**The International Students Olympiad in Hot Bulk Forging Technologies** **2017**

*CODE: TW214*

# Task

The task of this olympiad is to develop the forging process of a gear, based on a drawing of the machined part, as shown in Figure 1.

|  |  |  |
| --- | --- | --- |
|  | Machined Part.tif |  |
|  | Figure 1. Drawing of the machined part |  |

# Design of the forging part

**2.1. Definition of shape complexity factor**

The tolerances of the forging part could be determined by dimensions given in the drawing with the aid of the standard GOST 7505-89. The first step was to calculate the weight of the final part in order to estimate the weight of the forged part. With the quotient between the weight of the forged part and the weight of the enveloping body of the final part, the refinement factor *C* could be:

Where: C is the shape complexity factor; CFP is the forged part mass; CES is the enveloping shape mass that is the mass of the simplest geometry figure.

In this case, it is as a cylinder. It can be determined as follow:

Where: d is diameter of cylinder; h is height of cylinder and is density of material (7.85 g/cm3).

Where: CDetail is mass of machined part and KD is the design coefficient (1.5 …1.8)

CDetail = VDetail.7.85 = 202 (cm3).7.85 (g/cm3) = 1585.7 (g) = 1.5857 (kg)

= 1.5857x1.8 = 2.854 (kg)

C2 is chosen for caculation process.

**2.2. Definition of the group of steel**

Because the carbon content is 0.45 % for the workpiece material C45, group M1 is chosen for the steel grade (GOST 7505-89 - Table 1).

**2.3. Definition of the tolerance grade**

The tolerance grade is chosen from 4 possible grades: T1, T2, T3, T4.

The tolerance grade T4 is chose for steam hammer (16MN) following the GOST 7505-89.

**2.4. Definition of the basic allowances of forging part**

With C2, M1 and T4 and Initial index 11.

Following Table 3, GOST 7505-89.

**2.4.1. By diameters**

Table 1. Basic tolerance of the forged part

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Diameters** | | | | | |
| **Dimensions of the detail** | 125 | 85 | 60 | 50 | 60 | 38 |
| **Surface roughness, Rz** | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 10 |
| **Basic allowances, mm** | **1.4** | **1.5** | **1.3** | **1.3** | **1.3** | **1.5** |

**2.4.2. By thickness**

Table 2. Basic allowances of the forged part

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Thickness** | | | | |
| **Dimensions of the detail** | 10 | 12 | 2 | 6 | 30 |
| **Surface roughness, Rz** | 12.5 | 12.5 | 12.5 | 12.5 | 10 |
| **Basic allowances, mm** | **1.2** | **1.2** | **1.2** | **1.2** | **1.6** |

**2.5. Definition of the mismatch allowance**

The mismatch allowance for the forged part with the mass of 2.854 kg, plain parting line and tolerance grade T4 is 0.2 mm (Table 4, GOST 7505-89).

**2.6. Definition of the straightness error**

The straightness error for the forged part with maximum dimension from the machining surface of 125/2 = 62.5 (mm) and tolerance grade T4 is 0.3 mm (Table 5, GOST 7505-89).

**2.7. Definition of the nominal dimensions of forging part**

**2.7.1. By diameter**

125 + (1.4 + 0.2 + 0.3) = 126.9 mm

85 + (1.5 + 0.2 + 0.3 ) **=** 87 mm

60 + (1.3 + 0.2 + 0.3 ) = 61.8 mm

50 + (1.3 + 0.2 + 0.3 ) = 51.8 mm

60 + (1.3 + 0.2 + 0.3 ) = 61.8 mm

38 + (1.5 + 0.2 + 0.3 ) = 40 mm

**2.7.1. By thickness**

10 + (1.2 + 0.2 + 0.3)\*2 = 13.4 mm

12 + (1.2 + 0.2 + 0.3)\*2 = 15.4 mm

2 + (1.2 + 0.2 + 0.3)\*2 = 5.4 mm

6 + (1.2 + 0.2 + 0.3)\*2 = 9.4 mm

30 + (1.6 + 0.2 + 0.3)\*2 = 34.2 mm

**2.8. Definition of the tolerance dimensions of forging part**

Table 3. Tolerance of the forged part

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Diameters of machined part** | | | | | |
| **Dimension of the detail, mm** | 126.9 | 87 | 61.8 | 51.8 | 61.8 | 40 |
| **Permitted deviations of dimensions, mm** | +1.4  -0.8 | +1.3  -0.7 | +1.3  -0.7 | +1.3  -0.7 | +1.2  -0.6 | +1.1  -0.5 |
| **Tolerance, mm** | **2.2** | **2** | **2** | **2** | **1.8** | **1.6** |

Table 4. Tolerance of the forged part

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Thickness of machined part** | | |
| **Dimension of the detail, mm** | 13.4 | 15.4 | 34.2 |
| **Permitted deviations of dimensions, mm** | +1.1  -0.5 | +1.1  -0.5 | +1.3  -0.7 |
| **Tolerance, mm** | **1.6** | **1.6** | **2** |

**2.9. Definition of the draft, angle and radius**

In general, it is important to say that through the forging process, it is not possible to produce a hole. Because of this fact, there is a bottom remaining in the middle of the forging. Draft angles of about 7° to 10° enable a correct ejection of the part after the forging process. Moreover, appropriate radiuses at the edges of the forging reduce significantly the stress of the tool and extend the tool life.

|  |  |  |
| --- | --- | --- |
|  | Banvevatdap.tif |  |
|  | Figure 2. Drawing of the forged part |  |

By using GOST 7505-89 to determine the tolerances, each type of displacement) is already included.

