Research of a New Type Oil-Pan Forming Process

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Abstract. The technologic characteristics of the main oil-pan were analyzed with the aid of stamping molding analysis software. The structure, the working process and trying process of dies for drawing the main oil-pan were introduced; The technologic characteristics of the vice oil-pan were analyzed; The welding technologic characteristics of the main oil-pan and vice oil-pan were analyzed; The production process of the oil-pan were introduced.

Keywords: Oil-pan · Drawing · Welding

1 Introduction

The oil pan belongs to the automobile covering parts, which was a long box shaped drawing part with relatively complex shape and it's also a stamping part with high challenge. Usually, soft steel with good tensile properties was used as drawing material. The oil pan parts introduced in this paper adopt 2 mm thick ultra-deep drawing cold-rolled steel plate DC06. The material was an ultra-low-carbon steel which characterized with good surface quality, high dimensional accuracy, superior processing and welding performance in cold state, excellent deep drawing performance and has been widely used in the automotive industry. In recent years, how to increase the capacity of oil pan has become the research direction of various automobile companies due to the increasing demand of consumers for the oil change cycle. This paper introduces a production process of oil pan based on the combination of drawing and welding to increase the capacity of oil pan.

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2 Forming of Main Oil Sump

Through the comprehensive analysis of the parts structure and operating requirement, the process flow of the parts was preliminary determinate as follows: blanking - drawing (times not determined) - shaping - edge cutting, punching bottom hole - flanging - punching side hole (drilling side hole). Due to the absence of difficulties for blanking, shaping, edge cutting, bottom punching, flanging and other processes in the actual production, the drawing process will only be been studied in-depth research in this paper.

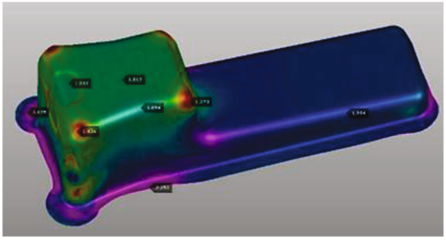

Fig. 1. Variation of oil pan thickness.

2.1 Process Analysis of Drawing

Through the comprehensive analysis of the parts structure and operating requirement, the process flow of the parts was preliminary determinate as follows: blanking - drawing (times not determined) - shaping - edge cutting, punching bottom hole - flanging - punching side hole (drilling side hole). Due to the absence of difficulties for blanking, shaping, edge cutting, bottom punching, flanging and other processes in the actual production, the drawing process will only be been studied in-depth research in this paper.

2.2 Process Analysis of Drawing

Surface scratches and creases were not allowed in the main sump. The flatness of the flange was required to be no more than 1 mm and can be matched with the engine seal to prevent oil leakage. One end of the main oil pan shell shows a dovetail shape, with a deep depth of 310 mm; The bottom was in the form of steps, with a shallow depth of 90 mm. In order to ensure the capacity of the oil pan and prevent the interference between the end face and the internal oil pump of the engine, the slope of the drawing mold on each side of the deep end was only 1. The Autoform forming software was employed for the formability analysis and structure optimization. After optimization, the thinning coefficient of the main oil pan thickness should not exceed the performance index of DC06-2.0 which can be considered to meet the requirements.

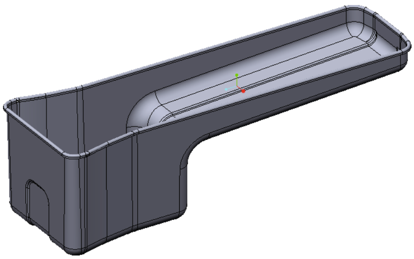

Fig. 2. Shape drawing of oil sump.

As can be seen from the simulation analysis figure (Fig. 1), the thinning of the bottom fillet exceeds the design requirements of the oil pan, which was mainly caused by the small fillet of the punch and can be improved by grinding the fillet of the punch in the process of mold verification to meet the requirements of the product. The actual shape after forming was shown in Fig. 2.

2.3 Process Analysis of Drawing

Due to the main oil sump drawing depth of 310 mm and width of 270 mm, the relative height was calculated by box drawing forming of calculation formula and methods: relative height = depth of oil pan/width of oil pan = 0.87, which was far greater than the maximum relative height of 0.589 achieved by one-time drawing of the box parts. In this respect, the drawing die of the main oil pan was designed according to two-time drawing forming.

