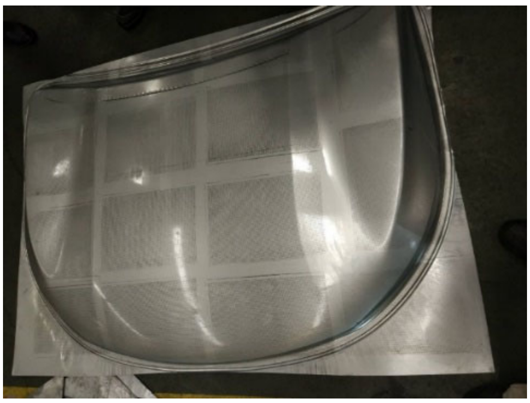

Figure 6. Formed parts of a certain car cover

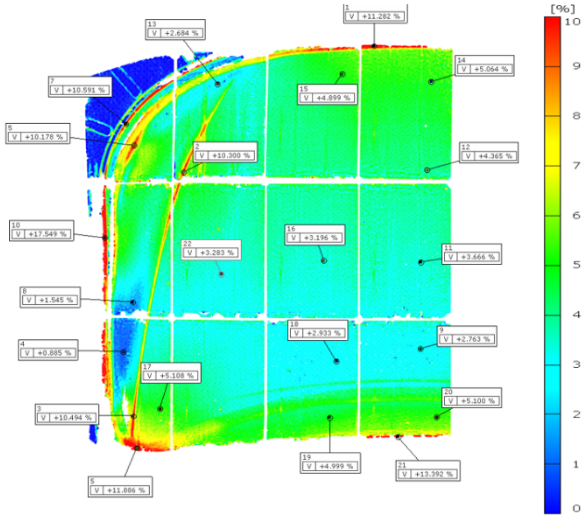

Figure 6. Argus measurement thinning results

4. Conclusion

The ARGUS mesh strain measurement system can effectively obtain the forming quality of various parts of the solid part, and the results can be compared and simulated with finite element simulation results, providing support for the next step of production and manufacturing, and further improving the production forming quality of this automotive panel.

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