Study on Die Structure for Reducing Extrusion Force of Porthole Die

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Abstract: The composition of extrusion force was analyzed. The die structures to reduce the force were put forward, such as reducing mold thickness and the compression area of metal feeding, the hollow bridge number, using the inclined surface of the metal feeding and the front feeding plate, the structure of porthole that one divides into two, the larger the feeder ratio. And the methods of chamfering in inlet of the bridge and appropriate reaming of porthole are also effective. Practice shows that reducing the height of chamber and decreasing the length of bearing are also available. These structures are verified by practice and the effect is good. The aim is to provide reliable reference to colleagues.

1. Introduction 
The extrusion force is one of the most important parameters in the extrusion process of aluminum profile. There are many factors affecting the extrusion pressure. In the actual extrusion process, it is also very common that the extrusion pressure is too high. The high pressure has certain advantages on the surface quality and mechanical properties of the product, but squeeze pressure will be very serious harm to the production. On the one hand, it will increase the unstable factors of metal forming and extrusion difficulties, on the other hand, it is easy to cause the premature failure of the mold and damage the extrusion equipment system. Therefore, in order to reduce the extrusion force in extrusion process, a great deal of research and exploration have been carried out by extrusion workers, experts and engineers. But the study mainly focused on the materials and techniques. In fact, different die structure for the same product, the extrusion effect is different, there may be pressure too high, and extrusion production is difficult. Especially the porthole structure of the most common and the most widely used is obvious and direct effect on extrusion pressure. In this paper, the structure of the porthole die which can reduce the extrusion force is analyzed, which can be used as reference in the die design.

2. Composition of extrusion force 
The extrusion force is composed of two parts, which are the force needed to overcome the metal deformation and the force needed to overcome all kinds of friction. Friction is the frictional resistance that metals have to overcome in the flow of the die, which is directly related to the distance of metal flow in the die. When the metal flows, the distance that passes, that is, the longer the metal process or flow path, the greater the area of contact, the greater the squeeze pressure, and the length of the metal runner is determined by the structure of the die. The force required to overcome the basic metal deformation, it is with the material properties, metal process parameters...
such as temperature, degree and so on, but with the structure of the porthole die for extrusion, the metal will be divided into several strands of aluminum rod because of shearing from bridge and mix and merge together in chamber of female die. From the metal forming process, it can be seen in the reasonable process conditions or under the same, the more the number of strands of metal flow is, the greater the force required, while the number of metal flows is related to the structural design of the porthole die or the number of hollow bridges, or to the choice of the feeder ratio. Rewelding and fusion of metals are related to the feeding ratio and the die structure parameters of chamber, the metal is eventually extruded from the wall thickness gap formed by the male die and female die, and the size of the gap directly influences the extrusion ratio. It can be concluded that the die structure has a great influence on the extrusion force.

3. The structure of reducing extrusion force in porthole die

In the design, fully considering the pressure factor is the most important and key. When the extrusion ratio leads to high extrusion pressure, the main contradictions to be solved is how to optimize the die structure and reduce extrusion pressure so as to ensure and improve the strength of the die. When the extrusion ratio is relatively small, the extrusion force is smaller, and then the structure of the die should be changed to increase the extrusion force so as to improve the welding force of the metal to improve the mechanical properties and surface quality of the profile products.

3.1 Reducing the thickness of male die

On the premise that the die strength is guaranteed, reducing the thickness of the male die properly is the most direct and effective way to reduce the extrusion force. On the one hand, the the distance of the metal flow can be directly reduce, on the other hand, reducing the thickness of the male die, the time of the metal into the welding chamber will be shorten to make the time when the bridge is divorced from chamber to bear force from the billet sheared be shorten.

3.2 Reducing the compression area of the metal feeder end of the male die

As shown in Figure 1. In Figure 1 (b), the core was covered by the whole area of bridge, the compression area in the center is large, in the extrusion process, it will form a big rigid region in the central part of the die, a larger rigid cone will form, therefore, it will produce high resistance, so the extrusion force will be larger. And in figure 1 (a), the part of the core is covered by the bridges, the rest are close to the edge of the hole or exposed in the feeding hole, the compression area is reduced. On the other hand, the feeder ratio also increases, so the pressure is smaller than the structure of figure 1 (b).

3.3 Metal feeding method with oblique plane

The feeder end face of the portholes of the male die is flat in the conventional porthole die. When the aluminum billet enters the portholes, it is the first to be sheared by the bridges. The maximum shear force occurs at the same time, and the force acting on the bridges is also the largest. If the feeding end
plane is designed a sloped gradient plane less than 20 degrees, when the bridge shear aluminum billet, it can avoid the maximum shear force does not occur at the same time, thereby it will reduce the peak of shear stress to reduce the pressure and improve the strength of the mold. As shown in Figure 2.

![Fig.2 the signal of the inclined feeder plane](image)

3.4 Using the front feeder plate
For some large section, the front feeding plate structure can achieve two ways to feed. In the first feeding, a larger feeder ratio can be used, it can greatly reduce the compression area of die, and in the second feeding, the width of the bridges can be reduced, it will decrease the force on the bridge from the secondary shearing of metal flow so as to reduce extrusion pressure. As shown in Figure 3.

![Fig.3 the scheme for twice diversion with a front feeder plane](image)

3.5 Reducing the hollow bridge number
As shown in Figure 4. A bridge structure can be used for some narrow sections. The structure shown in Figure 4 (a) shows a larger feeder ratio and a smaller compression area of the die. At the same time, the metal flow quantity to be cut is less, the power to overcome metal deformation is small, therefore, the extrusion pressure is smaller than the structure shown in figure 4 (b).
3.6 Using the structure form of porthole that one divides into two
For some profiles, the size of the core is relatively large, so that the feeding type of the porthole hole can be optimized without using the front feeding plate, and the structure of two in one will be adopted, as shown in Figure 5.

3.7 Reducing the height of chamber and the length of bearing
The higher the welding chamber is, the larger the extrusion pressure will be. This is because the higher the welding chamber is, the bigger metal welding chamber volume will be, the metal volume to bulk will increase, the energy required is greater, at the same time, the higher the welding chamber is, it will also increase the distance of metal flow, so the pressure is greater. Therefore, reducing the height of welding chamber can reduce extrusion pressure. But the height of welding chamber is too shallow, it will reduce the welding quality and affect the product performance. Therefore, in practice, the height can be reduced cautiously by 2mm to 3mm compared to conventional cases. The influence of the length of the bearing on the extrusion force is very sensitive. As the length of the bearing increases, the extrusion force to overcome the frictional resistance of the bearing will increase. The experimental results show that the extrusion force on the bearing is 5% to 10% of the extrusion force, so it is limited to reduce the extrusion force by reducing the overall length of the bearing. Of course, the choice of bearing should be taken into account, too long or too short are adverse, the length of the bearing will be reduced as much as possible without affecting the life of the die.
4. Conclusions
The structure of the porthole die is sensitive to the impact of the extrusion force. With the different of die structure, the extrusion force is different in the extrusion process, and the extrusion effect is different. When the pressure is high, to reduce extrusion pressure is the main work to do in the design of die structure. But drawing on the design principle of die structure which can reduce the extrusion force, it can also be used to increase the extrusion force in order to ensure the mechanical performance and surface quality of the profile under the condition of too low extrusion pressure. To make full use of the factors which die structures affect extrusion pressure can give full play to the role of the die structure. According to the different needs, rational die structure can be chose. Not only it can guarantee the smooth progress of extrusion, but also it can improve the strength and life of the die, the more important is to ensure the quality and performance of products.

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