Forced Demoulding Mechanism for High Rigidity Material Mould Used for Turbocharger Pressure Relief Valve

Lei Qiu 1,*, Lanlan Liu 2, Wei Xiong 3 and Jianwei Xu 3

1College of Mechanical Engineering, Ningbo University of Technology, Ningbo, China
2Department of Mechanical Engineering, JiangXi Technical College of Manufacturing, Nanchang, China
3Ningbo Aero Engine Power Technology Co., Ltd, Ningbo, China

*Corresponding author e-mail: qiulei@nbu.edu.cn

Abstract: This paper designed a forced demoulding mechanism for the high-rigidity material of the turbocharger relief valve. This mechanism could effectively overcome the shortcomings of traditional injection mold inlays, such as large volume and high production cost; The parameters of this mechanism were calculated to further optimize the performance of the mechanism; then the finite element simulation analysis was carried out to verify the feasibility of the mechanism under these parameters; Finally, the actual mold was trial-produced and the prototype of the pressure relief valve was trial-produced.

Keywords: Turbocharger, Pressure relief valve, Injection mold, Forced demoulding

1. Introduction
In order to adapt to the operating characteristics of the gasoline engine, the turbocharger equipped with it needs to be used in conjunction with the intake pressure relief valve [1]. When the driver loosens the throttle, the ECU issues a command to control the opening of the pressure relief valve to avoid supercharging the device surged. This shows that the pressure relief valve plays a very important role in the supercharger of gasoline engines [2]. In the pressure relief system, the valve body is the main body of the pressure relief valve. The manufacturing process and cost control of the valve body directly determine the overall performance and production cost of the pressure relief valve, thereby affecting the overall performance of the booster.

2. Forced Demoulding of Injection Mold
Considering the mechanical properties and economic benefits, the material of the pressure relief valve body is often selected as engineering plastics, such as PA66 + 30GF commonly used in engineering.

Figure 1 shows a common pressure relief valve. There are three buckles in the valve body, their function is to connect the circular support ring on the right side of the figure. This valve body is formed by an insert injection molding process. The insert is shown in Figure 2. It can be seen that the volume of the insert is large and the structure is complicated, which increases the production cost and difficulty of the manufacturing process.
The valve body, process of the valve mechanism, supercharger parts was thin-walled and as thin-walled为了让其有良好的弹性。

In the general process of forced demoulding, the injection mold mechanism can be used to realize the construction of its shape feature, which will increase the cost of mold manufacturing. Therefore, when the part structure is complex and special, or the size is too large, the core pulling mechanisms cannot be used for injection molding. In this case, we can consider the use of forced demoulding to achieve the shape characteristics of the buckle.

The general forced demoulding mechanism is often applied to engineering polymer materials such as PP, PE, ABS, POM, etc. These materials have good elasticity and are easy to form by this method, and the shape characteristics of parts prepared from these materials have low rigidity Features, such as thin-walled barrel parts, shell parts, etc.

In consideration of mechanical properties and heat resistance requirements, the material of the turbocharger relief valve body was PA66 + 30GF, and its grade was Zytel 70G30HSLR BK099, which was an engineering plastic material with high rigidity and poor elasticity[4], for this type of plastic parts forced release mechanism was rarely involved, this study would be based on a gasoline engine supercharger pressure relief valve, a new design method for high rigid plastic mold forced release mechanism research.

3. Valve Body Structure Analysis

The working characteristics of the pressure relief valve require that its reliability must be very high. The buckle on the valve body should be reliably connected to the support ring. During the demolding process of the production, the buckle damage is not allowed. In order to ensure the rigidity of the valve body, on the basis of PA66 + 30GF, 30% glass fiber reinforced, and the structural characteristics of the valve body as shown in Figure 3, so the valve body is very rigid everywhere, and was not easy to
deform.

Figure 3. Schematic diagram of the valve body structure

4. Working Principle of Forced Demoulding Mechanism
Based on the above analysis, and after many optimizations, this paper had developed a mold structure specifically for this type of strong disengagement. The structure was shown in Figure 4. This mold has a slender small insert structure. The micro insert is used to form the shape characteristics of the buckle, and the micro insert had a vertical degree of freedom in the ejection direction of the mold release and can move along the direction.

When the mold is opened, the part is ejected by the ejector rod. At this time, the micro insert extends with the valve body blank, but the extension stroke of the micro insert is constrained by the length. After the micro insert reached the end of the stroke, the ejector rod continues to move, which can carry out the second ejection, as shown in Figure 5, at this time, the micro insert is equivalent to a cantilever beam, and its top end is bent and deformed by the buckling area of the valve body blank, so that the micro insert and the valve body blank separation, complete the strong off action.

In short, this mechanism has two ejection actions. In the first stage, the buckle of the valve body blank is ejected together with the micro-insert and travels for a distance. Its purpose is to form the micro-insert into a cantilever structure and reduce its structure rigid, which aimed easy to deform its shape. The second stage ejection is used for forced demolding of the valve body buckle. After the first ejection, it can ensure that the stress caused by the bending deformation of the micro insert is small enough to damage the valve body buckle.

Figure 4. The first ejection
5. Parameter Calculation of Demoulding Mechanism

When the valve body blank is ejected for the second time by the ejector rod, the micro insert as described above is deformed by the buckle of the valve body blank, and the strong detachment process is completed when the deformation reaches the width of the buckle.

