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Research on the Improvement of Production Efficiency through Precision Surface Design of Automotive Cover Parts

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Abstract: The design and manufacture of large-scale mold for automotive cover parts is a bottleneck in the development of China's independent brand automobiles. In traditional mold design, due to the lack of unequal gap design on the mold surface, after the mold is completed by numerical control machining, the gap between the mold surfaces of the upper and lower molds is uneven after the molds are closed. However, the main reason for the uneven gaps is due to the deformation of the castings, inconsistent thickness of the formed sheet, machining errors, etc., which eventually lead to a low mold closing rate, color difference in the sheet parts, and non-compliance with the initial requirements of the fitters. This paper will take the post-operation as an example to introduce in detail how to solve the problem of uneven mold surfaces of the upper and lower molds through precise mold surface design, thus greatly improving the efficiency of production and the quality of parts.

1. Introduction

During the production of automotive molds, especially large cover part molds, there is a phenomenon of "hollowing out", that is, after the mold is fully closed, the gap around the edge is small, which results in only the edge of the mold being colored during molding. As it gets closer to the center of the mold, the gap between the upper and lower molds gets larger, leading to no coloration. This is mainly caused by the deformation of the mold casting, machine error, uneven thinning of the sheet, and other factors. This situation does not meet the production conditions, therefore, the fitter continuously modifies the mold to minimize the impact on the sheet, which leads to a large amount of fitter work, instability of the parts, and inability to ensure the quality of the parts.

This article deeply studies the above problems and mainly investigates the main factors that cause the inconsistency of the gap between the mold and the thickness of the sheet: the deformation of the mold casting (the larger the mold, the greater the deformation), the deflection deformation of the press itself, and the uneven thinning of the sheet due to the inconsistent product shape in the forming process. Therefore, a new compensation method for mold surface design is proposed. This leads to the concept of precision surface design. At the beginning of the development of the domestic mold industry, the mold surface used for processing did not undergo surface design. The fitter's research and design cycle was long, and there were many factors involved in on-site mold participation, and the quality of the parts was unstable. According to actual on-site problems and some foreign technologies entering the Chinese market, the domestic mold surface design has gradually standardized. Precision mold surface design: Without changing the process, the mold surfaces of the upper and lower mold are treated with unequal gaps, so as to meet the uniform gap between the upper and lower mold surfaces in the actual stamping production process, reducing the fitter's research and combination cycle, and improving the pass rate and stability of the parts. This method of treating the mold surface with unequal gaps is called precision mold surface design.

2. The Manufacturing Method and Effect of Precision Surface Design of Automobile Cover Parts are Introduced by Taking the Post-Sequence as an Example

2.1. Edge Trimming Process: Surface Treatment Method

2.1.1. Post-Processing Content

In order to make the surface quality, color, and pass rate of the parts stamped by the post-sequence mold meet customer requirements, and to reduce the grinding and fitting time, we carry out surface treatment on the post-sequence mold. The main contents of the treatment are:

A. Check the process numerical model;

B. The division and gap treatment of the pressing core symbol area;

C. Letting empty treatment for the lower mold;

D. Gap treatment of flanging and shaping inserts;

E. Check the surface treatment to ensure the accuracy of the processing basis;

F. Fill in the form.

2.1.2. Check of the Process Numerical Model

A. Whether there is an overlap problem in the transition area of the previous and subsequent numerical model surfaces;

B. Whether the surfaces of the previous and subsequent models interfere;

C. Boundary check, continuity check, and smoothness check of the model surface;

D. Whether there is a negative angle [1] in the stamping direction;

E. Whether the CH hole positions of the previous and subsequent processes are the same;

F. Whether the functional line meets the requirements to prevent the functional lines of the previous and subsequent processes from overlapping out of position;

2.1.3. Division and Gap Treatment of the Pressing Core Symbol Area

The post-sequence pressing core mainly carries out the function area tightening and non-function area letting empty treatment, and its basic principles are as follows:

A. The symbol area needs to be determined and an empty/dug-out range should be designated based on the functional line. The dug-out area must be simplified, meaning that small protrusions and locally complex model surfaces less than 10mm in height need to be removed. During the digging process, consideration should be given to the casting volume of the entity, and areas with a dig-out volume of ⩾10mm must be specifically marked.

