**The International Students Olympiad in Hot Bulk Forging Technologies**

**CODE** QCN04

University HEBEI university of science and technology

\_\_\_\_\_\_\_\_\_\_\_\_ 2017

***PROBLEM STATEMENT***

The Coupling cup-shaped part of a company was designed in this paper, which outputted of 30,000 pieces. The design process includes the calculation process and the result of the part, which using Qform to finish the design process for simulation and verification. The correct forging process analysis, the forging drawing, the rational design of the mold and the forging step would directly affect the product quality and yield level.

***PRELIMINARY CALCULATIONS AND CONSIDERATIONS***

The drawing of the forging part and 3D forging part were shown in Figure 1 and Figure 2.

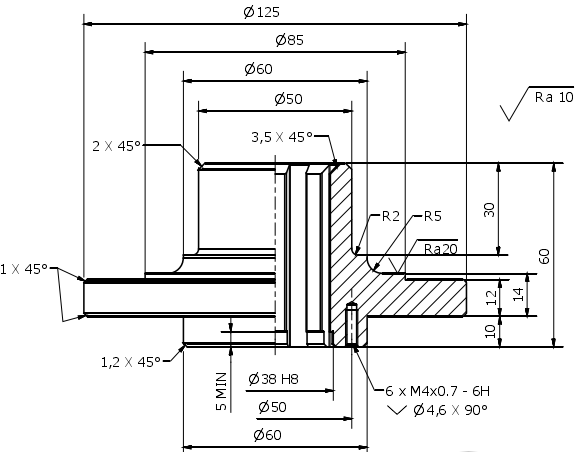
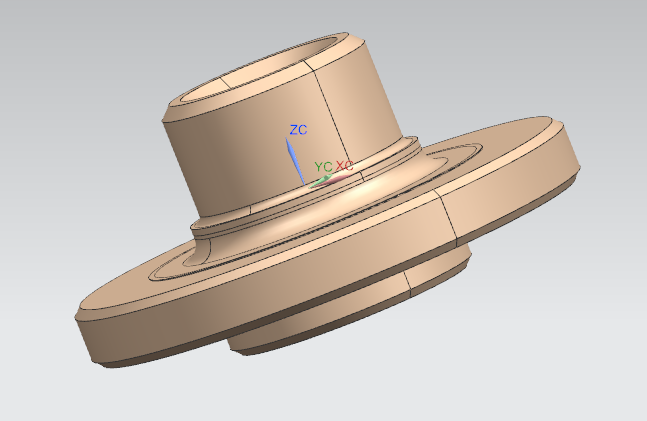
 

Figure 1 The drawing of forging part Figure 2 Three-dimensional forging solid

The initial calculation according to the technical requirements for the forging drawing and its related dimensions are as followed :

* 1. **Information of the work piece:**

(1) Work piece material: Carbon Steel C45 (1.0503)

(2) Weight of the forged product=2.112 kg

1.2 **Volume calculation of the forging product:**

(1) Volume of forging product by 3D modeling,

(2) The remaining of extra block and calculation of the processing allowance for the volume of forging according to the final forging parts,

The complex coefficient of forging: *S*= =0.327, determining the forging with level, which belongs to the general difficulty. And the forging material is determined according to the forging material, which is . Due to its high wheel, forging process will be carried out by multi-step forging way, which includes upsetting, pre-forging and the final forging.

***MANUFACTURE OF THE UPSETTING AND DUMMYING PROCESS***

2.1 **Related design of pre-upsetting**

This design will get the blank by free upsetting. The original blank is deformed by free upsetting, the upper and lower mold will use simple up and down anvil for anvil upsetting, so the relevant design of the mold was not discussed in the process.

The forging are cylindrical cup-shaped parts, so the original blank is cylindrical, combining with the actual production experience and the actual specifications of the material to select the original blank. In order to obtain the best result, the high diameter ratio *m* = 2.2 is adopted, and the calculation of the height and diameter of the cylinder blank is carried out by the principle of forging volume invariance. According to and , the approximation of *l* and *d* for the pre-forging cylindrical material can be obtained in the simulation as reference.

Free upsetting is the upsetting of the cylinder blank to obtain a part that is shaped like a drum.

With reference of the*l* and*d* approximation of the pre-forged cylindrical billet, the distance between the upper and lower mold will be set by repeated simulation of Qform, so as to obtain the specifications of the pre-forging blank. The simulation of pre-forging and the forging size are showed in Figure 3. So the size of the pre-forging blank is set: *d*=60mm, *l*=138mm.

So, =54.70mm, =100mm.

