INTRODUCTION

With the development of software technology, the invention of the 3D design makes the mould design implement the visualization and improve the assembly. The mold development from 2D to 3D design realizes the breakthrough of mold design technology:

1) 3D mould design can make the unprocessed mould ontology reappear spatially and intuitively. The design data can be directly used for processing, realized the integration of CAD and CAM, and processed with less or no drawings;

2) 3D mould design has solved a series of questions that the two-dimensional design is difficult to solve, such as the interference checking and the assembly simulation, CAE and so on.

The telephone base is shell and the surface is smooth, thus, there must have a good processing technology to ensure that the molding part have a certain roughness in the process of mould designing and manufacturing. The injection molding material is ABS. We must have a good conduct to make the thickness of the back cover uniformity, for example, in injection molding process, the uneven wall thickness can cause shrinkage to be not consistent, thus only through effective control of molding temperature can we adjust the shrinkage rate. Through the application of Pro/E to imitate the injection molding process, we can find that it can bring more welding scar and porosity to the surface of the telephone base. Also, the molding process can use reliable precision to locate the mould, but the cost is too high and it’s easy to damage the mould [1].

In order to meet the requirement that the surface of the telephone base is smooth, and to improve the efficiency of molding, we used straight gate. In order to reduce the damage for the surface of the plastic piece, and simultaneously not affect the surface quality of plastic parts and esthetic result, the gate is at the bottom of the distributary channel in the mould cavity and opened in the mold cavity, fed from plastic bottom longitudinally [1].

2 MOULD AND INJECTION MACHINE

2.1 Cavity number

According to the structure characteristics of the product, the way of the product placed in the molding process is that the rotary axis of plastic products is vertical with the axis of the sprue bushing in the molding, structure of one module and two cavities, and side parting [1].

2.2 Choice of the injection machine

2.2.1 Calculation of plastic volume

The volume of plastic parts: \( V_1 = 92.3 \text{cm}^3 \)

The volume of gating system: \( V_2 = 4.4 \text{cm}^3 \)

The volume of the plastic parts and gating system: \( V = 92.3 + 4.4 = 96.7 \text{cm}^3 \)

2.2.2 Calculation of the quality of plastic parts:

Checking the manual for the density: \( \rho = 1.05 \text{g/cm}^3 \)
plastic volume: \( V = 96.7 \text{cm}^3 \); density of plastics: \( \rho = 1.05 \text{g/cm}^3 \). So, the weight of the plastic parts: \( M = V \times \rho = 96.7 \text{cm}^3 \times 1.05 \text{ g/cm}^3 = 101.54 \text{g} \).

### 2.2.3 Number of cavity

According to

\[
 n \leq \frac{k m_p - m_i}{k} \tag{1}
\]

so

\[
 m_p \geq \frac{k n + m_i}{k} \tag{2}
\]

Where \( k \)-utilization coefficient of the maximum injection of injection machine is generally 0.8; \( m_p \) is the largest injection quantity of the injection machine, \( \text{cm}^3 \) or \( g \); \( m_i \) is the coagulation quantity of the gating system, \( \text{cm}^3 \) or \( g \); \( n \)-volume or quality of a single plastic, \( \text{cm}^3 \) or \( g \).

### 2.2.4 Volume of a pouring system

Its initial setting scheme is shown in Figure 1:

![Figure 1. Diagram of gating system](image)

According to the 3D model of the telephone base, Pro/E can be used to query the volume of a pouring system directly: \( V_f = 4.4 \text{cm}^3 \).

### 2.2.5 Injection machine

Choosing the CJ325NCII type of injection machine, its parameters are shown in Table 1.

### 3 POURING AND COOLING SYSTEM

#### 3.1 Gating system

The mainstream channel (as shown in Figure 2): The flow channel of plastic melts is from the injection machine nozzle to distributary channel in the molding process.

- Diameter of nozzle front hole: \( d_0 = 4.0 \text{mm} \); nozzle front spherical radius: \( R_0 = 10 \text{mm} \).
- According to the relationship of mold sprue and nozzle, we can obtain as follows:
  \[
  R = R_0 + (1\sim 2) \text{mm} \quad d = R_0 + (0.5\sim 1) \text{mm}
  \]

In this design, the nozzle spherical radius: \( R = 11 \text{mm} \), and the small diameter of mainstream channel: \( d = 4.5 \text{mm} \).

In order to take out the coagulation in the mainstream, the mainstream is conical, and the slope is between \( 2\sim 6^\circ \), the selection is \( 2^\circ \) here. After the conversion, the big end diameter of mainstream is 7.68 mm.