In this paper, the width of the buckle in the valve body blank is 0.3mm. At the moment of forced demoulding, the force at the contact position between the top of the movable micro-inlay and the valve body buckle reaches the maximum value. Based on this boundary condition, parameter calculation is considered, especially it should be noted that, if the safety factor is considered, the safety factor of glass-reinforced plastics was generally 2[5].

5.1. Force Analysis

According to the appearance characteristics, the force on the micro insert can be decomposed into a horizontal component force $F_1$ and a vertical component force $F_2$. The schematic diagram is shown in Figure 6.

\[
\theta_1 = \frac{-F_1 L^2}{2EI}
\]  

(1)
\[ \omega_1 = -\frac{F_1L^2}{3EI} \]  
(2)

Under the independent action of vertical force \( F_2 \), there is:

\[ \varepsilon_1 = \frac{F_2}{E} \]  
(3)

Under the single action of concentrated force couple \( M \), there is:

\[ \theta_2 = -\frac{ML}{EI} \]  
(4)

\[ \omega_2 = -\frac{ML^2}{2EI} \]  
(5)

Therefore, according to the superposition method, under the action of concentrated force couple \( M \) and horizontal force \( F_1 \) and vertical force \( F_2 \), we could derive the following formula:

\[ \theta = \theta_1 + \theta_2 = -\frac{F_1L^2}{2EI} - \frac{ML}{EI} \]  
(6)

\[ \omega = \omega_1 + \omega_2 = -\frac{F_1L^2}{3EI} - \frac{ML^2}{2EI} \]  
(7)

\[ \varepsilon = \varepsilon_1 = \frac{F_2}{E} \]  
(8)

In the above calculation expression, \( I \) is the moment of inertia of the micro-insertion section to its axis of symmetry. The schematic diagram of the cross-section of the micro-insert is shown in Figure 7. The cross-section is a rectangular parallelepiped with a circular arc edge, and this cross-section has an inertial moment enhancement effect [6].

![Figure 7. Schematic diagram of micro inserts](image)

In this paper, taking the moment of inertia of the rectangular section as the reference quantity, it was denoted as \( I_r \), the special section of the micro-inlay enhanced its moment of inertia, and the enhancement coefficient was denoted as \( \alpha \). However, the shape characteristic at the top weakens its moment of inertia, and the weakening coefficient was recorded as \( \beta \).

Then, the moment of inertia of the micro-inlay could be expressed by the following formula:
\[ I = \alpha \beta l_r \]  

(9)

The force arm of M was the depth of the notch on the top of the micro-insert, denoted as \( L_d \), we could get:

\[ M = F L_d \]  

(10)

In the above formula, \( F \) was the combined force of \( F_1 \) and \( F_2 \), that was, the interaction force between the micro insert and the valve body buckle. The angle between \( F_1 \) and \( F \) was denoted as \( \alpha \).

\[ F_1 = F \sin \alpha \]  

(11)

In summary, we could get:

\[ F = \frac{6 \omega E \alpha \beta l_r}{2(\sin \alpha) L^2 + 3 L_d (\alpha \beta l_r)^2} \]  

(12)

In the process of forced demoulding, the contact area between the valve body buckle and the micro insert was \( S \). The shape of \( S \) was a circular ring with a fixed length arc, but its radial length changed during demoulding. The inner and outer diameters are \( r_1 \) and \( r_2 \), and the fixed-length arc is \( b \), then:

\[ S = \frac{b}{2\pi} \cdot \frac{1}{2} \pi \alpha dr \]  

(13)

At the moment when the forced demoulding is completed, the area of \( S \) is the smallest and the value of \( F \) is the largest. The value of each value at this time should be the design value.

| \( \omega \) /m | E/Mpa | \( \alpha \) | \( \beta \) | \( L_1 \)/m | \( L_2 \)/m |
|--------------|-------|--------|--------|--------|--------|
| 3*10^-4      | 213000| 1.5    | 0.8    | 8*10^-8| 3*10^-4|
| 82           | 18.27 | 18.31  | 0.213  | 200    |        |

In summary, when the safety factor of the valve body material is 2, the design value of \( L \) should not be less than 1.66 * 10^-2 m.

5.2. Simulation Analysis

In this paper, the finite element model of the valve body and the micro insert was established, and the simulation analysis was carried out. In order to improve the calculation efficiency, the valve body model was slightly simplified. The model was shown in Figure 8, the equivalent strain was shown in Figure 9, and the deformation the amount was shown in Figure 10. In order to better show the deformation of the micro insert, Figure 11 showed the deformation of the single micro insert. It could be seen that the micro insert snaps under the maximum allowable stress of the valve body material the deformation at the location was between 0.279-0.3188 mm, which met the design requirements.

![Figure 8](image-url)
6. Experiment

According to the research results of this article, a prototype was produced. Figure 12 was the lower mold of the injection mold with the plunger and micro-inlay. Figure 13 was the prototype made with this mold. The buckle of the valve body blank was intact and No burr defects. After large-scale trial production, it was found that the forced demoulding mechanism had stable working performance, high efficiency, and good operability, so that the production cost of the pressure relief valve was reduced and the product quality was significantly improved.
Figure 12. The physical of the forced demoulding mechanism

Figure 13. Valve body prototype

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