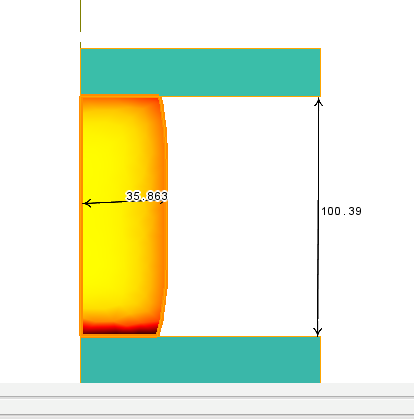


Figure 3 Forging die and forging size

According to the forging experience and access to the manual, the initial forging temperature of C45 is 1200 ℃, the final forging temperature is 800 ℃. In the forging temperature range C45 has a good forging performance. Therefore, it is assumed that the forging temperature of the blank is 1200 ℃.

2.2 **Related design of pre-forging process**

(1) Determination of pre-forging mold length, width and height

The forging part belong to the high forging. To ensure that the forging space can be filled and prevent the folding and keep the blanks stable in the final forging mold, forming upsetting is applied.

(2) Related design of rounded corners

In order to make the metal in the mold have a better flow, to be easy filling, and to improve the service life of forging mold, forging mold should be rounded. And the fillet radius is related with the forging shape and size. According to , the fillet radius can be determined: the cylindrical radius R=4mm, the radius of the fillet r=5mm.

(3) Related design of the drafting angle

For being easy to get liftouting, the pre-forging die will set the drafting angle. According to practical experience, it can be determined: the outside drafting angle could be 6°, and the internal drafting angle is 7°.

***FINAL FORGING DESIGN***

In order to facilitate the filling, the final forging mold will be compositely designed. We get the pre-forging blank for continuous process, which is finished in the final forging mold. The following is the final forging design process.

3.1 **Determination of the final forging mold length, width and height**

The final forging mold is manufactured and inspected in accordance with the hot forging pattern, and the size of the hot forging is generally considered to be 1.5% shrinkage on the basis of the size of the cold forging drawing. According to the actual experience, considering the relevant factors the size could be adjusted to be appropriate.

According to , the final forging process will set the volume expansion coefficient in the simulating with Qform. It can be 1.03.

The forging of this part belongs to the general forging. Due to mold wearing, dislocation, and its forging volume changes with heating oxidation, decarburization, etc, the shape and size of forging were changed, as well as some local surface of the forging also need machining. Therefore, it is necessary to reserve processing allowance. Through accessing to《forging practical quick check manual》,the increased machining allowance at the height of the forging can be determined, , while the horizontal direction .

3.2 **Related design of rounded corners**

In order to make the metal in the mold to have a better flow, to be easy to fill, to improve the service life of forging mold, forging mold should be rounded. And the fillet radius is related with the forging shape and size. According to , the fillet radius can be determined: the cylindrical radius R=3mm, the radius of the fillet r=5mm.

3.3 **Related design of punching recess and its fillets**

The forging has a center hole, but forging can´t directly forge through the hole. The hole must be left with a part of the recess. The following is the applicable conditions of flat-bottom recess:

or

When forging this part, d=32.4mm h=30mm. Due to , the form we adopted: flat-bottom recess.

The thickness of the recess + =5 mm.

The fillet radius of the recess

3.4 **Related design of the drafting angle**

For being easy to get liftouting, the pre-forging die will set the drafting angle. According to practical experience, we determine: the outside drafting angle could be 6°, and the internal drafting angle is 7°.

3.5 **The determination of the hammer tonnage and the type and size of the flash slot**

(1) The total deformation area is the sum of the projected area of the forging in the horizontal plane and the horizontal projection area of the flash. According to 1 ~ 2t hammer flash slot size to consider, total deformation area A= 38337.12 mm2 through calculation. We can select the forging hammer according to the calculated formula G = 63KA.

In this process, we take the steel coefficient as K=1, the projected area on the horizontal plane of forging and flashing (calculated by 50% of the volume of the flash box) is A, G=63KA=17152.38 kN. So the 2t double acting mold forging hammer should be selected.

(2) The determination of the flash slot

Selecting the type of flash slot as shown in the Figure 4, the relevant size is as following:

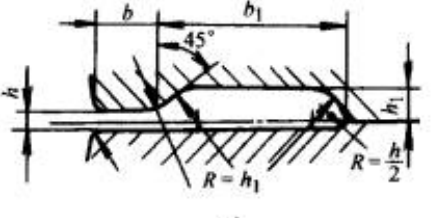


Figure 4 Schematic diagram of the flash slot

Among them,

3.6 **Tolerance calculation**

According to GB/T12362-2003 , the tolerance of the size of the forging can be got checking《forging practical quick manual》as shown in Table 1.