#### Table 1. Parameters of injection machine

<table>
<thead>
<tr>
<th>Type of injection machine</th>
<th>CJ325NCII</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parts of molding</strong></td>
<td></td>
</tr>
<tr>
<td>Injection weight</td>
<td>1020</td>
</tr>
<tr>
<td>Injection capacity</td>
<td>1149</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>153</td>
</tr>
<tr>
<td>Injection stroke</td>
<td>260</td>
</tr>
<tr>
<td>Spout radius</td>
<td>10</td>
</tr>
<tr>
<td>Nozzle hole diameter</td>
<td>4</td>
</tr>
<tr>
<td>Positioning ring diameter</td>
<td>150</td>
</tr>
<tr>
<td><strong>Parts of mode locking</strong></td>
<td></td>
</tr>
<tr>
<td>Clamping force</td>
<td>3250</td>
</tr>
<tr>
<td>Clamping Stroke</td>
<td>650</td>
</tr>
<tr>
<td>Mould-opening stroke</td>
<td>1350</td>
</tr>
<tr>
<td>Platen Size (HXV)</td>
<td>1020×933</td>
</tr>
<tr>
<td>Guide pillar spacing (HXV)</td>
<td>650×950</td>
</tr>
<tr>
<td>Minimum thickness of molar</td>
<td>250</td>
</tr>
<tr>
<td>largest thickness of molar</td>
<td>700</td>
</tr>
<tr>
<td>Ejecting force</td>
<td>73</td>
</tr>
<tr>
<td>Ejection stroke</td>
<td>150</td>
</tr>
</tbody>
</table>

![Figure 2. Diagram of the mainstream](image)

#### 3.1.1 Design principles of parting surface

(1) Form of parting surface

There is only a vertical parting surface in the mould.
(2) Design principles of parting surface

Many factors such as the position of the plastic part in the mould, the design of gating system, molding process, precision, shape, and introducing methods of plastic parts will affect the selection of parting surface. Through comprehensive analysis, the parting surface of the telephone base is shown in Figure 3:

Figure 3. Diagram of parting surface

3.2 Cooling system

The average mold temperature for working is 60°C. Using room temperature water of 20°C as the mold cooling medium, the outlet temperature is 30°C.

3.2.1 Cooling waterway diameter

Looking at the Table 3-26, the unit flow of ABS is 35×10^4 J/KG. On the basis of plastic volume, the diameter of cooling water pipe is 10 mm. The cooling water channel is shown in Figure 4.

Figure 4. Diagram of cooling waterway system

4 MAIN STRUCTURE SIZE

4.1 Calculation of cavity and core size

Shrinkage rate of ABS: 0.3%~0.8%

Average shrinkage: \( Q_{average} = \frac{0.3\% + 0.8\%}{2} = 0.55\% \)

Cavity diameter: \( D_{mold} = (D + DQ_{average} + 3\Delta)^\frac{3}{4} = 796.8\text{mm} \)

Cavity depth: \( H_{mold} = (H + HQ_{average} + 2\Delta)^\frac{2}{3} = 33.94\text{mm} \)

Core diameter: \( d_{mold} = (d + dQ_{average} + 4\Delta)^\frac{4}{3} = 761.97\text{mm} \)

Core depth: \( h_{mold} = (h + hQ_{average} + 2\Delta)^\frac{2}{3} = 32.43\text{mm} \)
4.2 Side pumping mechanism

4.2.1 Calculation of core-pulling distance

The computation formula of the core pulling distance is shown as follows:

\[ S = S_1 + (2 \sim 3) = 13.77 + 2.23 = 16 (mm) \]

Where \( S \) is the core-pulling distance (mm); \( S_1 \) is the minimal size of plastic pieces (mm).

4.2.2 Oblique guide pillar parting core-pulling

The most widely-used parting core-pulling mechanism is the oblique guide pillar parting core-pulling. It completes lateral core pulling in the process of parting with the mould opening force, its simple structure, easy fabrication, and the reliable parting action. Its structure is shown in Figure 6, the disc clamping slide block is installed in the T guide chute, so it can glide smoothly in the direction of the pull. The inclined guide pillar installed obliquely with the moving direction of opening mould, the inclined guide pillar fitted with slide block corresponding hole, and the inclined guide pillar moving relatively against the slide block when opening mould, which generates the lateral force component on the slider and forces the slider to finish the core-pulling motions [4].

The location of the push rod should be where the stripping resistance is the biggest. If the stripping resistances of all the plastic parts are the same, all parts

The angle of the inclined guide pillar is \( 20^\circ \). The size of the inclined guide pillar is shown in Figure 6. Material is made of high quality steel of T8A, and the quenched hardness is HRC55 ~ 60.