B. Overall compensation and lateral force compensation should be made in accordance with mold deformation [2];

C. After completing the overall compensation, carry out local compensation according to the layout of pressure sources (nitrogen cylinders, springs, and polyurethane), and perform graded compensation according to the grinding area and function;

D. To prevent the pressing core from rotating or sliding, prevent the phenomenon that the hole punching position is inaccurate due to large rebound of the part, the larger arc surface or vertical surface, and the plane corresponding to the side repair side punching function are symbolized; if the function lines are concentrated on one side, the area without function lines should also be symbolized.

2.1.3.1. Division of coloration grades

In order to ensure that the product surface color meets customer requirements and minimize the grinding and fitting working hours, we divide the pressing core into coloration grades, and the basic principles are as follows:

A. If there are no special requirements for the door inner panel post-sequence, the function area is generally colored;

B. The area with large flanging and shaping is given priority for coloring;

C. If the flanging and shaping function is close to the repair punching function, the symbol area of the flanging and shaping function is given priority for coloring;

D. The area within 20mm around the RPS point is generally colored;

E. The trimming waste area is colored virtually (or normally);

F. Whether convex or concave ribs are located in any functional area, they are not colored.

2.1.3.2. Division of symbol area

A. The trimming symbol area is 20mm, and the side trimming can be increased to 25mm. It should be noted that if the trimming line is located on the step, and the step width is <10mm, the symbol area should be calculated from the boundary of the large plane below the step; when the trimming step width is ≥10mm but less than 20mm, only the step area can be used as the trimming symbol area. As shown in Figure 1:

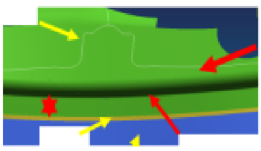

Figure 1: Trimming Symbol Area

If the step width is <10mm, the symbol area under the step is normally tightened with this area, and 0.02-0.3mm is appropriately increased on the step; if the step width is ≥ but less than 20mm, only the step area is tightened. If the project requires a symbol area under the step, the width of the symbol area under the step is 20mm, and let it empty 0.2mm.

B. When side trimming and side punching, a 20mm wide symbol area should be left on the corresponding upper and lower planes of the functional area, and this area should be left empty [3] 0.2mm; if the part is not hollowed out, the symbol area will be left empty 0.5mm together with the empty area;

C. The flanging symbol area is 50mm, and the shaping symbol area is 50-60mm;

D. In order to ensure the balance of the pressure pad core, several symbol areas with a width of 40mm should be left in the non-functional area, let it empty 0.5mm,

F. After the pressure pad core is hollowed out, it should be compared with the entity to prevent the phenomenon that the strength of the area where the entity is weak due to hollowing becomes even weaker after processing, causing the mold to break during mass production.

2.1.3.3. Basis for the compensation of the gap of the pressure pad core

A. Compensation according to the shape of the part and the thinning rate;

The more oblique plane in the part can be directly offset and tightened by 0.1mm according to the treatment method of the facade; in the area where the thinning amount is large in the drawing, compensation is still required in the subsequent sequence. If this area is located in a more impore. If the entity casting area is large, hollowing out is carried out for the non-functional area. When hollowing out 2mm, direct offset is not required, and if the void is less than 2mm, 5-10mm bridging is required; The hollowed-out area is simplified. Tant symbol area, the compensation amount should be appropriately increased, but it should not exceed 0.08mm at most.

B. Compensation based on mold structure, strength and nitrogen cylinder layout; If the pressure pad core is divided into positive and side cores, the strength of the side pressure pad core should be focused on. If the side core has enough nitrogen cylinders to apply pressure to it, there is no need to consider too much; if there are not enough nitrogen cylinders to apply pressure to the side core, additional compensation should be made to the side core area as much as possible to ensure coloring. If the pressure pad core is an overall structure, pay attention to the mold strength of the side repair, punch, flip, and integer symbol area.

The strength of the pressure pad core can be judged based on the mold entity and combined with past experience. If the strength is considered weak, the gap is compensated. The compensation amount can be determined according to the length of the mold, the structure of the mold, experience, etc.

According to the layout of the nitrogen cylinders, local compensation is made for some areas with weaker forces. The compensation amount is generally between 0.02~0.06mm. When the distance between two nitrogen cylinders is less than 200mm, compensation is not made in principle.