Table 1 Forging dimensions and their tolerances

|  |  |  |  |
| --- | --- | --- | --- |
|  | Forging size  (mm) | Tolerance  (mm) | Tolerance range (mm) |
| Width direction | 129 | +1.5  -0.7 | 2.2 |
| 60 | +1.2  -0.6 | 1.8 |
| 53.6 | +1.2  -0.6 | 1.8 |
| 32.2 | +1.2  -0.6 | 1.8 |
| Height direction | 63.6  30.1 | +1.2  -0.6  +1.2  -0.6 | 1.8  1.8 |
| Thickness direction | 15.7 | +1.4  -0.4 | 1.8 |

***FORGNG PROCESS FLOW CHART***

Forging process analysis and calculation

Related design of free upsetting

Related design of pre-forging（Design the pre-forging mold to get the appropriate pre-forging）

Related design of the final forging（Design the final forging mold to get the required forging）

***SIMULATION BY QFORM***

The simulation results were carried out by Qform after repeated simulation, and finally the simulation results were obtained. The relevant important parameters for the simulation process were shown in Table 2, and the parameters of the final forging process to be adjusted were shown in Table 3, the other relevant parameters could carry on from the previous process data.

Table 2 Important parameters for pre-forging simulation process

|  |  |
| --- | --- |
| Name of forging parameters | Forging parameters |
| Material of blank | C45 |
| Forging type | Hot forging |
| Forging driving | 2t forging hammer |
| Material of mold | H13 HRC50 |
| Preheating temperature of die | 200℃ |
| Lubricant | Water-based graphite lubrication |
| Final distance | 1.7mm |
| Ambient temperature | 20℃ |
| Volume change factor | 1.03 |

Table 3 Important parameters for the final forging simulation process

|  |  |
| --- | --- |
| Name of forging parameters | Forging parameters |
| Forging driving | 10MN hydraulic press |
| Final distance | 2mm |

5.1 **Related conclusions of simulation**

(1) The final forging process is shown in Figure 5, which includes the upper mold, the lower mold and the resulting part to get a better filling forging.

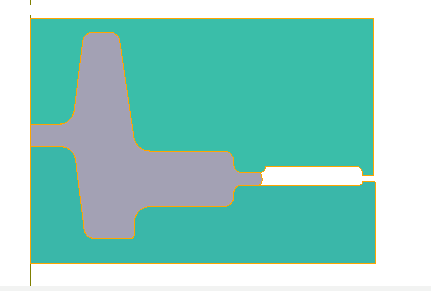


Figure 5 The molds of the final forging

(2) The final forging sizes were marked after repeated simulation by Qform. Figure 6 shows the dimensions of the finished parts after the final forging.

