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Research and numerical simulation analysis on forging process of 7055 aluminum alloy quick release hook

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Abstract: Aiming at the quick release hook of 7055 aluminum alloy, through analyzing the structure of the quick release hook, the forging drawing and die drawing of the parts are designed. The process route of parts forming is designed by empirical method, and the process route is numerically simulated by DEFOEM-3D. The results show that the forging structure is complex, the fluidity of materials is weak, and the flow speed of metal materials is uneven, resulting in defects. Therefore, the process route was optimized according to the defects and verified by finite element simulation. The results showed that the metal flow was reasonable and the defects disappeared, and finally the qualified process route was obtained.

1. Introduction

New materials are the key technology for promoting the development of high-performance aircraft. These materials can not only reduce the structural weight of aircraft but also enhance their strength and mechanical properties. Reducing structural weight is particularly significant for aviation products, as it can not only increase the carrying capacity of aircraft but also improve their maneuverability, extend their range, and reduce energy consumption.[1,2]

In the past, the raw material used in this part was 630 stainless steel. In order to reduce the overall weight of the product, the raw material has been changed to 7055 aluminum alloy, which is then machined after forging. Due to its low alloy density, high specific strength, and excellent characteristics, 7055 aluminum alloy is widely used in the fields of transportation and aerospace. [3.4]The corrosion resistance of aluminum alloy can be significantly improved by regression reaging heat treatment, and a strength equivalent to peak aging can be maintained.[5.6]

In this paper, we have conducted a structural analysis of the parts, designed the forging drawing and forging die, and optimized the process route through numerical simulation using DEFORM-3D. The results indicate that the optimized process route can effectively address any potential defects that may occur during the production process.

2. Part structure analysis

As shown in Figure 1, Figure 1 is the part modeling diagram of this part. The forging has a complex structure and is difficult to form.

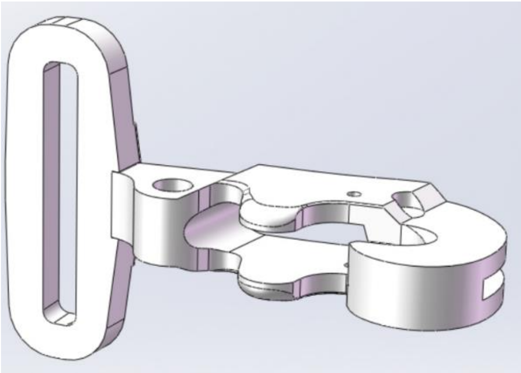
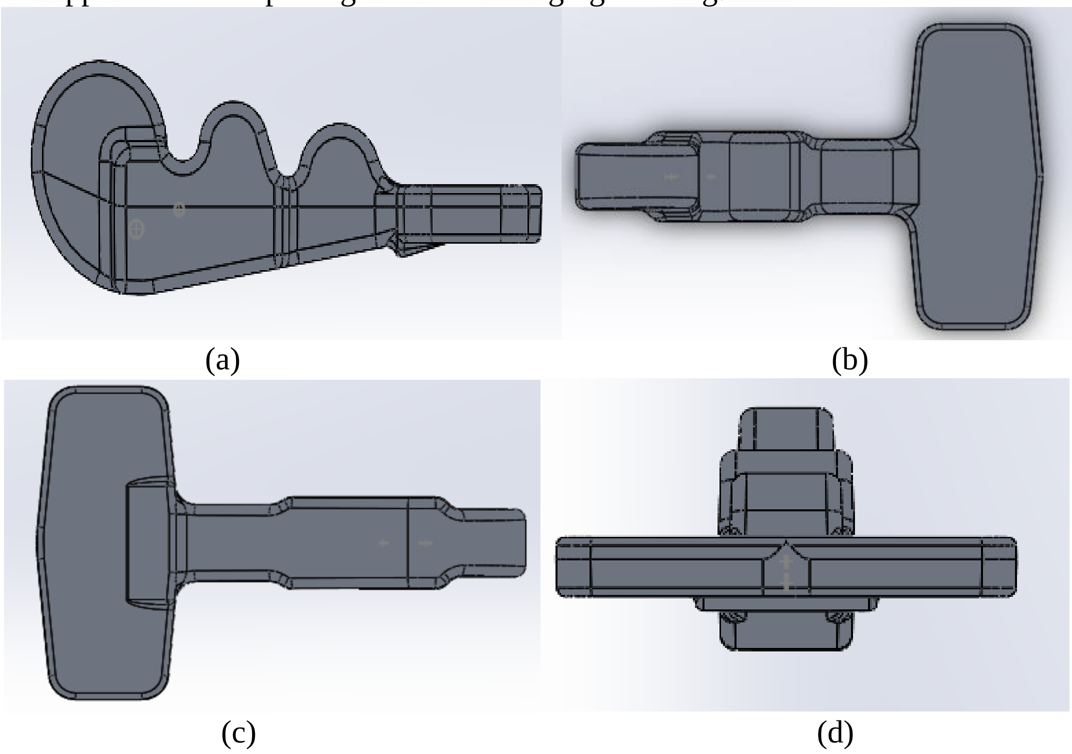


