Design of inspiratory linear die-filling system

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Abstract: Powder die-filling is an important process in the process of powder pressing. The effect of mold filling directly affects the subsequent pressing process and ultimately affects the quality of products. During the filling process, the air in the die has an obvious effect on the filling behavior, which seriously reduces the filling efficiency of the powder. Aiming at the influence of air in the process of powder filling, a set of inspiratory linear die-filling system was designed. The system is mainly composed of control module and mechanical module, in which the mechanical module includes two parts: filling device and inhalation device. The iron powder filling trial was carried out by using this system. The movement speed of the shoe was set as 250mm/s. It was found that the filling efficiency of the aspirated filling was improved by nearly 30% compared with that of the gravity filling. The results show that the aspirated die-filling can effectively reduce the influence of air on the powder filling behavior, and improve the filling efficiency of the powder die-filling.

1. Introduction

Tablet press is widely used in powder metallurgy, pharmaceutical and other fields, its work flow can be divided into three stages: die-filling stage, powder pressing stage, discharging stage. The process of powder filling in the powder die-filling stage has a great influence on the later pressing powder, and the uneven filling generated by die-filling will directly affect the pressing powder and the quality of the product [1].

According to the filling mode, the filling system can be divided into four categories: linear filling system [2-3], rotary filling system [4-6], suction filling system [7-9] and forced feeding filling system [10-11]. The filling devices of each filling system are shown in Fig. 1.

Guo et al. [12] found that in the process of powder die-filling, the influence of air on the filling is inevitable, and the presence of air will seriously affect the critical filling velocity of the powder die-filling process and reduce the filling efficiency. In the four filling systems shown in Fig. 1, compared with linear filling, suction filling effectively reduces the influence of air on the powder filling behavior and improves the filling efficiency. However, Mills et al. [6] found in the study that in the suction filling process, the influence of air on filling can be effectively reduced in the initial stage, while in the final stage, air is still inevitably sucked into the mold cavity, so that the air has an impact on filling.
Therefore, the discharge of air inside the die becomes an effective means to improve the filling efficiency. How to effectively discharge the air is the problem that needs to be faced at present.

Aiming at the problem of how to discharge air inside the die, this paper designed and developed a set of inspiratory linear die-filling equipment based on the linear die-filling system and suction die-filling system. This equipment can reduce the influence of air on the filling behavior, made the air inside the die by the method of inhalation in the flow state, and then improve the mold filling effect.

2. Overall structural design

The overall design of aspirated linear die-filling system is shown in Fig.2, which can be divided into control module and mechanical module, and the mechanical module can be divided into two parts: filling device and inhalation device.

The filling device adopts linear filling with fixed die, and the structure of lead screw guide rail drives the shoe to realize linear and round-trip movement. The lead screw guide rail realizes point control through servo motor.

The inhalation device uses an air extractor to pump air, and a filter is added in the inspiratory pipe to prevent the powder from being sucked into the pipe to produce trial error. In addition, the inhalation device also includes a rotor current meter to control the inspiratory size.

In the control module, the servo motor is controlled by PLC, and zero and limit switches are set to ensure the initial position of the filling process is consistent.

2.1. Mechanical module design

The filling device comprises lead screw rail, shoe and die. When the powder is filled, the servo motor
controls the leadscrew rail to drive the shoe to do linear motion. When the shoe moves to the die mouth, the powder in the shoe is filled into the die under the action of gravity and inhalation.

The shoe and die are designed to be flat, long, and straight, which is helpful to observe the flow pattern of powder in the filling process. The shoe and its fastening device are shown in Fig. 3. To facilitate the powder into the shoe, the top of the shoe is designed as a funnel, and the back plate of the shoe is properly extended for fastening with the slider. In addition, to facilitate the observation of the macroscopic characteristics of the powder filling process, the material is made of plexiglass, and the size of the inner cavity of the shoe is designed to be 20×160×200mm.

