An integral inlay type porthole extrusion die

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Abstract: A new porthole extrusion die named integral inlay in the male die for Al-profiles was presented. The porthole die structure is composed of four parts, which is different from the traditional structure. The key structure parameters of the new die were introduced. Mainly one male die was divided into two male dies, and the two dies were assembled by inlaying. Through a practical LED lamp aluminum profile, the characteristics of this product and the traditional die structure were analyzed. The selection of these parameters was described in detail, mainly including the structure of two male dies, the design of portholes, the structure of the front feeder plate, the chamber and the bearing belt. The results shows the new die structure is effective, the new die structure has the obvious advantages. Moreover, it can greatly improve the life of the die and simplify processing, as well as save materials. It is a die structure which is worth of being copied and popularized.

1. Introduction
Because of its light weight, beautiful appearance, corrosion resistance, good thermal conductivity and easy forming, aluminum alloys are widely applied in various fields. Aluminum profiles have been extended from the civil buildings in twentieth Century to various fields and industries, including automobile, rail, aeronautics and astronautics, electronic and electric power, computer and communication, machinery manufacturing and equipment. Especially as a heat radiation component, it is widely used in electronics and automotive industry. But these industrial profiles are often complicated, especially, the sections with double or multi cavities, and the design and manufacture of the die are very difficult. Therefore, the key to the production of this type of profile is the die. On the one hand, the die determines the dimension accuracy of the profile; on the other hand, more importantly, the die determines the cost of production. Die structure is also an important part of die design. Especially for the large profiles of LED luminaire, the development of the die is the key. The die plays a very important role in the popularization and popularization of LED lamps. Based on the development of a large LED tube of aluminum profile and its die, an integral male die mosaic type porthole die structure is put forward for peer reference.

2. Product characteristics analysis
Figure 1 shows a section of large LED aluminum tube, and its section area is 4909mm², which has good heat dissipation function.
This section has cores of 17 cavities with two layers inside and outside, and the shape is more complicated. At present, when the manufacturer produces this aluminum profile of LED lamp tube, the cost of the die is great. The reason is that, on the one hand, the processing of the die is difficult and the manufacturing cycle is long. In particular, the copper electrode is used for electrical machining, the copper electrode is processed and the material cost as well as the manufacturing cost are high. On the other hand, the strength of the die is not easy to be guaranteed and the die is easy to break\(^1\). It is mainly because the center area of the profile is large. In the extrusion process, the metal deformation resistance and the metal friction force produced by the extrusion rigid zone of the die center are too large\(^2\). The die will change seriously under the condition of high temperature, high pressure and high friction. The deformation of the die leads to the fracture of the feeding bridges. The strength of the die is mainly dependent on the quality of the die steel. In order to improve the life of the die, the imported steel is used, and the imported steel is expensive, so the cost of the die is high. More importantly, the die structure adopts the traditional design and processing ideas to make the metal between the inner cavity difficult form, which easily leads to the deviation of the geometric size of the product.

3. Traditional die structure

According to the characteristics of the profile, considering the appropriate extrusion coefficient and lower die cost, the traditional extrusion machine capacity and the size of the die are reasonable. The capacity of the extrusion machine is 55MN, and the inner diameter of the container is 365mm. After calculation, the extrusion coefficient is 21.3. The traditional die structure for large section profiles consists of three parts, which are the front feeding plate, the male die and the female die, as shown in Figure 2.

The defect of this structure is that the thickness of the male die is thicker, which leads to the difficulty in the machining of the portholes of the inner layer.
At the same time, it is difficult to process the metal channel of the connecting bar between the cores. It makes the metal supply difficult in these parts\cite{3}. It is also difficult to repair. In addition, the cores must be processed with copper electrode in the electric discharge machine. With a large section, the consumption of electrode material is large, and the polishing and grinding of cores is difficult, which prolongs the manufacturing cycle. The result of such the structure is that the precision of the die is low, and the symmetry parts are difficult to achieve uniformity and proportionality in the manufacture, so the size accuracy of the extrusion is difficult to be guaranteed. Although the die structure adopts the front feeding plate, the feeding ratio of the front feeding plate can be limited by the arrangement of the male, so it can not reduce the extrusion pressure fully\cite{4}. The portholes arrangement is shown in Figure 3.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig3.png}
\caption{The signal of portholes of traditional die structure}
\end{figure}

The main technical parameters are as follows:
1. the feeding ratio of the front feeding plate was 9.3.
2. the feeding ratio of the male was 8.7.
3. the front feeding plate has 8 outer feeding holes and 4 feeding holes in the inner layer, the width of the bridge outer is 22mm, and the inner bridge width is 16mm.
4. the male die has 8 outer feeding holes and 8 feeding holes in the inner layer, the width of the bridge outer is 20mm, and the inner bridge width is 12mm.
5. the thickness of the front feeding plate is 125mm, and the thickness of male die is 175mm.

