An Extrusion die for parallel collection Al flat tube of automobile heat exchanger

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Abstract: The structural characteristics of parallel tube aluminum flat tube profiles for automotive heat exchangers were analyzed. A new die structure is present, and a semi-integral core structure is proposed. The selection of new die structure parameters is introduced, which included the selection of extrusion machine capacity, the layout of hollow holes, the structure of the cores, the size of guiding holes, the structure of the welding chamber and the bearing of cores and the die hole etc. The practice shows that the new structure can effectively prevent the premature fracture of the cores and greatly improve the service life of the die.

1. Introduction

With the rapid development of the automotive industry, aluminum alloy parallel flow aluminum flat tubes for heat exchanger materials are necessary automotive air conditioning, and the demand is increasing. The parallel flow aluminum flat tube for automotive heat exchanger has the characteristics of flat and wide, thin wall, multiple inner holes, complex section shape, high dimension accuracy and difficult production. The die is the key factor in the three main factors of extrusion die, raw material and extrusion technology. Because the parallel flow flat tube has many closely spaced cavities and small inner cavity area, it is required that the metal distribution in the feeding cavity of the extrusion die is reasonable, and the stability of the core is strong. However, with the complex core and small core area, the traditional die design technology often makes the metal diffusion improper in the cavities, which causes the strength and rigidity of the core to be insufficient, and it is very easy to cause the deformation or fracture of the core during the extrusion process. Therefore, in order to improve the extrusion formability and reduce the cost of extrusion die, we must distribute the metal in the diffuser reasonably, so that we can get the right core strength. In this paper, a new structure is introduced through practical examples. Practice has shown that it is effective.

2. Analysis of the structure and process of the profile

Figure 1 shows a typical parallel flow aluminum flat tube for automotive heat exchanger.
Fig. 1 the section of parallel flow aluminum flat tube section for automotive heat exchanger.

The profile shows that it has 17 cavities, the size of the cavity is 5 x 3mm, the thickness of the profile is 0.5mm, the maximum ratio of width to thickness of the profile is 188, and the sectional area of the profile is 119.6mm². Therefore, the die structure must be focused on reducing the extrusion pressure, ensuring the rigidity and strength of the core to ensure the life of the die.

3. The selection of parameters of die structure

3.1. change the traditional design of feeder holes

In the traditional design, 2 or 4 feeding holes are used, and 6 feeding holes are adopted in new structure, while the angle of the bridge and the horizontal direction is more than 90 degrees (110 degrees). The advantage is that it is better to pre distribute the metal, which can better limit the flow of metal in the centre which velocity is usually fast, and make the metal distribution from the center to the ladder. The metal distribution way of increasing from the center to the outside eliminates the difference of metal velocity due to the decreasing gradient of pressure from the center to the outer side of the container. The layout of feeder holes is shown in Figure 2.

S1 and S2 are the area of the corresponding feeder holes respectively

Fig. 2 the signal of feeder holes arrangement

After the simulation in the design process and the feedback from the trial of die, the area of the feeder hole after correction is $S_2 = (1.15 \sim 1.2) S_1$. When the feeder hole satisfies this condition, the result of the die is the best, including the consistency of the metal flow rate and the service life of the die. The width of the bridge is 16mm and 10mm, respectively. On the one hand, the choice is to consider the strength and combine the characteristics of the profile, on the other hand, in order to obtain the maximum feeding ratio and reduce the extrusion pressure. The advantages of 4 10mm bridges and lateral inclination are that the flow of metal is increased from the center to the outside. On the other hand, the trial data shows that when the bridge is less than 12mm, the factor of the bridge bottom can be ignored when the bearing of the die hole is selected, thus eliminating the pressure gradient in the radial direction of the container. The influence of the bridge on the metal velocity is more likely to make the metal flow rate at all sides tend to be consistent. In order to ensure the surface quality, the 4 bridges of with a width of 10mm adopts
the way of sinking, which increases the chamber depth at the corresponding part, thus increasing the welding force. As shown in Figure 3.