Figure 1: Three-dimensional modeling diagram of quick release hook

3. Design of aluminum alloy quick-release hook forgings and die design.

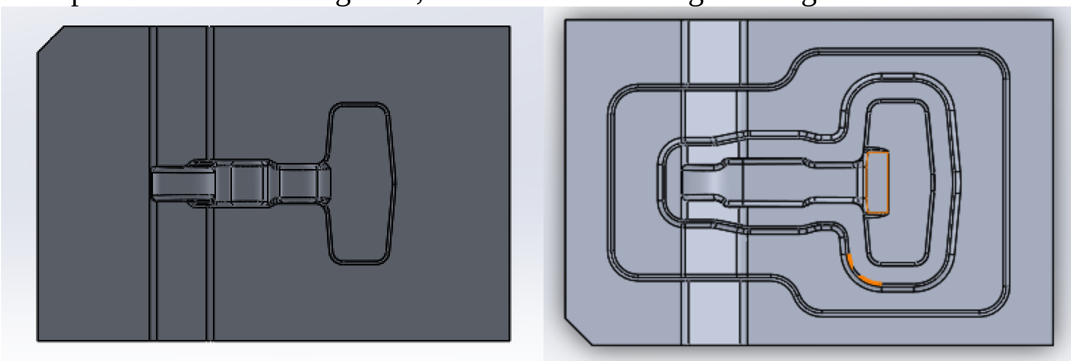
As shown in Figure 2, the forging diagram of aluminum alloy quick-release hook is similar to the T-shaped structure, in which the lateral spacing of the T-shaped structure is large, and the maximum size is 61 mm. At the other end, the head is curved upward, and there are a small number of protruding parts, all of which are difficult to form. Therefore, when the die is designed, the horizontal position in the middle of the quick release hook part is taken as the parting line, which can effectively parting the forgings and facilitate trimming. Through 3D modeling software, the die shape is designed through the upper and lower parting surfaces of forging drawing.



(a)Front view; (b)Top view; (c)Bottom view; (d)Right view

Figure 2: Drawing of quick-release hook forgings

Mold cavity is the key part to control the forming of aluminum alloy quick-release hook. Reasonable design of mold cavity is beneficial to improve the high-precision forming of quick-release hook. The lateral deformation of quick-release hook is large. Comprehensive analysis shows that it is difficult to form this quick-release hook part at one time, so the double die of pre-forging and final forging is adopted. As shown in Figure 3, it is a mold modeling drawing.



(a) (b)

(a)Top die; (b) Bottom die

Figure 3: Mould modeling drawing

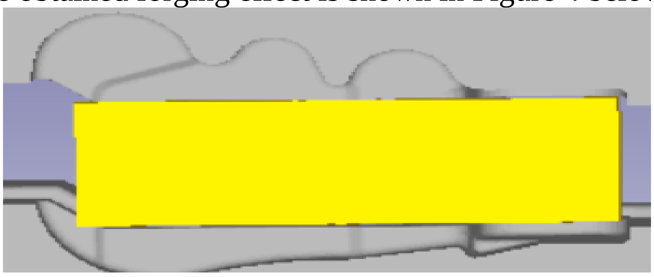
4. Formulation and optimization of forging process flow

It can be known from the outline dimension drawing of the forging drawing that the lateral deformation of the quick-release hook is large and the metal flow is large, so it is necessary to ensure that the filling is complete and the streamline is uniform during the forming process here. At the same time, the protruding part of the end is controlled to be completely filled, so as to ensure that the parts maintain good mechanical properties and high material utilization rate after molding. Reasonable design of forging process can effectively improve the production efficiency and quality of forgings.