4. Improved die structure
To change the traditional structure form, the front and rear male die are divided into two parts. The cores of the inner and outer two layers are placed on the two male dies respectively, and the two male dies are processed separately, and then they are inlaid together. This is the key to the improvement of the die structure. The structure of the die consists of the front feeding, the front male die, the rear male die and the female die. The die structure is shown in Figure 4.
4.1 the structure of the front male die

The structure of the front male die is shown in Figure 5.

This structure enables the core which is the largest cavity corresponding to the product to be machined by turning. Because of the change of structure, in the process of manufacturing, the cost of manufacturing is greatly reduced and the processing cycle is shortened greatly without using copper electrode and EDM. The simplification of processing ensures the accuracy of die manufacturing so that the final quality of products is guaranteed. Meanwhile, the technological hole of 40X145mm is designed in the center of the front male die, which can improve the hardenability of the die during heat treatment, thereby the mechanical properties and strength of the die can be improve.

The main technical parameters are as follows:
(1) the maximum outer diameter of the feeding holes is 336mm.
(2) the number of portholes is 16.
(3) the feeding ratio is 9.8.
(4) the width of the bridge is 14mm, and the thickness is 100mm.

4.2 the structure of the rear male die

The structure of the rear male die is shown in Figure 6.
Fig.6 the structure signal of the rear male die

Its core can also be processed by wire cutting after the turning by using the uniform and symmetrical arrangement of the cores.

The main technical parameters are as follows:
1) the maximum outer diameter of the feeding holes is 338mm.
2) the number of feeding holes is 20.
3) the feeding ratio of is 8.2.
4) the width of the bridge is 12mm, and the thickness is 80mm.

It can be seen that the number of feeding holes in the front male die and the rear male die is much more than that of the traditional. This is based on the empirical value. The more the number of feeding holes and the smaller the width of the bridge are, the more uniform the flow velocity of the metal is. Therefore, under the premise that the total area of the feeding holes is not reduced or reduced little, the bridge with a width of 12mm is adopted. In this way, the velocity of metal flow at the die hole will tends to be consistent, so that the bearing of such a large die hole can be consistent, and the working procedure of working bearing using the EDM is saved by turning.

4.3 the structure of the front feeding plate
The structure of the front feeding plate is shown in Figure 7. The number of feeding holes in the front feeding plate is less than that of the traditional one, so the area of the portholes is large. The feeding ratio of the first predeformation of metal is larger, which is beneficial to reduce the extrusion pressure and improve the strength of the die.

Fig.7 the structure signal of the front feeding plate

The main technical parameters are as follows:
1) the maximum outer diameter of the feeding hole is 320mm.
(2) the number of portholes is 4.
(3) the feeding ratio is 11.8.
(4) the width of the bridge is 36mm, and the thickness is 120mm.
(5) the expansion angle of the front feeding plate is from 5 to 10 degree, which can reduce the extrusion pressure by more than 20%. Thus the pressure of the die can be reduced.
(6) the bridge of the front feeding plate adopts the way of back and forth chamfering. On the one hand, it can reduce the resistance of metal into the feeding holes when extruding. On the other hand, the neutral layer of the bridge section can be basically maintained or downward shifted, the tensile stress of the die and delaying the fracture of the bridge can be reduced, thus the strength of the die will be improve.

4.4 the chamber and bearing of the female die

The chamber and bearing as shown in figure 8.

![Fig.8 the signal of the chamber and bearing of female die](image)

The shape of the chamber is based on the outer edge of feeding holes into the chamber of female die[6]. As the bridge of rear male die is smaller under satisfying the strength, the bearing can be consistent according to the experience. that is the bearing under the bridge does not have to be divided into segments[7]. This is more conducive to ensuring the roundness of the outer circle. The bridge pier under the bridge can reduce the width of the bridge, so as to improve the die strength, and the depth of the chamber can be get 26mm according to the machine capacity.

5. CONCLUSIONS

The key of the overall mosaic structure of the male die is to decompose the traditional a male die into two male dies of the front and rear male die, and put the cores of the inner and outer layers on the different male dies, so that the machining of the die can be greatly simplified, and the precision of the die manufacturing and the material saving can be ensured. According to the extrusion and tracking of the die after the structure improvement, the practice shows that the new structure is quite effective, the extrusion forming is good, the size precision of the profile can reach the high precision level, and it is a kind of structure worth replicating and popularizing.

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