![Fig. 3 shoe and this fastening devices](image1)

![Fig. 4 die](image2)

Fig. 3 shoe and this fastening devices

Fig. 4 die

Fig. 4 shows the die in the filling device. The bottom of the die is provided with an air vent. If the vent is blocked, the powder is only filled by gravity. If the vent connected with the inhalation device, it is an inhalation filling. Therefore, the results of the two different filling methods can be contrasted to verify the effectiveness of the inspiratory die-filling system. The die material is made of plexiglass, and the flange at the die mouth is easy to fix it on the table. The size of the internal die is 60×20×250mm.

The inhalation device comprises inhalation port, inhalation pipe, filter, and rotor flowmeter. The inhalation port is connected with the pump, through the adjustment of the flow area of the rotor flowmeter can control the size of the inhalation, inhalation pipe, and the bottom of the die between the air vent connected filter, prevent powder inhalation pipe.

2.2. Control system design

In the inspiratory linear die-filling system, the leadscrew rail is the main device of the whole equipment. In order to meet the movement speed of the shoe at 0-1m/s, the motor speed is selected to be 3000r/min. Based on this, Schneider servo motor is selected, whose model is BCH0602012A1C. The power is 0.4KW, the maximum torque is 3.81Nm, and the maximum speed is 5000r/min.
The control system adopts PLC control servo motor to carry out positive and negative rotating motion, and then drives the shoe to carry out linear reciprocating motion. Three infrared sensors are installed at the lead screw guide rail, which are used as the limit switch and zero-point position. When the device is running, it is necessary to confirm whether the shoe is at the zero-point position first, and then the movement speed and movement distance can be set to make the shoe move in a straight line and fill the powder into the die. The system's return to zero process is shown in Fig.5, and the automatic control flow chart is shown in Fig.6.

3. System validity verification

According to Fig. 2, the aspirated die-filling system is established, and the trial device is shown in Fig.7. By comparing the experimental results of gravity filling and inspiratory filling, the effectiveness of inspiratory die-filling system was verified.

The device was used to trial the filling trial of iron powder in the inspiratory die-filling system. The moving speed of the shoe was set as 250mm/s. The bottom of the die should be sealed when filled by gravity. When the shoe pass through the die mouth, iron powder is filled into the die under the action of gravity, and the same conditions are repeated three times.

When the inhalation filling trial is carried out, the inhalation device should be connected to the inhalation port at the bottom of the die. The initial conditions should be consistent with the gravity filling. When the shoe pass through the die mouth, iron powder is filled into the die under the action of gravity and inhalation.
After the end of the trial, the two trial results were compared, and it was found that when the bottom of the die was sealed, that is, there was no inhalation. After the iron powder was filled, there would be splashing phenomenon at the die mouth, which was significantly improved after inhalation, as shown in Fig. 8.

![Gravity filling](image1) ![Inhalation filling](image2)

**Fig. 8 Splashing phenomenon when iron powder is filled**

After the filling, the iron powder filled in the die obtained by gravity filling and inhalation filling was weighed, and the filling mass obtained by gravity filling was about 245g, and the mass obtained by inhalation filling was about 315g. The filling efficiency was improved by nearly 30%. It can be seen that the inhalation die-filling system can effectively reduce the influence of air and improve the filling efficiency, which indicates that the inhalation filling scheme is feasible.

4. Conclusion
In order to reduce the influence of air on the filling behavior in the process of powder die-filling, a set of inspiratory linear die-filling system is designed in this paper. The system uses PLC to control the lead screw guide rail to drive the shoe to do linear motion and uses the rotor flowmeter to control the aspirated size, so as to realize inspiratory die-filling.

The experimental results show that the filling efficiency of the inspiratory die-filling system is 30% higher than that of gravity filling when the speed of the shoe is 250mm/s, which indicates that the inspiratory die-filling system can effectively reduce the influence of air on the filling behavior and improve the filling efficiency.

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