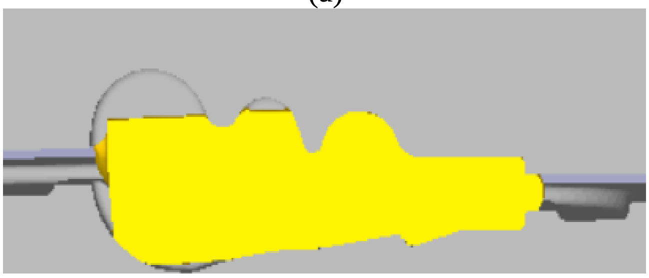
4.1 Forging process flow formulation

In the process of pre-scheme design, a bar with a diameter of 28mm and a length of 87mm is directly used for one-time forging, as shown in Figure 4 below.

The advantages of this scheme are: less forming work, less time-consuming, and less temperature drop of forgings in a short time, which is beneficial to forming. The above forging process is simulated in DEFORM-3D, and the obtained forging effect is shown in Figure 4 below.



(a)



(b)

(c)

(a) Step 1; (b) Step 22; (c) Step 30

Figure 4: Pre-scheme Forging Simulation

As shown in Figure 5, from the simulation results of die forging, it can be seen that the end parts and other positions are not fully filled, some complex parts are not fully formed, and the head and tail materials are not fully flash, which may cause the defects of insufficient forming and insufficient filling in actual operation. Therefore, the direct use of one-step molding process not only requires a long bar, but also leads to insufficient feeding in some complex parts, which makes it difficult to form parts.

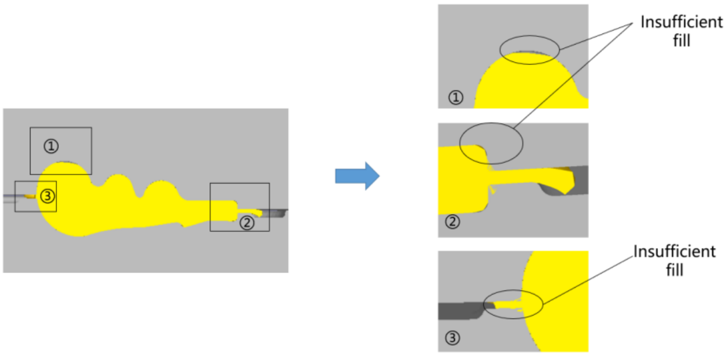
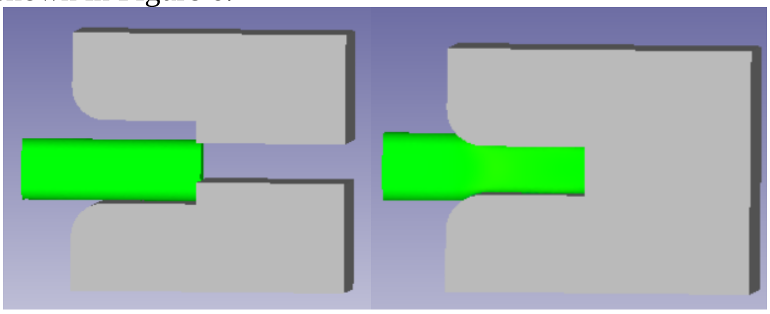


Figure 5: Pre-scheme simulation defect

In view of the problems in the above process scheme, a new process scheme is redesigned.

Based on the pre-plan, this plan adds the blank-making process, flattening one end of a bar with a diameter of 28mm and a length of 82mm, and carrying out finite element analysis on the blank-making process, as shown in Figure 6.