When the direction of the slide block out mould is vertical with the opening direction, the computation formula of the length of the inclined guide pillar is shown as follows:

\[ L = \left( \frac{D + d}{2} \right)^2 \frac{h}{\cos \alpha} + \frac{S}{\sin \alpha} + (10 \sim 15) = 116 (mm) \]

Where \( L \) is the total length of oblique guide pillar (mm); \( D \) is the diameter of the big end (mm); \( d \) is the distance of pulling (mm); \( h \) is the diameter of the slide guide section (mm); \( S \) is the thickness of the fixed template (mm); \( \alpha \) is the inclination of the inclined guide pillar (\( 20^\circ \)).

4.3 Selection of the die-set

There are two national standards of injection molding die-set: GB/T12556—1990 and GB/T12555—1990[5]. Due to the nowadays rapid development of plastic mold, the essential standard is formed in parts of the country. The design is shown in Figure 7 and the dragon standard mould frame is adopted. Its type is FCI4545A80B100.
of the plastic will be arranged uniformly, so that it can make sure the requirements of the push rod. Based on the stiffness and strength of the push rod itself, and after putting into the mold, the face also should be with the cavity bottom level or higher cavity 0.05 -0.1 mm [7].

5.1.1 Calculation of the force of push rod
For the general model and the shell shape parts, the ejection force is calculated according to the following formula[8]:

\[ Q = Lhp(f \cos \alpha - \sin \alpha) \]

Where \( L \) is the perimeter of the cross section of the parts of core or punch tightly wrapped (cm); \( h \) is the depth of the folded tightly parts(cm); \( p \) is the positive pressure on the unit area by the shrinkage of the plastic parts, which is between 7.8~11.8MPa; \( f \) is the coefficient of friction which is between 0.1~1.2; \( \alpha \) is the coefficient of friction.

\[ L=761.97\,\text{mm} \]
\[ h=32.43\,\text{mm} \]
\[ Q=761.97\,\text{mm} \times 32.43\,\text{mm} \times 10\,\text{MPA} \times [0.1 \times \cos(0.5) - \sin(0.5)]=2471.1(\text{N}) \]

5.1.2 Design of the push rod

![Image of the push rod](image)

Figure 8. Launch institution

1) The strength of the push rod is calculated according to the following formula:

\[ D=\left(\frac{64 \times \phi^4 \times 1^2}{n \times \pi^2 \times E}\right)^{\frac{1}{4}} \times Q^{\frac{1}{3}} \]

Where \( d \) is the diameter of the circular push rod(cm); \( \phi \) is the length factor of the push rod which is 0.7; \( l \) is the length of the push rod (cm); \( n \) is the number of the push rod; \( E \) is the elastic modulus of push rod materials (N/cm²); \( (E=2.1 \times 10^7\,\text{N/cm²}) \); \( Q \) is the total ejection force.

\[ D=10\,\text{mm} \]

2) Check the push rod pressure:

\[ \sigma = \frac{4Q}{n \pi \times d^2} \leq \sigma_s \]

The stress of the push rod is qualified, the rigidity:HRC50~65.

The launch institution is shown in Figure 8.

6 EXAMINATION

6.1 Examination of process parameter of injection machine

1) Examination of the clamping force and injection pressure

\[ F > p(nA + A_1) \]

Where \( p \) is the pressure of the cavity injection, \( p=113\,\text{MPa} \); \( A \) is the projection area of the plastic parts in parting surface(cm²); \( A_1 \) is the projection area of gating system in parting surface(cm²); \( F \) is the rated clamping force of injection machine, \( F=3250\,\text{KN} \). Through calculation, the condition was established.

6.2 Examination of the distance of mould opening

The Opening mould distance of the injection machine should be greater than that distance when taking out the plastic parts (including the gating system):

\[ S \geq H_1 + H_2 + (S \geq 10) \]

Where \( S \) is the largest distance of the injection machine (mm); \( H_1 \) is the demoulding distance (mm); \( H_2 \) is the height pf the plastic parts, including pouring system (mm).

\[ S_k=65+106.5=161.5\,\text{mm} \]

\[ S_k \leq S=1350\,\text{mm} \]

7 CONCLUSIONS

The mould design of the telephone base fully demonstrated the advantages of the virtual design. The rated clamping force and the largest distance of the injection machine are accorded with requirement. This paper shows that using Pro/E to finish the model of the injection mould and imitate the process of opening mould can reduce the time and cost of research and design, and it’s conducive to the further improvement design for the finished product.

REFERENCES


