The Forming Size Control of the Refrigerator Door Shell Oval-shaped Bend

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Abstract. Focusing on the important defect affecting the quality of the refrigerator door in the actual production- bending resilience, a formula of rebounding calculation is established. The ultimate goal is to achieve the control of the door bending rebounding within the scope of the technical requirements through the compensation control of the bending radius value of the punch and die.

Introduction

With the development of industrial technology and people's appreciation level, the design of household electrical appliances attract more and more attention, and the refrigerator door has become increasingly complex. After having entered into 21st century, the refrigerator door shells with the section shape of ellipse are becoming more and more welcome.

An Analysis of the Refrigerator Door Shell Forming

The two-dimensional engineering diagrams and in-kind of a certain refrigerator door shell parts is shown in Figure 1 and 2. The material is clad plate and the thickness is 0.5mm. The size of the part width direction is 570mm, and the length direction on the size is 760mm. The two-dimensional drawing of the door shell parts and the parts diagram is shown in Figure 1 and Figure 2. By analyzing, the stamping process for the part is processing the gap and Hole, bending and oval shape[1].

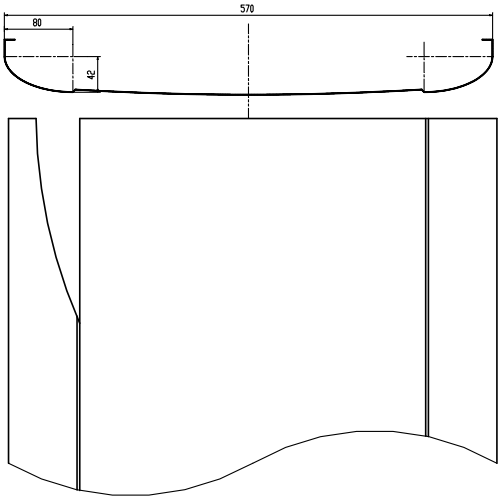

Fig. 1 Two-dimensional diagram for a part

Fig.2 Actual char for the part

In the course of refrigerator oval door shell forming process, the bending spring back has a serious effect on the door casing and plug hand-clasping and other plastic parts with precision, and may result in a large assembly of residual stress, thus affecting the reliability of the use of the door shell, making the high rejection rate in the actual production, and seriously affect the progress of the new product development. So the correct calculation of the elliptical arc bending springback of the

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oval refrigerator door shell has become the key to the success of the bending mold design[2]. The three-site assembly of the door casing, plug and clasping the kind is shown in Figure 3.

Fig.3 Field assembly of refrigerator door shell, plug and handle

Analysis of Refrigerator Door Shell Part Technology and the Establishment of Constitutive Equation

Refrigerator door appearance material is coated with organic material coated on a plate, that is, it is 0.5 ～1mm thick steel plate coated with resin material. In the forming process of organic coatings and substrate, it is needed to consider the organic coating and basic plate as a whole blank layer. The experiments in the electronic tensile testing machine on the standard coating plate sample tensile result in the coating plate mechanical properties numerical.

In the course of the refrigerator door shell bending deformation, material staying within the elastic plastic deformation range, so the sectional constitutive relation is introduced[3].

$$\sigma_i = \begin{cases} E\varepsilon_i & \text{In elastic region} \\ A\varepsilon_i^{\,n} & \text{In the plastic zone} \end{cases}$$

Here value E is got through uniaxial tensile test, and value A and value n is got through unidirectional tensile true stress-strain curve by numerical fitting. Based on the experiment and the related formula, the mechanical properties of the coating plate are obtained as shown in table1.

Table1. Mechanical properties of coating plate

sample	$\delta(\%)$	$\sigma_{0.2}/MPa$	σ_b/MPa	n	A/MPa	γ	E/GPa
Longitudinal							
1	24.26	255.114	439.702	0.237	558.78	1.872	177.026
2	24.78	249.845	445.314	0.215	562.32	1.694	177.914
Average value	24.52	252.479	442.508	0.226	560.55	1.783	177.470
Transverse							
1	23.96	258.573	447.451	0.216	556.98	1.981	176.200
2	24.28	259.681	434.526	0.227	558.37	1.863	173.150
Average value	24.12	259.127	440.988	0.221	557.67	1.922	174.675
45°							
1	24.57	246.972	436.018	0.218	560.24	1.254	177.277
2	24.36	257.385	439.627	0.200	561.30	1.184	176.383
Average value	24.465	252.178	437.822	0.209	560.77	1.219	176.830
final average	24.368	254.594	440.439	0.219	559.16	1.711	176.325

Put the experimental data into the sectional constitutive relation of the plastic deformation range, the coated sheet material constitutive equation can be got:

$$\sigma_i = \begin{cases} 176.325\text{X}10^3 \varepsilon_i & \text{In the elastic region} \\ 559.16\varepsilon_i^{0.219} & \text{In the plastic zone} \end{cases}$$

The Determination of the Oval Spring-back Calculation Formula

When the fillet radius of the bending work piece is R<10t, the bending radius work piece is generally of little change. It only needs to consider the bending angle of the rebound and this can be done by consulting relevant experience. When the fillet radius of the bending work piece is R>10t, the bending radius of work piece can be obtained by using the spring-back calculation formula.