C. The area that is not easy to color should be compensated based on past experience.

2.1.3.4. Number model and coloring single color labeling standard

A. Number color labeling: the symbol area is represented by green, and the empty area is represented by blue.

B. Coloring single color labeling: operate according to the color prompt on the coloring single.

2.1.4. Treatment of Clearance in Lower Die

2.1.4.1. In order to make the parts better fit on the subsequent molds and reduce the fitting time, we perform clearance

Treatment on the subsequent molds. The main principles of the clearance treatment are as follows:

A. Drawing male mold, because it needs to be formed by the convex corner, only the concave corners with R>5 are given clearance;

B. The range of the lower mold symbol area is adjusted according to different functions. In order to ensure that the part is not damaged by the pressure pad core, the range of the lower mold symbol area should be at least 10mm larger than the pressure pad core;

C. The clearance amount varies slightly according to different functions. The non-functional boss is wiped off, the concave platform (rib) is offset by 0.5mm for clearance. On the premise of not affecting the function, some concave ribs with a radius less than 2mm can be left empty by 1-2mm, to ensure that the machine can be in place to reduce the fitter's fitting amount;

D. In order to ensure the accurate positioning of the parts, the large vertical surface with positioning function is not moved, and the positioning hole and pin steps are not moved;

E. Some small vertical surfaces that do not affect the lower mold symbol and positioning are all pushed away. The area where the convex and concave fillets are connected will wipe off the convex and concave corners and connect them with a curved surface bridge, to ensure the maximum clearance and reduce machining time;

E. The convex and concave corners with R>5 are given clearance treatment. The convex corners are larger and the concave corners are smaller. The clearance amount is best about 0.5mm. In principle, fillets with R≤5mm are not given clearance treatment; when R=6mm, let it to R=4mm when the clearance amount is >0.2mm;

G. When the function line crosses the symbol area, in order to ensure that the parts do not deform when the mold works, the convex and concave corners perpendicular to the function line in the symbol area are not left empty; the places where the non-function line passes in the flanging and shaping symbol area are made according to the drawn male mold, that is, the convex corner is not let, and the concave corner is let; for those with larger flanging and shaping amounts, the convex corner closest to the function line is not left empty [4];

H. If there is a large area in the lower mold that has no function but the entity has been cast, this area can be hollowed out on the basis of ensuring the fitting and balance of the parts;

I. When undergoing clearance treatment, the entity is considered, and areas with a clearance amount of ⩾10mm are specially marked.

There are two implementation methods for the transformation of convex and concave fillets.

2.1.4.2. Digital modeling method

This method involves reconstructing the convex and concave fillets of the mold surface through filleting or constructing surfaces. The transformation value of the digital modeling method tends to be more theoretical. Its advantages are: (1)There is no need to consider the clearance problem of convex and concave fillets separately during programming, the clearance is given along with the lower mold surface, reducing the probability of human error; (2)The generated program tool path at the convex and concave fillets is the same as before the transformation, no need for programmers to manually edit the tool path; (3)There are no additional tool jumps or lifts during CNC machining, saving machining time; (4)The machined convex and concave fillets are smooth, basically no need for fitters to manually fit, saving time and effort. Its disadvantage is that it takes a lot of time to fillet or construct surfaces when designing the mold surface, and the workload is multiplied. For complex inner and outer panels of doors, etc., it delays the manufacturing cycle node.

2.1.4.3. Programming method

That is, during mold surface design, only the convex and concave fillets that need to be transformed are identified and segmented. During programming, the clearance of the convex and concave fillets is controlled by the program using the software's clearance setting. Its advantages are: (1) The workload of mold surface design is reduced, only need to recognize and segment the convex and concave mold fillets; (2) Use the software to set the clearance amount of the convex and concave fillets, simple and clear. Its disadvantages are: (1) After the convex and concave fillets are hollowed out, they form a step difference with the mold surfaces on both sides. The programming software considers this as a root state and should be deburred, thus forming a deburring tool path at the step , the tool path is complex, and programmers need to manually edit; (2) During CNC machining, the deburring tool path increases, tool jumps, lifts and other phenomena frequently occur, leading to increased machining time, increased tool wear, and ultimately increased cost; (3) After machining, there are steps or undercuts at the convex and concave fillets, and fitters need to fit according to the actual situation.

2.1.5. Comparison and Demonstration of Mold Surface Processing Theory and Practice

Figure 2: Trim process mold surface treatment effect diagram and color band standard

Explanation: Under the backdrop of the increasingly shorter mold development cycle, a detailed treatment of the upper and lower molds is conducted during the mold surface design phase, in order to ultimately shorten the mold manufacturing cycle, improve the quality of the mold, and enhance the competitiveness of the company[5]. Taking Figure 2 as an example, before improvement, the fitter's fitting time was 40 hours, and after improvement, the fitting time was reduced to 25 hours, improving efficiency by 40%.