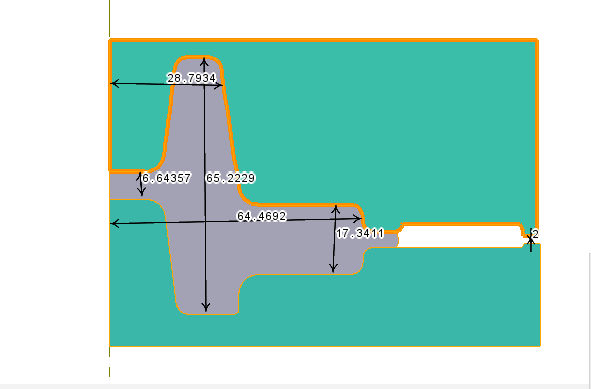


Figure 6 Forging dimensions

5.2 **Simulation conclusions of the forging process**

(1) Temperature analysis of the final forging

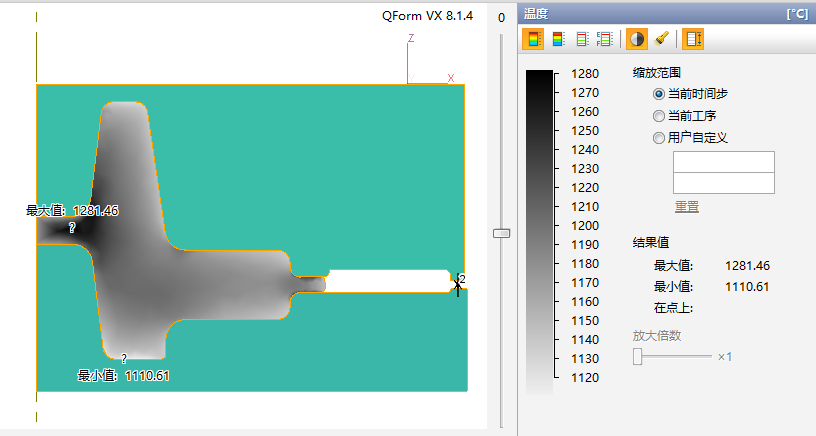


Figure 7 The final forging temperature distribution

After the final forging, the size and shape of the forging part are within the allowable range, which are consistent with the following analysis of the forging simulation process. Figure 7 shows the final forging temperature profile, it can be clearly seen from the figure that the surface temperature of the part that is fitted with the molds is low, while the internal temperature of the part is higher. This situation appeared because that the mold carried out heat conduction heat dissipation during the process of the high temperature forging. The forging temperature is 1150℃, while the internal temperature of the forging is up to 1200 ℃. This phenomenon is caused by a large amount of heat due to the large plastic deformation of the heart during the forging process, which get the forging temperature higher.

(2) Analysis of average forging stress

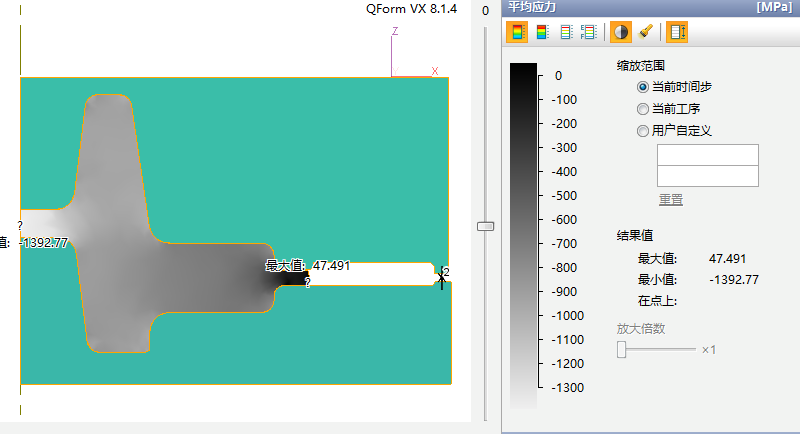


Figure 8 The final forging average stress distribution

From Figure 8, the average stress distribution of the final forging can be seen. The average stress of the whole forging parts are negative, and the part whose average stress closing to 0 will be machined to remove, so the forging part will be in a three-way compressive stress ,So that the resulting part is not easy to be damaged in the stress status.

(3) Selection of driving equipment during the pre-forging process

The pre-forging equipments for selection are 2t forging hammer and 10MN hydraulic press. The temperature distribution for the pre-forging part of Qform simulation was shown in Figure 9 and Figure 10.

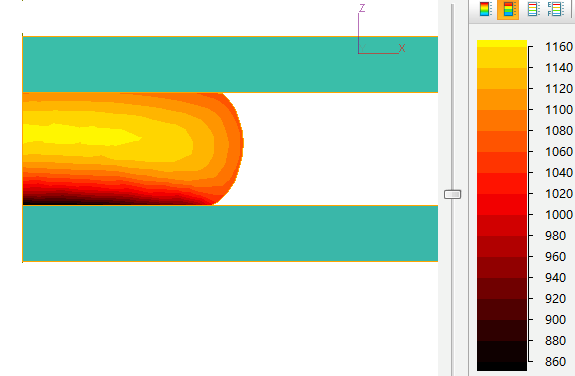
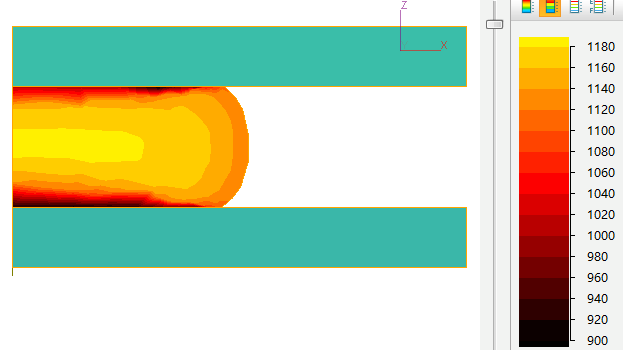
 

Figure 9 Driving of the 2t forging hammer Figure 10 Driving of the 10MN hydraulic press

The pre-forging includes the simple upsetting process. It is obtained from the figure that the temperature distribution of the forging hammer parts does not have much difference, but the temperature of the upper and lower mold surface is different with the heart of the part when using hydraulic machine, which is because that the contact time between the hydraulic machine and the blank surface is too long Caused by too much heat loss. The plastic strain with the driving of the 2t forging hammer and 10MN hydraulic machine were shown in the following Figure 11 and Figure 12.

