Progressive stamping process and die design of high strength steel automobile structural parts

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Abstract. High strength steel has high strength and poor plasticity. When it is used in parts with large material thickness, complex shape and many working procedures, higher requirements are put forward for mold design. This paper introduced the forming characteristics, layout scheme, overall structure design of multi-station progressive die and design key points of important parts of a high-strength steel plate car mounting part. The progressive die including blanking, drawing, local forming and bending and other 13 processes was designed. The preforming and secondary forming were adopted to form the reinforcing ribs. The double-row with center carrier layout pattern was adopted to reduce the bending side force, and made the material utilization higher. The sub-die and insert structure’s using was convenient for die machining and debugging. The practice has proved that the die structure is reasonable and reliable, which can guarantee the quality of the products. It can be used as a reference for the design of similar products.

1. Introduction
With the development of stamping technology, in order to improve the efficiency of stamping, reduce production costs, some small and medium-sized complex automotive structural parts will more use of multi-station progressive die, which in traditional stamping process mode many sets of dies will be used. A lot of research has been done on the progressive stamping process and die design of automotive structural parts, for example Xu Chaohui[1]designed a progressive die for an automobile dust cover, simulated its forming process by the sheet analysis software, the design of 8-station die structure is finally confirmed, which includes blanking, deep drawing, partial forming and flanging. Wen Jie et al[2]carried out stamping process analysis of automobile bumper support, and designed a layout scheme of 8-station progressive die. The structure design of the die and the main parts is carried out by using the structure of insert and double inclined wedge.

In addition, the demand of automobile safety and fuel economy makes high strength steel plate widely used in automobile parts processing field. The high strength steel plate not only brings the light weight to the automobile, but also puts forward the higher request to the mold structure design, because of its strength increase and plasticity decrease. Especially for the parts with complex structure, large thickness and big deformation, it is particularly important to select reasonable layout and control the deformation sequence of parts by using progressive die production. Chen Zhichao et al[3]. analyzed the stamping process of parts according to the characteristics of a high-strength steel automobile structural part, and designed a double-lined 13-station progressive die. However, the study about multistep progressive die design used in complex high strength steel parts are still not popular. Therefore, this paper puts forward to study a high strength steel car mounting part stamping process, the process was analyzed, the final layout plan was determined, and a rational structure of multi-
station progressive die was designed, which can reduce mold manufacturing costs, and improve production efficiency.

2. Stamping process design

The car mounting part is shown in figure 1. Its material is ST52, thickness is 2.5mm, and annual output of 1 million pieces. It is one of the symmetrical parts. Its overall shape is asymmetrical, just like the character "Z". The flat and larger surface is the mounting surface of the part, which has an elliptical hole and two small convex bulges. There are two reinforcing rib structures which are close to each other and basically symmetrical in appearance. The reinforcing ribs have four holes to be punched. There are three places on the part to bend, the end has a large stepped bending, the bending angle is 93°, the straight edge height is 3mm. No warping is allowed around the bending, and the burr should not be too large, otherwise it will affect the assembly and appearance of the product.

![Car mounting part](image1)

**FIG. 1 Car mounting part**

![Part thickness distribution diagram](image2)

**FIG. 2 Part thickness distribution diagram**

In NX, one-step inverse forming of punch engineering module can use to analyze the formability of car mounting par, and the thinning, stress and strain of the part during the stamping process can be obtained. As shown in FIG. 2, it's the part’s thickness distribution map. It shows that the thinning near the stepped bending between the two reinforcing ribs is about 0.43mm (17.3%), and the thickening around the bottom of the reinforcing ribs is about 0.42mm (16.9%). In stamping, it is generally accepted that the thickening of the formed part shall not exceed 10% and the thinning shall not exceed 30%. Therefore, how to form the two reinforcing ribs in accordance with the requirements, to avoid cracking and reduce wrinkles, is the difficulty of the stamping process design of this part.

According to the previous part structure characteristics analysis, three stamping process plans are proposed to be compared:

1. Single dies production. It shall use at least 8 sets of dies, which includes 4 sets of punch die (punch partial contour, cut edge, punch 2 holes on reinforcing ribs, punch hole between reinforcing ribs), 2 sets of bending die (bending flange side, bending head), 2 sets of drawing die (forming convex bulges, forming reinforcing ribs). Work piece need to be positioned for many times, the operation is not convenient, the accumulative error will be larger, and the production efficiency will be low, so it is not conducive to mass production.

2. Compound die production. All the processes to be completed in a die, reinforcing ribs also need to be formed in one-time stamping, while the work piece is prone to excessive thinning or even crack due to its poor material flow condition. The 2 holes on the reinforcing ribs and the hole between the two reinforcing ribs are not on the same plane, so it is need to add side piercing device, the die structure will be complex, so it is not conducive to be adjusted and maintained.

3. Progressive die production. The complex procedure of the work piece can be decomposed into simple basic procedure, for exam the reinforcing ribs forming, which can be divided into two
steps. The irregular contour of the work piece can also be divided into sections, which can make punch and die easy to design and manufacture. The strip adopts automatic feeding mechanism, using pilot-pin to guide the positive positioning, which can avoid the large accumulated errors caused by multiple positioning. So the stamping parts quality is stable, easy to achieve automation and improve production efficiency.

