Structural Optimization and Control System Design for a Rake Dryer

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Abstract: Optimization of process parameters and process intelligent control of the production process is an important part of the design and development of drying equipment. This research proposed a new type of jacket and conical screw belt composite heating device dryer, to achieve the material fully turned over, drying layer temperature uniformity, improve the drying efficiency of the material and energy efficiency. We design the humidity and temperature control system of the dryer for the overall design based on the PID, and optimise the drying control method, to ensure that the quality of the material drying, and to improve the automation and production efficiency of the equipment. The study helps to determine the process parameters of the material production process and improve the stability and quality of the product.

Keywords: Grain Drying; Process; Process Control; PID

1. Introduction

Drying technology and equipment is the equipment for the development of high-tech industry and cutting-edge industrial base. In recent years, with the rapid development of China's industrial and agricultural production, the demand for drying equipment is growing, and the overall level of drying equipment is also improving. After years of development, it has begun to enter a more mature stage, and can better meet the actual needs of users in various fields.

Vacuum dryer is an important member of the drying equipment, which removes the moisture of the material in the container by pumping away the air inside the container to reach a predetermined vacuum degree. When drying, the tank is in a vacuum state, the jacket is heated by hot water (or steam or heat-conducting oil), the material is constantly turned over in the tank and absorbs heat to evaporate, and the water vapor is continuously discharged through the vacuum pipeline, so as to achieve the purpose of drying the material. Vacuum drying greatly reduces the boiling point of the liquid to be expelled, and can be easily applied to heat-sensitive materials, eliminating the possibility of explosion of oxides in contact with heat. Compared with ordinary drying relying on air circulation, the powdered samples will not be blown or moved by the flowing air.

The designed harrow dryer is a common, intermittent motion drying equipment, commonly used to transform materials from liquid or suspension to solid. The screw belt harrow dryer is a new type of batch-produced drying equipment suitable for a wide range of materials with a higher drying rate developed on the basis of the harrow dryer by combining the heat transfer drying principle of the hollow paddle dryer. Stirring component includes spindle and more than one screw belt, screw belt is spiral shape around and set in the spindle on the outside, screw belt near the wall of the inner cylinder, screw belt with rake teeth, rake teeth and the inner wall of the inner cylinder with a gap between the mixing process at the same time heating and drying and axial and radial reciprocating mixing effect, so that the degree of drying of the material to become more uniform. Due to the built-in rake teeth and screw belt and use, so that the material in the stirring slurry turning, the relative speed of the material and the heat transfer wall of the dryer to accelerate the contact, the heat transfer rate is increased, in favor of the evaporation of moisture. To achieve

its drying uniformity, high vacuum, to avoid cross-contamination, easy to operate the process of easy to get started as well as the ability to deal with granular, powder, block and other different forms of materials and many other advantages, rake dryer has been widely used in the pharmaceutical, chemical, food processing and metallurgical industries.

2. Working Principle of Harrow Dryer

Harrow dryer in the operation process, through the feeding device will be a large number of raw materials to be dried into its internal. After entering the interior, through the repeated action of positive and negative rotation of the rake teeth, the raw materials in which the continuous turning and heat, so that the water contained in it gradually evaporate, so as to achieve the de-watering and drying of raw materials. Among them, the heat transfer medium in the heat exchange device is generated by the burner or heater inside the harrow dryer, and is sent into the equipment through the special exchange cylinder. Heat transfer medium and raw materials after turning the repeated indirect contact for heat exchange, not only can improve the evaporation rate of water in the raw materials, to avoid hot gas or hot oil and other pollution of raw materials, and turning the process makes the raw material heat more uniform, the degree of drying of the finished product is more uniform in all parts of the finished product, and at the same time avoid the raw material overheating problems.

After separating the raw material from the moisture, the water vapor and moisture are quickly removed from the dryer through a special exhaust system such as a dust collector, thus ensuring the drying effect of the raw material and preventing the water vapor from re-contaminating the solid finished product. It is worth noting that the raw materials need to be kept inside the rake dryer for a period of time, according to the different moisture content of the raw materials and the need to achieve the degree of dryness, the holding time varies. Finally, the raw material is discharged from the material outlet to obtain the desired finished product.