It can be seen from the figure that the plastic deformation of the final forging part which is drived by the 2t forging hammer after removing the mechanical processing parts is more average, while it is very uneven when getting drived by the 10MN hydraulic machine, so the performance of the resulting parts will be worse than the 2t Forging hammer.

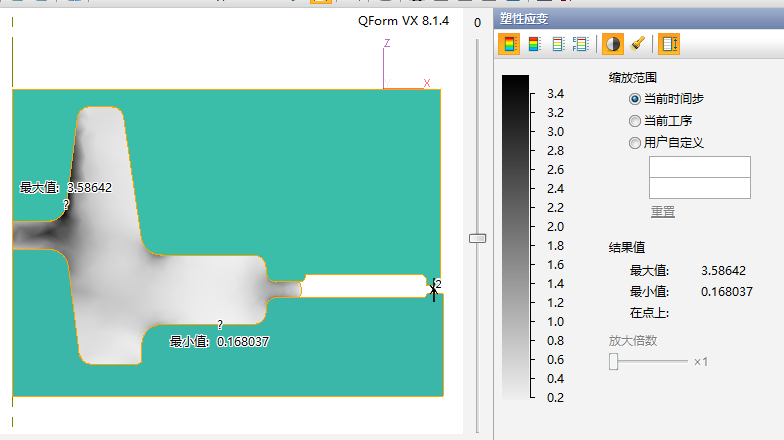


Figure11 The final forging strain diagram by 2t forging hammer

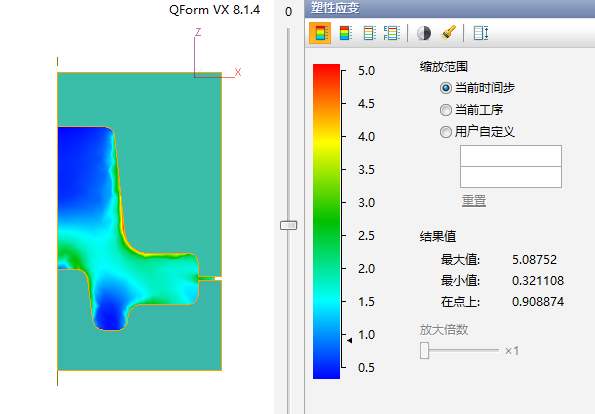


Figure 12 The final forging strain diagram by 10MN hydraulic press

It can be obtained that the 2t forging hammer will be selected for pre-forging driving according to the above analysis.

(4) Analysis of the forging flow line

The contact distance of the pre-forging part was tracked by Qform simulation software to estimate the material flow during the forging process and to observe the defects in the forging process, such as being folded or overlapping. During the forging process, the Coupling part base flow line is good, even the skin is squeezed, the streamer returns, but in the final machining process, the skin will be machined and removed.

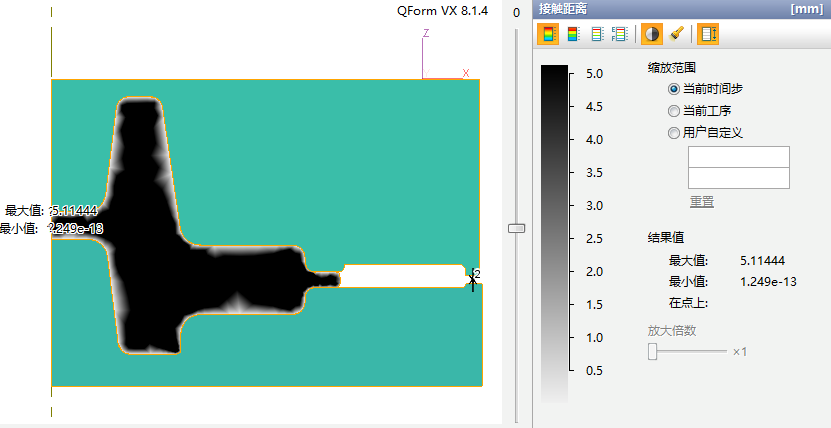


Figure 13 Continuous chart for the contact distance of the final forging part

***SUMMARY***

Through upsetting, pre-forging and the final forging to the original blank, the design modification and calculation for the forging molds and blanks are finished. And Through the repeated simulation with Qform to continuously improve, a relatively satisfactory forging process is obtained.