According to the above comparison and the actual production condition, the progressive die stamping production scheme is selected.

3. Layout design

Layout design is the key job of progressive die design, which reflects the rationality of the part whole stamping process, it includes the station setting, the relationship between each station, the positioning method, the material utilization and the die structure design[5]. The principle of layout design is piercing and blank the contour first, then bending and other forms, and finally the separation of parts from the strip[6].

According to the comprehensive analysis of the stamping process, material utilization, mold structure, mold strength and manufacturing cost of the parts, through the comparison of a variety of plans, the center carrier is adopted to arrange in double rows, as shown in figure 3. A total of 13 stations are designed, of which 11 are working stations and 2 are empty ones. The strip width is 430mm and the feeding step is 170mm. The station arrangement is as follows: (1) notching, piercing four large process holes and one pilot hole (2) blanking partial contour and piercing two small process holes (3) preforming 2 convex hulls (4) forming 2 ribs and bulges (5) empty station (6) cut side-edges (7) bending 95° angle (8) piercing four mounting holes on the reinforcing ribs (9) fold flat (10) bending 93° angle and sizing (11) piercing a mounting hole between two reinforcing ribs (12) empty station (13) work pieces separation.

The advantages of this layout plan are as follows:

(1) according to the symmetrical characteristics of the product and its output requirements, two pieces in one die (double row) stamping production is adopted, work pieces and strip connected with the center carrier. It can effectively prevent the material deviation when bending, eliminate the
side force when stamping. It can increase stamping stability and die life. After calculation, the material utilization is 75.1% in double-row, which is 5.5% higher than that in single-row (69.6%).

(2) the workpiece contour blanking adopts the method of segmental blanking to set the procedure, avoiding punches and dies exist complex shape, avoiding the production of sharp angle structure which can bring out stress concentration, facilitating the manufacturing and processing of punches and dies, and improving the use strength of working parts.

(3) use two drawing procedures to form the reinforcing ribs. The pressing convex hulls (preforming) procedure is added before forming the reinforcing ribs, which plays the role of pre-storage of materials. The size (depth and rounded corners) of the convex hulls are adjusted by combining with numerical simulation and physical mold testing to improve the material flow condition during the forming and solve the quality problems of wrinkling and cracking of the reinforcing ribs.

4. Die design and manufacture

Die structure design includes the design of process parts and auxiliary parts. This die adopts formal structure, four-pillar ball guide pin guide bush die set, positioning device adopts automatic feeding mechanism and pilot pin positioning, the die shut height is 487.5mm. According to the actual production conditions, the stamping equipment adopts the XUDUAN JL36-400, its nominal pressure is 4000kN, and the stroke times are 26 times/min. The assembly drawing of this die is shown in figure 4.

The main characteristics of this die are as follows:

(1) The size of the die is large (width and length of the die template is: 2500×550mm). Considering the problems of template preparation, die assembly and test, the composite sub-die structure is adopted. Each sub-die is fixed on the die base by screws and pins. The sub-die structure can also reduce the influence of heat treatment deformation on the template manufacturing accuracy. In order to reduce the accumulative errors during the sub-die assembly process, the associated assembly gap is processed on each sub-die structure by wire cutting. The gap is only used for assembly, and it will be cleared after the correct location of the sub-die is determined.

(2) The first and second work stations are partial contour blanking, blanking area is large, in order to make the die structure compact, easy to design and process, so here die uses integral structure. When assembling, use cylindrical pin to locate, screw to fix die on die backing plate. For the rest of the stations, the die use the insert structure, fixed by embedded method. Firstly, the insert is embedded into the corresponding hole of the die holder or the block with groove, and then fixed on the die backing plate with screws. The die with a small bottom area is designed as a bench structure, and a shoulder is designed at the bottom edge of the fixed end, which is fixed by the stepped hole of the die holder. The die thickness is based on the die thickness of the first and second stations and is adjusted according to the height of the work piece.

(3) The deformation resistance of high-strength steel is great, so the stress of the die is greatly increased compared with that of the ordinary low-carbon steel and single-process die. In order to avoid the interference of punches and dies, increase the die strength, an empty station is set between the forming and cutting process of reinforcing ribs. Before the final work piece separation process, an empty station is set to add additional necessary procedures (such as trimming, sizing etc.) for the convenience of die testing and adjustment.
5. Conclusion

This paper takes a high strength steel plate automobile structure part as the research object, the stamping process was analyzed, the die type and the stamping process plan was determined, the layout pattern, the die was designed, and the parts were manufactured. The main characteristics of this design are as follows:

(1) A double-row with center carrier layout pattern is adopted to reduce the bending side force of unsymmetrical single-side bending parts;

(2) The preforming process is adopted to facilitate the flow of materials and avoid the fracture of complex surface:
(3) The composite sub-die structure is adopted, which is convenient to solve problems such as template material preparation, die assembly and testing, and reduce the influence of heat treatment deformation on the template manufacturing accuracy.

After adjustment of the die, the qualified parts are produced, as shown in fig. 5. The product quality is stable, the mold runs smoothly, achieves the expected effect, it can be used as a reference for the design of similar products.

![FIG. 5 Left and right car mounting parts produced](image)

**References**

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