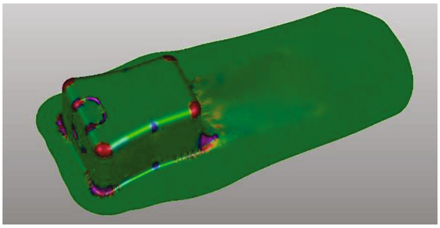

Fig. 3. One-time pull-out limit diagram.

The boundary conditions were set to analyze the oil pan formability according to the simulation analysis of the stamping analysis software combined with the current situation of the company's equipment and materials, including drawing, stress and strain, dangerous sections, etc., which can be properly compensated in the mold design. According to the comprehensive analysis, in the process of primary drawing and secondary drawing, the fracture was prone to occur at the transition of the fillet corner at the end of the oil pan (Fig. 3 and Fig. 4), and

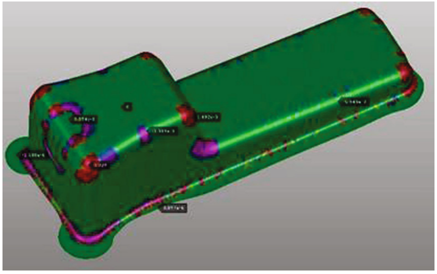

Fig. 4. Two-time pull-out limit diagram.

the stress exceeds the material strength limit. Due to the deviation between the software simulation and the actual operation, the two-time drawing scheme can be determined to be feasible.

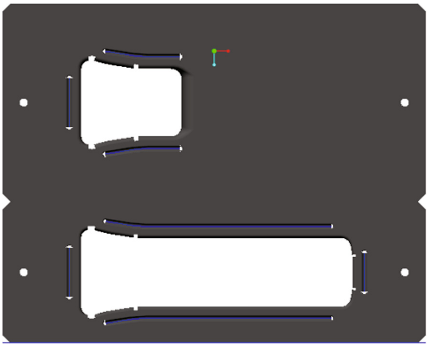

Fig. 5. Position diagram of drawbead.

The mold adopts circular drawing bead, which was distributed around the straight-line section, and there was no drawing bead at the transition part of the rounded corner. The structure and position of the final tendons were shown in Fig. 5. As the side shape of the main oil pan was strictly required by the welding procedure, the gap between the punch and concave dies was reduced as much as possible and preliminarily determined to be 1.1t in order to reduce the deformation degree of the oil pan after drawing forming. In the subsequent die test process, the height and clearance of drawing beading, the clearance of convex, concave dies and local fillet corners were adjusted appropriately according to the state of the die and the drawing situation, so that it can be successfully drawn and consistent. The mold structure was shown in Fig. 6.

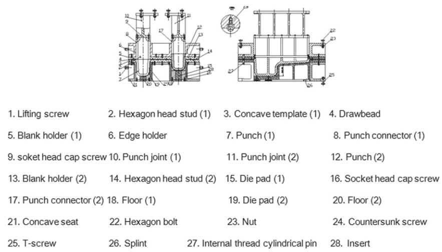

Fig. 6. Diagram of drawing die structure.

2.4 The Working Process of the Mold and the Verification of Drawing Die

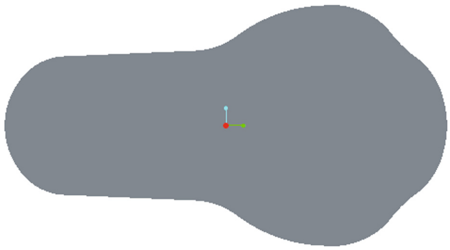

Fig. 7. Diagram of material structure.

The blank type of oil pan was calculated, and the size of sheet material required for drawing was preliminarily determined by the stamping analysis software. As shown in Fig. 7, the material type was modified and optimized in the mold verification process.

Mould Verification Process. Because of many uncertain factors in the drawing process, the verification of drawing die for deep oil pan is a very difficult job. So much practical experience is required, not only the drawing of hydraulic press and the sealing pressure need to be adjusted. It is also necessary to grind the convex and concave molds of the mold itself, and a certain lubrication method is required.

First of all, a trial drawing was carried out for a drawing, only a certain amount of drawing oil was applied to the surface of the template and the sheet, and serious cracking occured after drawing. The final drawing result was shown in Fig. 8, by adjusting the sealing force of the four corners of the blank holder and grinding the drawbead. The friction of the material flow was reduced by grinding, adjusting the corners of the convex and concave molds and the gap between the convex and concave molds, what's more, laying plastic film to increase lubrication, and adjusting the blank holder pressure. After many adjustment tests, the cracks were eliminated and good results had been achieved.