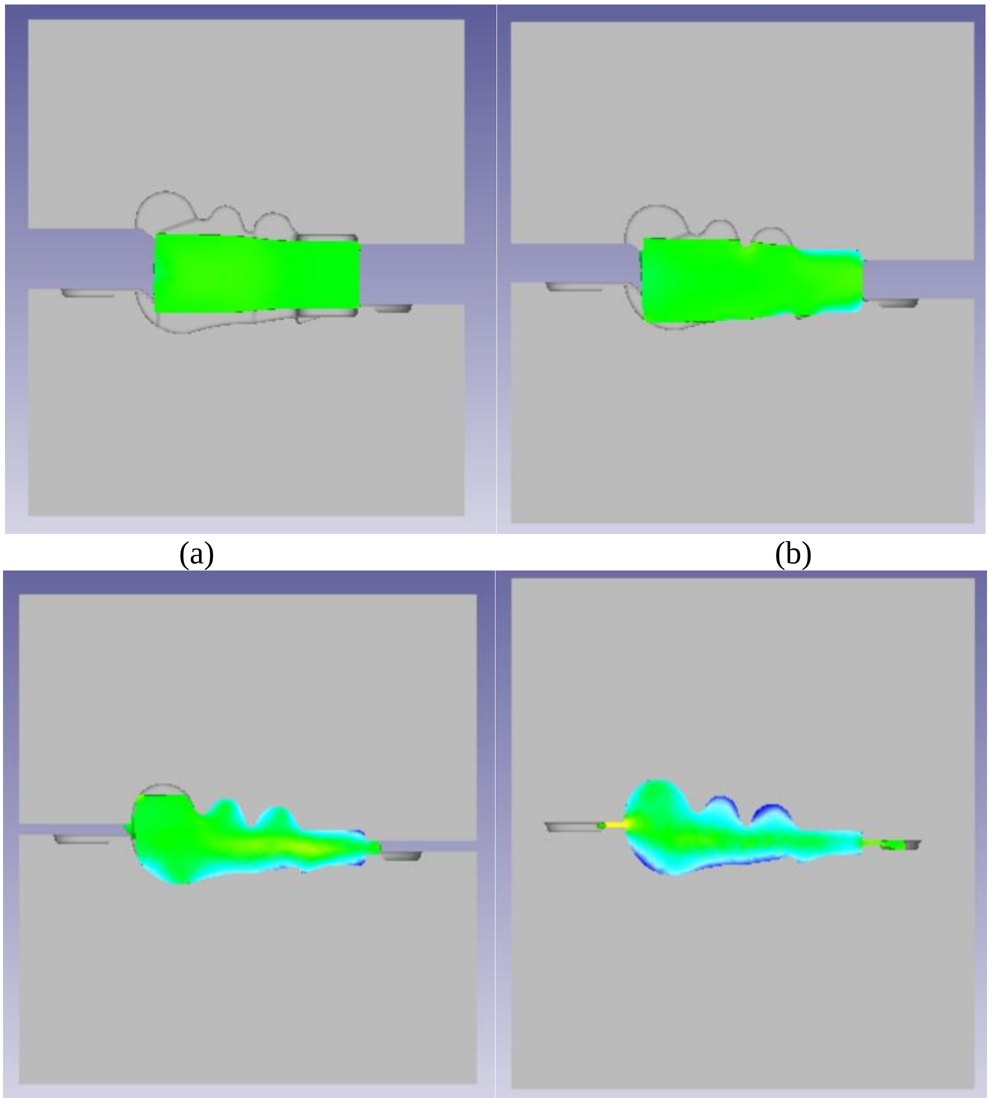


(a) (b)

(a) Step 1;(b)Step 5

Figure 6: Freforging process

After the pre-forging die is formed, the final forging die is formed, and the final forging forming process is analyzed by finite element method, as shown in Figure 7.



(a) (b)

(c) (d)

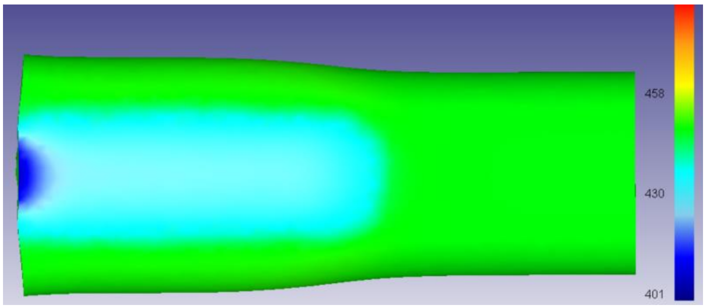
(a)Step 2; (b)Step 18; (c)Step 33; (d)Step 47

Figure 7: Final Forging process

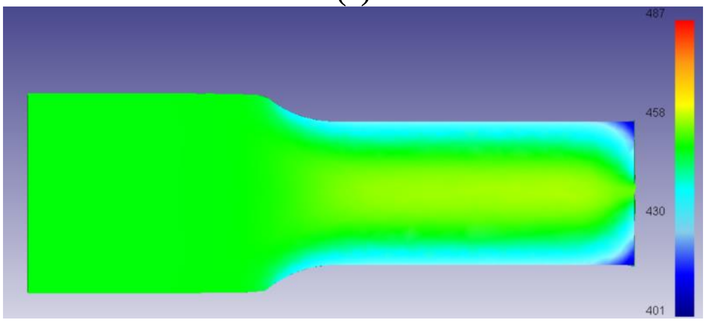
5. Analysis of blank forming process

5.1 Analysis of Blanking Temperature Field

In the process of blank making, the final deformation of the bar and the contact with the die will cause the temperature of the blank to change. Through the post-treatment in DEFORM-3D, the cross section of the deformed blank can be analyzed, as shown in Figure 8 below, which shows the temperature field distribution during the blank making process. The initial temperature of blank making is 450℃.



