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Research Article

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Optimization of the middle-die hole chamfer of pharmaceutical tablet press

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ABSTRACT

To solve the problems with increasing die wear in the tablet production process, this research attempts to study the relationship between mold hole chamfer and stress and deformation from the ring mold hole axial path, through modeling die bore and finite element static analysis with CATIA V5R16. The conclusion is when middle-die hole chamfer is 67.5 °, die wear gets smaller. Afterwards, the experiment of granulation practice shows that the modified middle-die can remarkablely prevent mold bore wear.

Key words: mold bore wear, chamfer, optimization, CATIAV5 R16

INTRODUCTION

In the production of tablets, the die is critical for the quality of the tablets. After longtime use of the die, the die aperture wear leads to misalignment of hole punch and die hole, which the moving punch rod friction increases greatly. The proper production can not proceed when the friction gets more serious.

The cause of the die bore wear is multifaceted, which includes raw materials, process and the way it is used for the first time, etc. specifically, the more the axial load is, the more the loss is to the mold.

This article focuses on the relationship between manufacturing parameters of cone angle of ring mold material guide hole and the wear from the die hole. In order to study the relations study the relationship between mold hole chamfer and stress and deformation from the ring mold hole axial path, CATIA V5 R16 is utilized to complete the die hole modeling and finite element static analysis, and ultimately provides a basis for optimization of the structure of the mold. The problem of mold bore wear die can be solved from the perspective of design.

EXPERIMENTAL SECTION

Establish the structure model of mid-mode

The mode structure

Experimental equipment: Hunan Zhongcheng Pharmaceutical Machinery Factory TDP-1.5 herbal pills molding machine. Technical Parameters: Maximum tablet pressure $15KN$, Maximum tablet diameter $12mm$, Filling depth 11 mm, Yield $3000\,pc/h$, Power 3700W, Speed $1400r/\min$, Dimensions 570×380×630 mm, and Weight 95 kg. The structure and parameters of the die hole are shown as Fig. 1. The main parameters of the die hole: the diameter of the die hole $d = 12mm$, chamfered outer diameter $d_1 = 12.8mm$, mold thickness $L = 22mm$, feed angle α =60°, Die hole chamfer θ =60°.

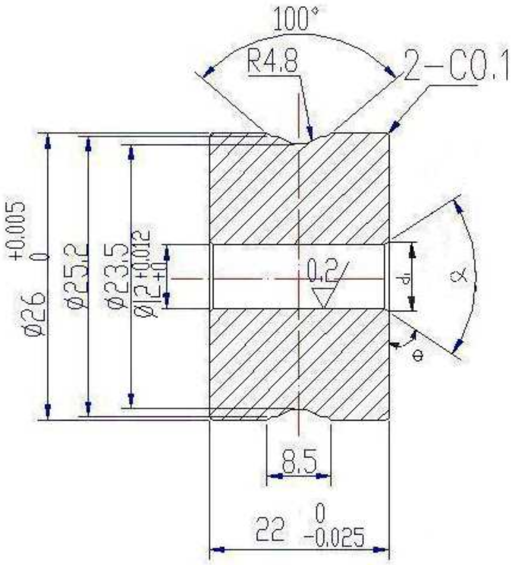


Fig.1 the structure of the middle-die

The establishment of structure model

Geometric modeling (shown as Fig.2) is indispensable for finite elements analysis with CATIA V5R16, Because hole model is axially symmetric, it is feasible to build 1/4 of the model. Provide respectively $\alpha = 60^\circ$、45°, 2 of parts models are established (shown as Fig.3) [1,5], with $\alpha = 60^\circ$.

