A new extrusion die for aluminum profiles

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Abstract—A new type of extrusion die is put forward, in which cemented carbide material is used to inlay the working part of the die, so as to improve the wear resistance of the die. The necessity of using cemented carbide in extrusion die is introduced. The selection of cemented carbide was introduced by taking the actual round tube aluminum profile as an example. The method for determining the size of cemented carbide and the mosaic method of cemented carbide were described. Based on the results of extrusion, the common extrusion die and cemented carbide extrusion die were compared. The results show that the wear resistance of the die can be greatly improved by the use of cemented carbide. Thus the life of the die is greatly improved.

1. Introduction

In the past, with the limitation of mold manufacturing level and social demand, as well as the influence of high mold cost accepted by traditional concepts, we did not realize that economic benefits could be analyzed and studied from the perspective of mold life. With the development of mold industry, the application of high-quality, high-performance and high-efficiency mold, the life of mold gradually attracts the attention of the world [1], and the life of mold has great potential. In the new era that the rapid development of industrial products drives the rapid development of mold industry, whether the mold is large-scale, complex or high-precision, high efficiency, ultimately depends on the improvement of mold life. Aluminum alloy is widely used in various fields because of its good corrosion resistance and weldability. At present, the consumption of extrusion die for aluminum production is very large every year. The extrusion die is made of high-quality hot working die steel H13, which has good red hardness and impact toughness, but its hardness after heat treatment is lower than HRC51, and its wear resistance is poor. Although the surface hardness HV1100 can be achieved after nitriding treatment, the main reason for die failure is die wear, and the total die life is still limited [2]. Therefore, to improve the wear resistance of the die is of great significance to improve the life of the die, which will bring significant economic benefits. The hardness of cemented carbide can reach over hrc80, which has high wear resistance, but low bending strength and poor impact toughness. Therefore, if the two are combined organically, the service life of the die can be greatly improved. This paper introduces the method of inlaying cemented carbide in the extrusion die through practical examples, which can effectively improve the service life of the die and provide reference for peers.
2. Selection of cemented carbide

The cemented carbides commonly used are cobalt tungsten (YG), cobalt tungsten titanium (YT), cobalt tungsten tantalum and cobalt tungsten titanium tantalum. The physical and mechanical properties of typical cemented carbide die base steel H13 are shown in Table 1.

| Material | Density (kg/m³) | Hardness (HRC) | Bending strength (MPa) | Modulus of elasticity (MPa) | Coefficient of linear expansion (20~550°C) |
|----------|----------------|----------------|------------------------|----------------------------|---------------------------------|
| YT15     | 14             | 91             | 1180                   | 5.4X10³                    | 6X10⁻⁶                          |
| YG8      | 14.7           | 90             | 2200                   | 6.2X10³                    | 5X10⁻⁶                          |
| H13      | 7.8            | 48             | 1150                   | 210X10³                    | 12.8X10⁻⁶                       |

Therefore, on the one hand, the coefficient of thermal expansion of cemented carbide is small. Compared with the thermal expansion coefficient of tool steel, cemented carbide is much smaller [3]. This should be considered in the design and manufacture of the mould. On the other hand, the elastic deformation and plastic deformation of cemented carbide are very small. This is a good aspect for the mold, but it shows a bad aspect. That is to say, hard alloy is very sensitive to stress concentration in die, which is easy to cause die damage. Therefore, it is not suitable to use cemented carbide for all kinds of aluminum products with various shapes, but it is suitable to use cemented carbide inserts for the simple shape of circular tubes and varieties with large fillets due to the small stress concentration. The base material of the mould is H13 steel. The selection of cemented carbide as inlay material is based on the reason of its high hardness, good wear resistance and good thermal conductivity. The reason why cemented carbide can not be used as matrix material is that it is hard, brittle, poor toughness, low impact toughness and sensitive to stress concentration. The choice of cemented carbide is based on the alloy with cobalt content because the mechanical properties of cemented carbide are mainly determined by the cobalt content and the particle size of tungsten carbide. The higher the cobalt content is, the higher the compressive strength is. Relatively speaking, the wear resistance of the alloy with low cobalt content is more important or significant [4], while that of the alloy with high cobalt content is more important or significant. In the extrusion die, the problem of wear on the die surface should be solved, and the wear resistance of the die should be emphasized. Therefore, YG8 cemented carbide with low cobalt content should be selected. This is totally different from YG15 which has good impact performance in cold stamping die. In addition, the hot wire expansion coefficient of cemented carbide increases with the increase of cobalt content, and the working temperature of extrusion die is about 500 °C. Therefore, in order to avoid the change of profile wall thickness caused by excessive thermal expansion of alloy at high temperature, cemented carbide with low cobalt content should also be selected. Therefore, the thermal expansion of YG8 at high temperature is negligible for the base steel [5].

3. The method of inlaying cemented carbide

3.1 The determination of the size of the female die inlaying hole and cemented carbide

The figure 1 shows the sectional drawing of aluminum section pipe.

In order to improve the wear resistance of the die hole in the female die, the method of inlaying cemented carbide is adopted. Because the working temperature of the die is in the scale from 520 to 540 °C, the coefficient of thermal expansion of the cemented carbide and the die base material H13 is different at this temperature, but it is required that the bonding between the inlaid alloy and the die base must be firm and reliable when working, so the heating and pressing method is adopted. The pressing requirement is to ensure that the single side clearance between the alloy and the inlay hole of the female die is less than 0.02mm at 520-540 °C. At room temperature, the gap between the two is interference fit [6], which can ensure that the cemented carbide does not drop at room temperature.
3.1.1 Processing of cemented carbide
YG8 is selected as the cemented carbide with the thickness of 8mm. Its processing method is to use slow wire cutting. First the inclination of the hole will be cut, then the hole and the shape at one time will be cut, which can ensure the concentricity of the hole and the shape. On the other hand, the size of the bearing can also be ensured to be 3mm.

3.1.2 Processing of female die
The female die and the male die are processed according to the normal process when the alloy is not inserted. After assembly, the male and female dies shall be disassembled again, the female die hole shall be precisely turned according to the cemented carbide size. The dimensional relationship between the two is shown in Figure 2.

Figure 2 the dimension diagram of die inlay hole in the female die and cemented carbide

The dimensional relationship is as follows:

1) $D_1 = 1.01 \times D_0$ (mm)
2) $D_2 = D_1 + 40$ (mm)
3) $D_3 = 0.996 \times D_2$ (mm)

3.2 Heating and pressing of cemented carbide
Put the processed lower die and cemented carbide into the box furnace, slowly heat them to $520 \pm 5 \, ^\circ C$ and keep them warm for 2 hours [7], then put them out of the furnace for quick pressing. In order to ensure the smooth pressing, the cemented carbide can be discharged about 1 minute in advance [8]. After
the press mounting is flat, use a copper hammer to gently tap around the inlay hole of the lower die. Since the depth of the inlay hole is 0.5mm higher than that of the cemented carbide, the beating of the copper hammer can make the edge sink and press the cemented carbide. The assembled lower die is shown in Figure 3.

![Figure 3 the female die with carbide inlaid](image)

4. CONCLUSIONS

At present, the application of cemented carbide in the extrusion die of aluminum profile is in the ascendant. With the characteristics of cemented carbide, its suitable profile varieties still need further study. However, for the applicable profile, the key to inlay carbide in the die is to determine the reasonable size of the die material and the carbide due to the large difference in linear expansion coefficient, and to consider the method of press fitting, so as to give full play to the potential and role of the carbide. The results also show that the wear resistance of the die can be greatly improved and the life of the die can be greatly improved by using the hard alloy.

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