Forming Analysis and Die Design of the Connecting Plate of Automobile Door Inner Panel

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Abstract. Door inner plate connecting plate is the key part of automobile door assembly, and deformation is highly nonlinear. The stamping process of the connecting plate was analyzed and the forming process design was determined. The drawing forming of the parts is analyzed, and the FLD diagram and the thinning rate cloud diagram of the connecting plate are obtained. According to the result of cloud image, the drawing forming process of parts is analyzed, and the stamping defects such as wrinkle and crack in the drawing forming process of connecting plate are forecasted. It is concluded that the drawing forming process of parts is good as a whole, the local thinning of parts is more than 25% seriously, and the cracking trend is improved by increasing the radius of fillet. UG and CAD software were used to design a complete set of drawing die and pressure test, and reliable drawing parts were obtained. The reliability of stamping analysis and die design was verified.

1. Introduction
The inner plate connecting plate of the automobile door is one of the key parts of the automobile door assembly, which has the characteristics of high surface quality requirement, complex shape, high dimensional accuracy, thin material and so on [1]. In this paper, the car door inner plate connecting plate stamping forming process was analyzed, and the forming program was determined. Secondly, the drawing forming of connection plate was analyzed, and stamping defects was predicted. UG and CAD software were used to design a complete set of drawing die, and the reliability of stamping analysis and die design was verified through production preloading, which also provided some practical significance for stamping forming analysis and die design of similar parts.

2. Stamping Process Analysis of Connecting Plate
The connecting plate of the inner plate of the car door is welded under the door assembly, and there is one left and right door each, which is symmetrical in shape. Therefore, only one part is taken for analysis. The part model is shown in Figure 1. The maximum contour of the parts is about 720mm × 315mm × 245mm, and the weight is about 1.3kg, and the thickness of the parts is 1.2mm, and the material is DC54D+ZF40/40, which is a kind of cold-rolled galvanized steel plate for deep drawing[2]. The forming surface of parts is more complex, the curvature changes greatly, and the surface quality is required high. The maximum thinning rate of parts should not exceed 20% to prevent cracking and neck shrinkage. The parts and the inside plate of the car door need to be connected by spot welding, and there can be no defects such as stack, burr, surface scratches [3].

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The forming depth of parts is more than 20mm, and the parts need to punch 23 holes, including 5 specialised holes, 18 round holes, the diameter of Φ 5.2mm to 25mm range, and the shape around the trimming line is more complex, and between the surface and the surface is too large, which put forward a very high request to the process design.

The stamping process of the parts is designed from the aspects of stamping forming performance and stamping forming scheme of the parts. In the early stage of the process design, finite element software is needed to determine the stamping direction, the shape of the pressing surface and the supplementary surface of the process. In order to improve the production efficiency, the process design of the connecting plate parts with one mould and two pieces is adopted [4-5].

3. Finite Element Simulation of Connecting Plate Forming
In this paper, UG software is used for modeling, and the modeled files are transformed into IGS format and imported into the analysis software. Friction plays a key role in forming the connecting plate. Too large is easy to cause cracking defects, and too small is easy to cause wrinkling defects. In this paper, the friction coefficient was selected as 0.15. Blank holder force can effectively control the feeding speed of sheet material, too fast or too slow will lead to the production of parts defects. The initial blank holder force in this paper is chosen as 780kN. In order to realize the finite element analysis of drawing forming, the punching holes on the parts are supplemented according to the requirements of drawing process. The clearance of the convex and concave die plays an important role in the forming of parts. In this paper, the clearance of the convex and concave die is selected as 1 times the material thickness.

In order to ensure the uniform forming force and correct size of the parts, combined with the symmetry of the left/right door inner plate connectors, the forming process adopts the stamping process of one die and two pieces. The flow process of the blank sheet is symmetrical and the forming is relatively uniform, as shown in Fig. 2.
As shown in Fig. 3, according to the forming limit of the connecting plate in Fig. 3, it can be concluded that the overall forming part of the part is within the range of the safety zone, and there is a lot of feed in the middle waist and just below. There are obvious wrinkling areas outside the pressing surface and trimming line, but they are trimmed off in the subsequent trimming process, which has a very small impact on the surface quality of the part.

Fig. 3  Forming limit diagram of part

As shown in Figure 4, according to the thinning rate cloud figure 4 of the connecting plate parts, it can be concluded that the thinning rate in the local position of the parts stamping is more than 20%, and the serious area is more than 25%, which has a certain impact on the later use of the parts. The stamping forming of connecting plate parts is a combination of sheet metal deep drawing deformation, sheet metal bending deformation, bulging deformation and other comprehensive deformation. In order to reduce the thinning of the local position of the parts, the fillet radius of the serious thinning area should be increased to reduce the degree of deformation and increase the feeding to reduce the thinning without affecting the use of the parts [3].

Fig. 4 Thinning rate cloud chart

Combined with the punching deformation characteristics of the connecting plate, from the perspective of actual production, the radius of the fillet in the local area where the parts are seriously thinned is increased, as shown in Fig. 5.
4. Design of Drawing Die for Connecting Plate

According to the process design analysis, the connecting plate parts for process was supplemented, and the drawing forming parts of the numerical model was import to the UG software, and the overall mold was designed.

The concave model cavity is directly generated by the imported digital model. According to the size of the blank plate, the size of the model surface is determined. According to the maximum forming depth of the parts, the depth of the cavity is determined. According to the empirical value, the distribution of the balance block, the thickness of the reinforcement plate and the size of the lifting lugs are determined. The concave model cavity is processed separately with Cr12MoV material and then stitched into the cavity. The heat treatment is quenching and low temperature tempering. The mould base adopts integral casting, the material is HT300 [2], and the structure is shown in Fig. 6.

The blank holder cavity is determined by the digital model, and the punch edge is set 2mm gap, the size of the surface is determined by the blank size, the distribution of the jacking rod follows the principle of force balance, the jacking rod jacking height is consistent with the forming depth of parts, weight reduction holes, lifting devices are determined by the enterprise experience value.

Because the blank holder has a large bearing force and is easy to wear, the whole casting process around the blank holder is made of HT300, and the pressing surface is made of separated processing and then stitched together, and the material is consistent with the die material. Two feed racks and guide racks are respectively set before and after, and four limit blocks are added at the four corners. [2] The structure of blank holder is shown in Fig. 7.
Fig. 7 Blank holder structure

Punch is directly generated by the import of the digital model, according to the maximum forming depth of parts, determine the height of the punch, according to the experience value to determine the pad distribution, thickness of the reinforcement plate, lifting lugs and other dimensions, die base thickness according to the maximum size of parts and mold pressure.

In order to ensure the working strength of the punch, the punch and the die base are processed separately. The material of the die base is HT300 and the punch material is MoCr. The convex model cavity is shown in Fig. 8.

Fig. 8 Convex cavity

According to the preliminary process design scheme, the results of finite element analysis and the data of mold design, the trial-production of the mold and the pressure test of the parts were carried out to produce the connecting plate of the inner plate of the automobile door, as shown in Fig. 9.
5. Conclusions

(1) The stamping process of the connecting plate was analyzed, and the forming process design of the parts was determined. The drawing forming process of parts is analyzed, and the forming limit diagram and the thinning rate cloud diagram of parts are analyzed according to the technical requirements of whether there is cracking and wrinkling. The reliability of parts forming is guaranteed by increasing the fillet radius of local thinning serious area.

(2) UG and CAD software were used to design the punch, blank holder and concave die parts of the drawing die. Through the production pressure test, the drawing forming parts of the connecting plate were pressed, and the rationality of stamping process analysis and die design was verified.

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