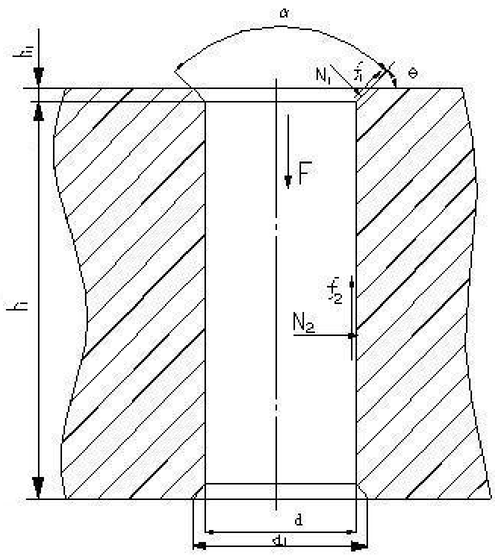


Fig.2 structure of the middle-die Hole and force diagram

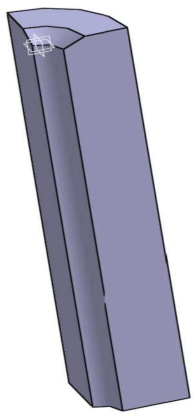


Fig.3 3D model of the feed angle of 60°

Calculation of finite elements loaded of the die hole [6]

First, make calculation of finite elements loaded with die hole as the object; and then analysis of stress: (shown as Fig.3)

F — axial force, f_1---Chamfer cone friction, f_2---Friction from inner surface of mold hole, N_1---positive pressure in the feed hole, N_2 --- positive pressure from inner surface in die hole.

From the analysis above, the shaped material coming from the die hole satisfies the following relationship:

$$F = \mu_1 N_1 \sin\theta + N_1 \cos\theta + \mu_2 N_2 \quad (1)$$

In order to make finite element analysis, the following assumptions are made:

①、the friction coefficient between chamfer cone, the die hole and the material, between the upper and lower punches, according to the related references, $\mu_1 = \mu_2 = 0.18$;

②、If the pressures from conical surface and the pressure from inner surface in die hole are equal, so

$$p_1 = p_2 \Rightarrow \frac{N_1}{A_1} = \frac{N_2}{A_2} \Rightarrow \frac{N_1}{\frac{\pi h_1}{2\sin\theta}(d_1+d)} = \frac{N_2}{\pi dh} \Rightarrow N_1 = N_2 \frac{h_1(d_1+d)}{2\sin\theta dh} \quad (2)$$

In（2）, A_1、A_2 are chamfering cone surface area in the die hole and cylindrical surface area, formula(2) led into (1), then

$$F = \mu N_1 \sin\theta + N_1 \cos\theta + \mu N_2 = \mu N_2 + (\mu \sin\theta + \cos\theta) N_2 \frac{h_1(d_1+d)}{2\sin\theta dh}$$

$$\Rightarrow N_2 = \frac{F}{\mu + \frac{(\mu\sin\theta + \cos\theta) h_1 (\frac{2h_1}{tg\theta} + 2d)}{2\sin\theta dh}} \quad (3)$$

If F is given the maximum value, $F = 15KN$. The other parameters are $d = 12mm$, $h = 21mm$, $h_1 = 1mm$. From formula (2) and (3), when θ varies, N_1, N_2 varies also. For $f = \mu N$ is known, $f_1 and f_2$ will varies.

According to formula（2）and（3）, the values of N_1, N_2, f_1, f_2 can be obtained when θ varies.

The finite elements load are added to 3 models, we can see in Tab.1

Tab.1 the values of N_1, N_2, f_1, f_2 when θ varies.

ID	feed cone angle α	die hole chamfer θ	force bearing of middle-die hole f_1	f_2	N_1	N_2
1	60°	60°	0.36	12.3	2	68.2
2	45°	67.5°	0.1	3.38	0.55	18.75

单位：KN

When the die hole is loaded using CATIA V5 to make stress analysis,

it's needed to figure out the pressure and resolution. Take 60° chamfer of cone hole for example, $A_1 = 7 \times 10^{-8} m^2$, $A_2 = 7.9 \times 10^{-5} m^2$, the results are shown in Tab.2.