Fig. 8. The graph of one-time drawing breakage.

Secondly, trial drawing was performed on the secondary drawing die. To reach the final shape of the product, the secondary drawing was to draw 90 mm again on the basis of the primary drawing. It was relatively easy to form due to the shallow drawing depth. Whatever, there were also many problems in the extension process. During the verification process, only a certain amount of drawing oil was applied to the surface of the template and the sheet material. Serious cracks occurred at the fillet of the bottom of the oil pan and the sealing surface after drawing. The friction of the material flow during the molding process was reduced by matching the size of the round corners of the convex and concave dies with one and two pulls, and maintaining the gap between the convex and concave molds, grinding the round corners of the convex and concave molds, as well as spreading plastic film to increase the lubrication. As shown in Fig. 9, the secondary drawing was completed while no cracks appeared.

Fig. 9. The graph of drawing.

3 The Forming of Auxiliary Oil Pan

Since the drawing depth of the auxiliary oil pan is relatively shallow, the deepest part is only 94 mm. It has a shape of square box, and it is easy to form. There is no difficulty in production. Therefore, this paper only analyzes its requirements and process characteristics.

In order to increase the amount of oil in the sump, an auxiliary oil sump was added on both sides of the main oil sump. Since the auxiliary oil sump on the main oil sump was a spatially curved shape, in order to closely fit the main and auxiliary oil sumps, the joint surface of the auxiliary oil pan was designed to have the same shape as the side surface of the main oil pan. In order to facilitate welding, a suitable size flange edge should be reserved for the joint surface of the auxiliary oil pan. Due to the deviation of the size of the part after forming from the theoretical size, the position should be adjusted at all four sides of the auxiliary oil pan during the shaping and trimming process, so as to ensure the flange edge of the auxiliary oil pan.

4 The Welding of Main and Auxiliary Oil Pan

The auxiliary oil pan needed to be welded to the side of the main oil pan after the main and auxiliary oil pans were separately formed. The welding seam of the new oil pan was three-dimensional and irregular, and the total length of the welding seam was more than two meters. The DC06 drawn plate used in the shell contains very low carbon content while the plate was thin, so that manual welding cannot guarantee the welding strength of the parts, and it is difficult to meet the appearance quality requirements. In order to reduce the leakage rate after welding of the oil pan, improve the welding quality and appearance aesthetics, it is necessary to introduce and apply a robot welding system to complete the welding according to the application requirements of the oil pan. The use of robot welding has higher requirements for the size consistency of the oil pan and the joint surface gap, which should not be greater than 2 mm, otherwise the welding will be broken or unable to be welded during welding. The operation process of the robot is shown in Fig. 10.

During the welding process of the main and auxiliary oil pans, it was found that the gap between the parts of the joint surface was greater than 2 mm due to mold grinding, springback after drawing, etc., which also resulted in a low pass rate of one-time welding. In order to solve this problem, measures such as welding and repairing the mold in the area with a large gap, reinforcing the joint surface of the main and auxiliary oil pans, and expanding the shape of the mold center have been adopted to reduce the gap between the convex and concave molds. The maximum joint gap was only 1 mm with all these measures. After the welding was completed, it is necessary to conduct an air tightness test on the oil pan in order to check the tightness of the weld.

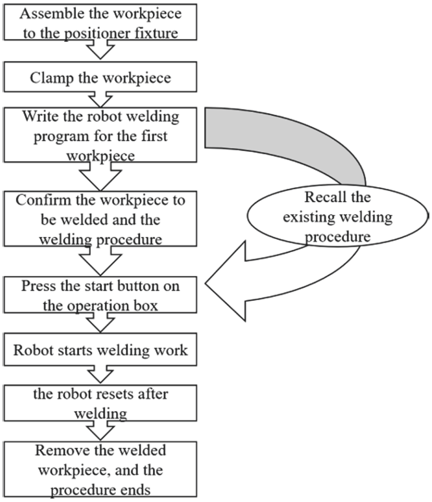

Fig. 10. The operation process of the robot.

5 Conclusion

The new diesel engine oil pan was designed in the case of the limited installation space. The oil storage capacity should be increased, if it cannot be stamped and formed at one time. While the stamping and welding forming scheme not only meets the design requirements, but also meets the application requirements. The development and research of the new oil pan process was the new breakthrough in drawing technology and welding technology. It not only reached a leading level in related fields and made important contributions to the improvement of market competitiveness of the company, but also created significant economic and social benefit.

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