(a)



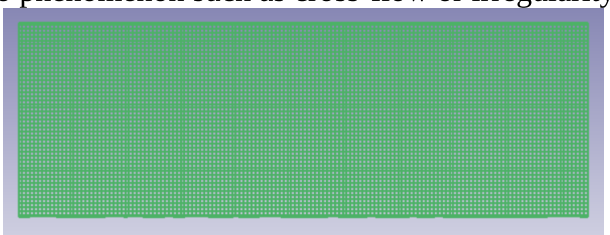
(b)

(a)Top view; (b) Cutaway view

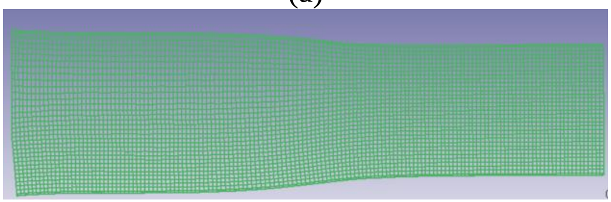
Figure 8: Temperature field distribution in blank making process

5.2 Streamline analysis of blank metal

Select grid deformation tracking, divide the grid at the cross section into grid types, and select the appropriate grid density. Before and after the deformation is completed, the grid deformation changes to the direction of metal flow, as shown in Figure 9, which is the grid deformation and ore grabbing in the blank making process. As can be seen from the figure, the metal flows naturally, the streamline is complete, and there is no phenomenon such as cross-flow or irregularity.



(a)



(b)

(a) Crosswise; (b) Portait

Figure 9: Metal streamline in blank-making process

5.3 Stress field analysis of blank making

As shown in figure 10, the stress distribution during blank making. As shown in the figure, the area with large equivalent pressure is the large deformation area, where the equivalent pressure is about 40MPa.