![Fig.3 the schematic diagram of the bridge](image)

3.2. Determination of mold core structure
In order to ensure the strength of the mold core and improve the rigidity of the core, the core is semi integral and the cone angle of the core is 40 degrees. The so-called semi integral type is compared with the traditional core. As a whole, the core is that the core is a whole with only one cavity in the hollow section, and as a hollow section with multi cavities, the depth of the flow guide hole in the traditional cavity (between the cores) runs through the core, and the semi integral core, that is, the depth of the flow guided hole is still not half of the core, and the lower part of the core is still the whole. The structure is shown in Figure 4.

![Fig.4 the signal of core structure](image)

3.3. The determination of the size of the guided flow hole
In order to ensure the rigidity of the core and the metal supply of the forming in thick cavity wall, the traditional way of setting the flow guided slot is cancelled, only the way of the flow guided hole is used, which is the biggest difference from the traditional die with multi cavities. The traditional depth of the flow guided hole is consistent with the depth of the chamber, which runs through the whole core. When the size of the core section is less than 10 by 10mm, it will be an important factor for the insufficient rigidity of the core. The experimental data show that for the profiles shown in Fig. 1, the optimum depth of the core hole is from 5.5 to 6.5 mm. The structure of the flow guided hole is shown in Figure 5.

![Fig. 5 the diagram of the dimension of flow guided hole](image)

At the same time, the traditional design does not consider flow guided hole of the most lateral or the most edge core. For the die its profile shown in Figure 1, the most outboard core is also designed as a
half flow guided hole and a complete flow guided hole is formed by matching with the chamber at the same place in the female die. This ensures that the metal supply state of all parts tends to be consistent, thus it will avoid the pressure difference between cores. Therefore, the cores do not deform and break.

In the traditional die, the metal space capacity of the outer core in the chamber is the most, which is greater than the metal capacity of the inner, because the capacity of the inner cavity is determined by the space of the flow guided hole, which is restricted. So it causes the uneven load of the core, as shown in Figure 6, in the picture, the pressure P1 is larger than P2.

![Fig.6 the force diagram of core](image)

3.4. the chamber structure

Based on the stress analysis of the above core and the actual wreckage of the core, the flow baffle pier is designed at the most outboard part of the die hole in the chamber of female die, so that the flow of metal is also supplied in the way of the flow guided hole, which can eliminate the unbalanced force of the core caused by the uneven supply of metal. The chamber is shown in figure 7.

![Fig.7 the signal of chamber structure](image)

3.5. the bearing determination of core and die hole

In order to ensure uniform metal flow rate during extrusion, the selection of the core belt is also the key. The bearing of cores is shown in Figure 8.

![Fig.8 the bearing of cores](image)

The length bearing of the cores are determined in accordance with the length of bearing of female die hole, different from the traditional one, the cores are higher the chamber plane 3mm. The bearing of die hole is shown in Figure 9. The chamber depth is 14mm, the core length is 5mm.
3.6. the die assembly
The die is composed of two parts: the male die and female die, which is the same as the traditional structure. Because most of the alloys used in the parallel flow tube are 1XXX pure aluminum or 3XXX series of aluminum alloys, the mechanical properties of the two alloys are lower than that of the common 6XXX series aluminum alloy. Therefore, the thickness of the male die can be reduced from 5 to 10 mm properly in the design, which is more conducive to reducing the extrusion pressure. The die assembly is shown in Figure 10.

4. Conclusions
For extrusion die of automobile parallel aluminum flat tube profiles, its main form of failure is the fracture of the cores. Therefore, in the design of die, the key is to consider how to effectively reduce extrusion pressure and ensure the rigidity and strength of cores. The specific methods are to determine the layout of feeder holes and feeding ratio reasonably, and adopt the semi integral and conical core structure, and the most important is the selection of the size of the flow guided holes. In order to prevent the uneven force of the cores effectively, the practice shows that it is very effective to use the flow blocking pier in chamber of the female die. At the same time, it is also the key to choose the bearing of cores and die hole reasonably. Only by considering these factors comprehensively, we can get the best plan to improve the life of die.

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