2.2. Mold Surface Treatment Method in Forming Process

2.2.1. Treatment Method for Flanging Insert

The mold surface of the flanging insert can be offset by 0.1mm in the tight direction; if no treatment is performed, the programming department directly controls the gap to 0.9 times the material thickness [6].

2.2.2. Treatment Method for Shaping Insert

When dealing with the coloring of shaping inserts, we also need to consider the level of coloring and the fitting work time. The plane perpendicular to the stamping direction should be prioritized for coloring. To achieve this, we generally require the vertical surface to be 0.1mm tight and the horizontal surface to be 0.2mm tight during processing. The so-called vertical and horizontal surfaces here are defined relative to the stamping direction, we refer to the shaping surface perpendicular or with a larger angle to the stamping direction as the horizontal surface, and the shaping surface parallel or with a smaller angle to the stamping direction as the vertical surface.

The specific operation method is as follows:

(1) Offset the entire shaping block in the tight direction by 0.1mm (E);

(2) Then move the entire shaping block in the tight direction along the stamping direction (ctrl+D) by 0.1mm;

(3) If there are convex and concave ribs on the shaping block, keep the convex rib in the original position without moving, and make the concave rib 0.5mm wider than the original surface;

(4) If there are shapes connected by convex and concave angles on the shaping insert, they need to be processed for expansion [7]. The specific method is: extend a plane along the "tangent" of the lower boundary of the original convex angle, offset this plane by 0.2mm for expansion, and then make the convex angle inverted to the original size concave angle expansion.

2.2.3. Mold Surface Treatment Inspection Specifications

(1) The continuity, boundaries, and trimming of the model surface are checked.

(2) The smoothness of the model surface is examined.

(3) The range of the press core and the lower mold matching area is inspected.

(4) The unequal gap of the press core and insert is assessed.

(5) The convex mold expansion amount is evaluated.
(6) The plane where the CH hole and the positioning hole are situated remains stationary [8].
(7) The symmetry and the gap of the RPS points [9] are inspected.
(8) The color marking of different functional surfaces is checked.

2.2.4. Fill in the Form

(1) The mold surface gap planning diagram is filled in by the mold surface planning personnel.
(2) The mold fitting coloring form needs entries for over-processed items such as press cores and flanging shaping blocks.
(3) The mold gap indicator diagram requires entries for over-processed items like press cores and flanging shaping blocks.
(4) For the mold surface design inspection form, all items that have undergone mold surface treatment are recorded.

3. Future Development of Mold Surface Design

Considering factors that affect the fitting cycle and the quality of process parts, fine processing of digital mold surfaces is the trend, by combining theoretical analysis and empirical data before CNC programming and machining of the mold.

3.1. Model Surface Treatment Plan

Develop a part mold surface compensation plan based on theoretical analysis, combined with the results of CAE simulation and field actual conditions [10].

3.2. Part Rebound Compensation (Early Mold Surface Treatment)

The early theoretical analysis of mold rebound compensation needs to be carried out based on the initial mold surface. In combination with the process, a comprehensive part rebound analysis is carried out using CAE and field implementation. The rebound compensation is beneficial to the current level of mold surface treatment, making qualified rebound compensation digital models, and improving the qualification rate of parts.

3.3. Final Die Design

After the process rebound compensation is completed, the final version of the mold surface design is carried out to meet the process requirements, realize the final design intention, achieve a shortened fitting cycle, improve the first mold success rate, improve the first press quality, reduce the number of subsequent debugging rounds, improve machining efficiency, reduce the time of CNC machine tool occupancy, avoid repeated errors, avoid ineffective work, in order to achieve the purpose of shortening the manufacturing cycle and improving the manufacturing quality.

4. Conclusion

The development of mold surfaces has reached a very mature stage at this point. To seek development, it is necessary to find a breakthrough. The mold surface is the department that combines the technical department and the production department most closely, with the advantages of theory and practice. However, there are some rules and standards for mold surfaces that are extracted from practical production experience and lack theoretical support. Therefore, we should research the theoretical basis of edge pressing and verify it in practice. When we research and explain what we are doing now in a theoretical way, we will find that the direction of progress will suddenly become clear. The refinement of mold surface design will become more and more important in future mold production.

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