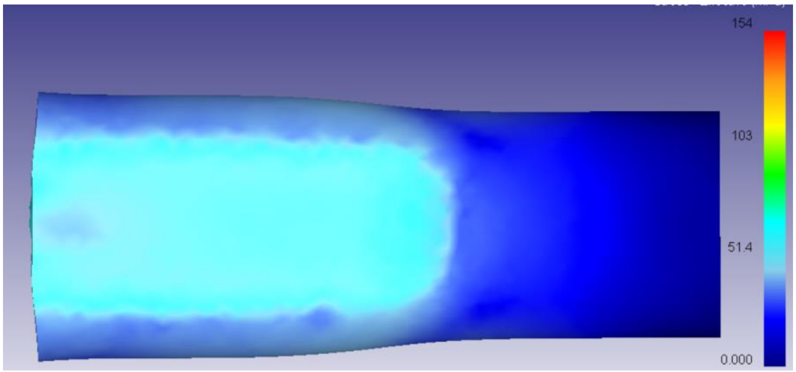


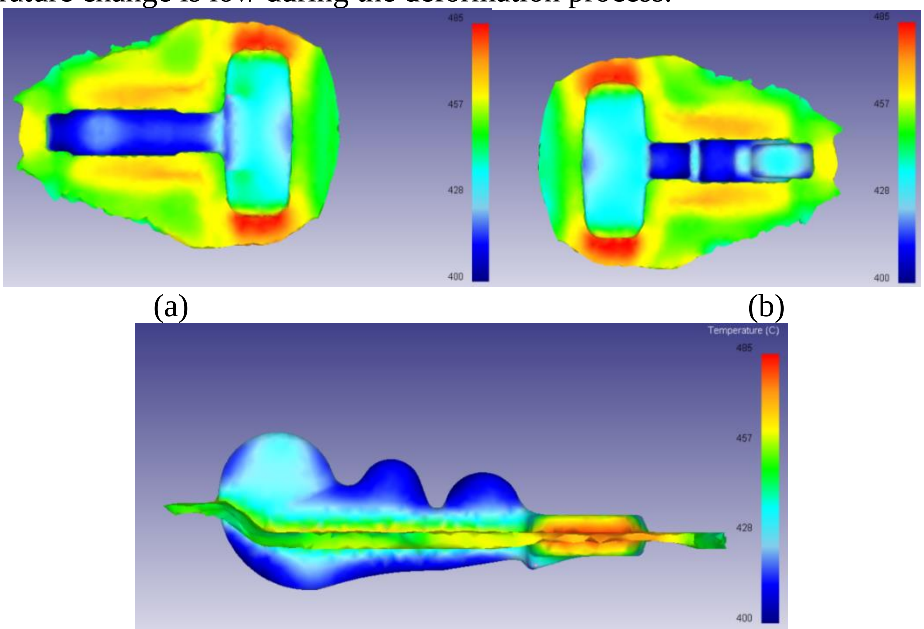
Figure 10: Blank stress field

To sum up, only the cylindrical bar and the press are needed to make the blank through the flattening process, and the forming die is relatively simple, and the temperature changes evenly during the forming process, with little fluctuation, normal equivalent stress and complete metal flow curve.

6. Analysis of final forging process

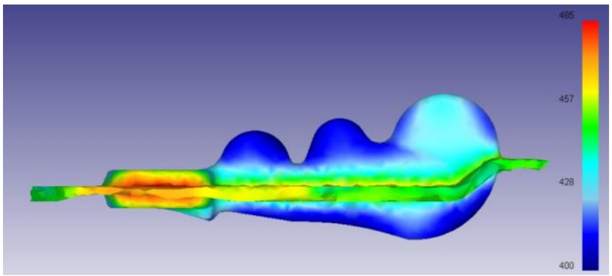
6.1 Temperature field analysis

As shown in Figure 11, it shows the temperature distribution in the final forging process. After the blank is made, great deformation occurs through the final forging. According to the temperature distribution of the temperature field, the main body temperature of the forging changes greatly, and the highest temperature of the temperature field is 485℃. The location is at the flash, where the deformation is serious, which causes the temperature to rise. However, because the high temperature is everywhere at the flash, it has no influence on the quality of the parts, so the temperature change here has no great reference value. This paper focuses on the analysis of the temperature change of the main body of the forging quick release hook. The theme temperature is between 420℃ and 450℃, and the temperature change is low during the deformation process.



(a) (b)

(c)



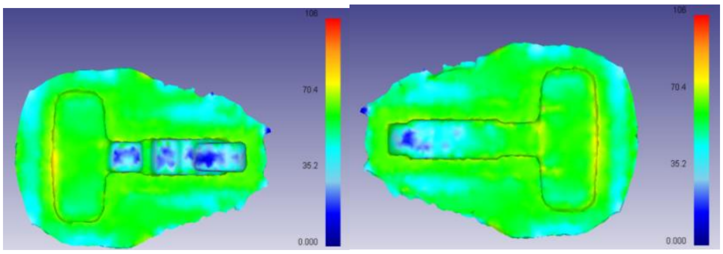
(d)

(a) Bottom view; (b) Top view; (c) Left view; (d) Right view

Figure 11: Final Forging Temperature Field

6.2 Final forging stress field

As shown in Figure 12, it is the distribution diagram of stress field in final forging, and the overall equivalent stress of the part is about 50MPa except for flash. The maximum equivalent stress is 70MPa, which appears at the edge of the part and is far away from the main body of the part. At the edge, the equivalent stress reaches the maximum due to the severe deformation at the corner.



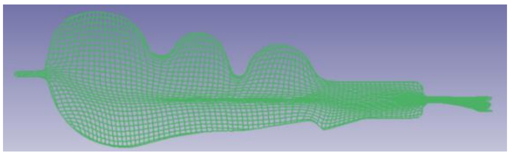
(a) (b)

(a) Top view; (b) Bottom view

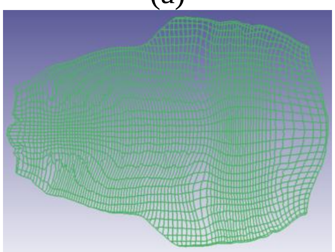
Figure 12: Distribution of Stress Field in Final Forging

6.3 Final forging metal streamline

As shown in figure 13, the final forging flow line is complete and clear, and there is no cross-flow phenomenon. In the final forging process, the blank metal mesh has no distorted mesh, and the metal rheological property is good.



(a)



(b)

(a)Portait; (b) Crosswise

Figure 13: Metal streamline in final forging process

7. Conclusions

1) According to the design of the parts, the forgings and dies are designed.

2) According to the forging shape, the process route is designed by empirical method. Through DEFORM-3D, it is found that the defects of insufficient filling will appear and the product quality will be affected.

3) Numerical simulation was carried out by DEFORM-3D, and the process route was optimized, and the rationality of pre-forging and final forging process route was obtained.

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