Tab.2 pressure and force resolution of middle-die hole

feed cone angle	die hole chamfer	pressure and force resolution of middle-die hole			
α	θ	f_1	f_2	N_1	N_2
60°	60°	0. 36*KN*	12. 3 *KN*	2 *KN*	68. 2 *KN*
		f_{1x}, f_{1y}, f_{1z}	f_{2x}, f_{2y}, f_{2z}	p_1	p_2
		180*N*, 180 *N*, −311. 76 *N*	0 *N*, 0 *N*, −12300 *N*	$2.9\times10^{11}\ pa$	$8.6\times10^{8}\ pa$

Next, we can make calculations of division of tetrahedral grids[3]. in the platform of Advanced Meshing Tools, in the dialog box of Tetrahedral Grid Row Differentiator, the grid size is given $0.5mm$, absolute sag value is $0.1mm$. After the entity is hidden, the result can be seen in Fig.4.

Fig.4 finite element mesh generation

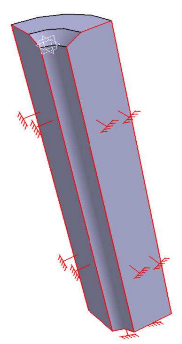


Fig.5 part constrained

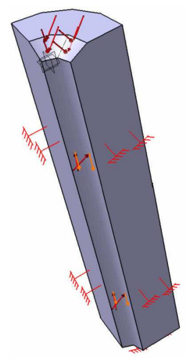
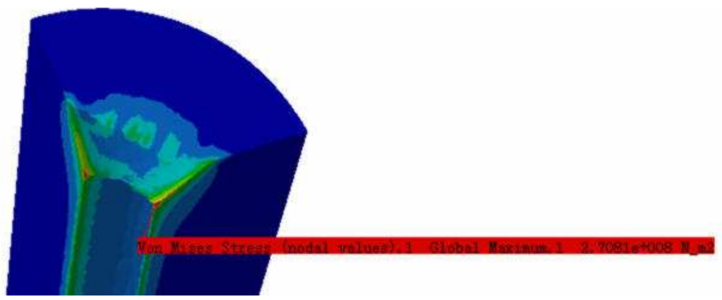


Fig.6 part loading

Analysis of the finite element stress[7,8]

In the platform of Generative Structural Analysis, the 3D properties are attached to the given parts. Set clamped boundary conditions and load parts model, see Fig.5 and 6. afterwards, loads are made in the chamfer cone hole and the cylindrical inner surface of the mold hole. Finally, calculations are made, the results are shown in Fig.7.



(a) die bore chamfer 60° $\sigma_{max} = 2.7081\times10^{8}\,Pa$

(b) die bore chamfer 67.5° $\sigma_{max} = 1.1161\times10^{8}\,Pa$

Fig.7 the Von Mises stress distribution of chamfer 60°、67.5°

RESULTS AND DISCUSSION

In Fig.2, the Von Mises stress distribution of the chamfer of die hole shows that the stress on of chamfer 67.5° is much less than that of 60° ,which is widely used in practice. The greatest stress is exerted on the inner surface in compressed cylindrical hole at chamfer of 67.5°, and at chamfer of 60°, it's on cone of feed hole, where feed cone hole tends to be worn. Sometimes, plastic deformation occurs.

Another study shows when the speed is fixed, Taper of the die hole has remarkable effect on compressed shaping[9,10]. When taper α increases from 30° to 45° , the biggest compressed density in granulation increases too, with the smaller rate of energy consumption; while taper α increases from 45° to 60° , the biggest compressed density in granulation decreases with much bigger rate of energy consumption. When taper α is 30° , it is not conducive to compression molding; when α=45° (θ=67.5°), the compressed density becomes biggest, with the least rate of energy consumption and the best compression molding effect.

CONCLUSION

This article takes the die bore wear and some parameters as the research objects, making some important fruits:

First, the conclusion that the die bore chamfer of 67.5 ° is much better in production is derived from 2 kinds of analysis axial Von Mises stress distribution, combined with the relationship analysis between rates of compression, energy consumption, and cone angle of feed hole.

Second, all these results are applied into the mold template of the herbal pills molding machine TDP-1.5, to improve the parameters of chamfering structure. The experiment indicates that the mid-mold with aperture of 12 mm, die bore chamfer 67.5° can manufacture 3000～3500 pc/h. Compared to the die bore chamfer of 60° , it can improve the production, guarantee the quality of tablets, relieve die wear and prolong the lifetime of the mold, so the cost can be reduced.

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