Vatdap.tif

Figure 3. 3D model of the forged part

# Design of the fillet radius and draft

Outside drafts are 7o and inside drafts are 70.

The fillet radius R of external corners of forged part have calculated using the formula:

R<0.5.(n+n1)+a

Where: n, n1 are allowance values, mm. a is chamfer dimensions with 45o angle, mm. (R=6 mm)

# Determination of flash land and flash gutter configuration and flash mass

Dimensions of gutter depend on flash thickness ho on the gutter ridge that may be calculated using the following expression:

Where: FF.P is the plan view area of forged part on the parting line.

# Design of the billet

The dimensions of the billet could be defined through the volume of the forged part. First of all, the diameter of the billet was set to 50 mm and the height accordingly to 140 mm to prevent buckling. Normally, the billets for hot forging are set to length by shearing. Because of the big burr formation when shearing large diameters, the diameter of the billet was chosen to 56 mm.

Lwp = m.dwp m = 2.8 d =

Where: V is volume of forged part and L is length of billet

V = 2.768x105 = 276800 (mm3)

dwp = 50 mm

Lwp = 50x2.8 = 140 mm

Choose size of workpiece is: 56x140

Volume_forgingpart.tif

Figure 4. 3D model for volume caculation

In the following table, there is some information regarding the raw part:

Table 5. Parameters of the billet

|  |  |
| --- | --- |
| Material | C45 |
| Density | 7,85 g/cm3 |
| Volume forged part | 276800 mm3 |
| l/d quotient of the billet | 140/56 = 2.5 |

Regarding the dimensions of the billet, it is important to say that the length of the billet had to be enlarged a bit because a first simulation said that the die was not filled completely. Through an appropriate design of the flash gap, the engraving could be filled completely due to a high internal pressure.

Mohinhdap.tif

Figure 5. 2-D forging process simulation model

# Production sequence

Because of the chosen billet dimensions and the relatively small thickness and the big outside diameter of the forging, it was advantageous to forge the part in two steps. When using more steps, cooling effects should be kept. The forming forces will rise when the part cools down. Because of this fact, a fast transfer between the steps is recommended.

In the first step, there is an upset forging and a centering operation at the bottom side of the billet. The centering has a circular design to approximate the engraving of the lower die of the second operation.

The second operation is the final forging step with a flash gap, so that an adequate internal pressure can be built up inside the tool.

The simulation parameters are shown in the following table:

Table 6. Parameters of the simulation process

|  |  |
| --- | --- |
| Material | C45 |
| Forging temperature | 1100 °C |
| Lubricant | Graphite and water |
| Press drive tool 1 | Mechanical press, motion into negative z-Axis |
| Press drive 2 | Stationary |
| Material of the tool | L6 HRC42 |
| Temperature of the tool | 200 °C |
| Environment | Air, 20°C |
| Strokes | At OP1: one stroke  At OP2 and OP3: 4 strokes each |
| Cooling of the part | Transfer: 5 sec, tool: 6 sec |

# Simulation results

**7.1. Upsetting operation**

**Nhiet_upsetting.tif**

Figure 5. 2-D upsetting process simulation model

**7.2. Final forging operation**

**7.2.1. Mean stress, effective stress and temperature of forging part**

|  |  |
| --- | --- |
| **Meanstress.tif**   1. **Mean stress** | **Mophongnhiet.tif**   1. **Temperature** |
| **EffectiveStress.tif**   1. **Effective stress** | **Bieu_do_luc.tif**   1. **Load – Displacement diagram** |

Figure 6. Simulation results for forged part

**7.2.2. Mean stress, effective stress and heat transfer of dies**

|  |  |
| --- | --- |
| **Die_stress.tif**   1. **Mean stress** | **Dies_effective_stress.tif**   1. **Effective stress** |

|  |
| --- |
| **Dies_Temperature.tif**   1. **Heat tranfer** |

Figure 6. Simulation results for dies

# Conclusions

In this forging process, a forging sequence for producing the raw part of a gear in two steps has been designed and simulated. The final design of the forged part is based on the given drawing of the machined gear.

It came true that the design of the forging dies is not perfect. The wrinkle formation may have been reduced through another iteration loop. Possible improvements could have been bigger radiuses at the edges of the second operation and a more intensive preforming in the first step.

Furthermore, a variation regarding the forging press (with another velocity path) may have brought other results. This measure would have influenced the contact time and also the tool wear.