Because the parts of the main bending shape is oval, and the curvature radius is far greater than 10t, it must be the compensation method utilized to correct the long and short ellipse half shaft radius value. And the spring-back can be eliminated. This kind of summary experience formula usually is the accumulation of certain data using mathematical fitting method[4].

$$r = \frac{r'}{1+3\frac{\sigma_s r'}{Et}}$$

Through formula [2], we can get the following by transposition and simple mathematical transform

$$\frac{R}{R'} = 1 - \frac{3\sigma_S}{E}\frac{R}{t}$$

From this, we can see that $R/R' = f(R/t)$ is a linear equation. And to the coating plate, it is as below:

$$\frac{R}{R'} = 1 - 0.003429(\frac{R}{t})$$

From the bending deformation condition formula, the relative relationship between the relative bending radius (R/t) and elastic deformation zone (t') is obtained. It is also a linear equation[5].

$$t' = 0.0023(\frac{R}{t}) - 0.001$$

Elastic deformation zone size and relative bending radius (R/t) is in linear relation, and (R/t) and (R/t') is also in the linear relationship. So it is assumed that the relative bending radius and rebound (R/R') is also in linear relationship. When the data of Y, X regresses, the linear equation is:

$$R/R' = 0.99184 - 0.004045(R/t)$$

The following correcting formula can be got by multiplying any constant with (R/t)

$$R/R' = 1 - 1.179703 \times 0.003429(\frac{R}{t}) = 1 - \frac{3.6\sigma_s}{E}\frac{R}{t}$$

Transform and arrange:

$$R = \frac{R'}{1+\frac{3.6\sigma_s}{E}\frac{R'}{t}}$$

And the calculation formula of rebound angle is：

$$\Delta a = \frac{3.6\sigma_s Ra}{Et}$$

This is the circular arc bending spring back calculation formula of the refrigerator door shell coated plate.

Refrigerator Door Shell Forming Die Design Based on the Spring-back Compensation

From the above research analysis, by using approximation method, the semi-major axis of 80mm and the short half shaft of 40mm elliptical arc are divided into two sections of circular arc, and then the circular arc compensation is conducted in accordance with different applicable conditions.

Among these：

The small radius value is r=29.14mm, and the convex die size calculation for rebound is:

$$r = \frac{r'}{1+3\frac{\sigma_s r'}{Et}} = 23.3(mm) \qquad \Delta a = \frac{3\sigma_s ra}{Et} = 18.15°$$

The big radius value is R=137.96mm, and the convex die size calculation for rebound is:

$$R = \frac{R'}{1+\frac{3.6\sigma_s}{E}\frac{R'}{t}} = 56.7(mm) \qquad \Delta a = \frac{3.6\sigma_s Ra}{Et} = 37.42°$$

The size of convex die is shown as fig. 4:

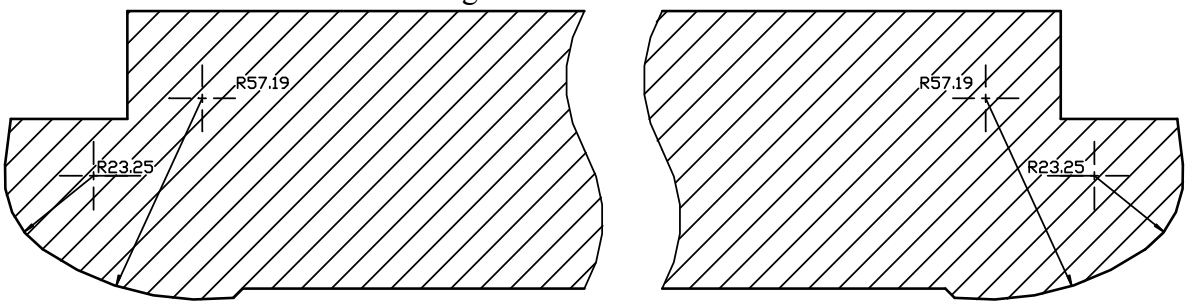

Fig.4 Diagram of convex die

The size of the concave die is accordance with that of the convex die, and the assembly clearance is material thickness, that is, it is 0.5mm.

Summary

The research conclusion is applied to production practice, the design and manufacture of a certain type of refrigerator door shell bending forming die, with the plug. Through trial assembling with plugs, fasteners, box liner and other plastic pieces, and then foaming material injection into the formation of a refrigerator door body, various technical indicators are in full compliance with the requirements of the company.

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