3. Disadvantages of the Traditional Harrow Dryer

Harrow dryer, due to its good sealing without cross contamination, uniform drying of the finished product, can deal with a wide range of raw materials, in the traditional industrial field has been widely used in the field of environmental protection at the same time also has a certain degree of use, for example, Xu Jianru et al. will be used in the drying of organic waste, for the separation of composite fertilizer [1]. However, a good vacuum degree also means that the whole equipment has a high degree of sealing requirements, such as unreasonable packing material selection and size manufacturing defects, etc. can easily lead to insufficient vacuum degree of the equipment [2]. Similarly, the rake teeth can also lead to sealing problems. In view of the abnormal scraping between the rake teeth and the inner wall, which leads to the failure of the packing seal between the mixing shaft and the end cap, Fan Haijun et al. analyzed the main reasons and proposed control measures, and also pointed out the need to control the deflection of the mixing shaft to avoid the scraping of the inner wall affected by the thermal expansion of the rake teeth [3].

Usually, in order to ensure the sealing of the stirring shaft and the shell, the structure of the hollow shaft is adopted, and the hollow rake teeth are welded on the stirring shaft, and these lead to a certain extent to the problem of deformation, bending and fracture easily on the stirring shaft. For this reason, Xie Yilin et al. analyzed the mechanism of fracture failure of the shaft of a 12m3 rake dryer and found that the fracture was related to the stress concentration phenomenon at the shaft weld [4]. While Xiangyu Li carried out dynamic response analysis and numerical simulation of the stirring shaft, and analyzed the effect of temperature field and cyclic fatigue on the stirring shaft [5].

The structure of the striking bar also affects the cylinder, stirring shaft and rake teeth, such as causing insufficient sealing of the equipment, easy deformation of the shaft and easy fracture of the rake teeth, especially for some special raw materials. Guo Ailian et al, for the traditional rake dryer in the treatment of easy to slate materials, the knock bar structure is easy to shaft thrust direction of the lateral shear force, resulting in deformation of the knock bar fatigue fracture, which affects the sealing and normal use of the chain instead of the original knock bar, to avoid the normal use of the problem caused by the fracture as well as the sealing problems caused by the impact of the chain [6].

In addition to the problem that the vacuum

degree is easily affected by the deformation and fracture of the rake teeth, stirring shaft and knockout bar, the rake dryer also has the problem of large energy consumption and insufficient use of heat energy. Because the steam, hot air and hot water in the heat exchange device are usually used at one time, resulting in a large amount of energy waste. For this reason, He Deqiang developed a new type of harrow dryer, which adopts a folded jacket structure to make the hot water flow through the jacket more evenly heated, while the use of a special runner-type hot shaft to improve the heat transfer effect of the hot shaft, and between the end cover and the hot shaft designed a new type of double sealing structure, to solve the problem of leakage of materials and foreign objects. Chen Hai, on the other hand, used MVR technology to design an MVR-rake dryer, using a steam compressor, the secondary recovery of steam is fully compressed and recycled as a new heating heat source, to achieve the purpose of complete recovery of latent heat as well as energy-saving effect [8].

4. Structural Design of New Harrow Dryer

The structure of the harrow dryer is shown in Figure1.

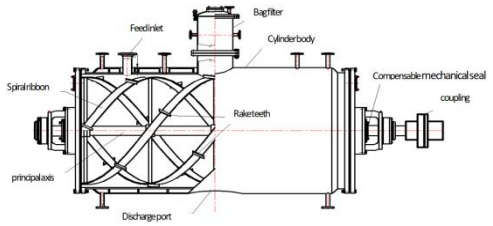

Figure 1. The Main Structure Sketch of Rake Screw Belt Vacuum Dryer

Figure 2. Physical Mixing Device

The shell of rake dryer mainly consists of two parts: jacket and cylinder, the cylinder plays the role of supporting other structures, while the cylinder can pass hot air, hot oil, hot water, for the indirect contact between raw materials and heat transfer medium, which is convenient for the two to be next door to each other and heat exchange. The research proposes a new type of dryer with jacket and conical screw belt composite heating device, which achieves full turning of materials, uniform temperature of drying layer, and improves the drying efficiency of materials and energy utilization; the energy efficiency measurement and calculation system is designed, and the drying control method based on energy optimization is realized.

The torque is transmitted to the mixing shaft by the transmission mechanism, and several left and right rake teeth are installed on the mixing shaft. The material to be dried is added from the upper part of the equipment, and under the stirring of the rotating rake teeth, the material is lifted up in the circumferential direction and then falls down, and at the same time, it keeps moving forwards or backwards in the axial direction, and the material in the tank is circulated and pushed away, and the wall of the cylinder and the stirring system of the heating medium are exchanged, so that the solvent can be evaporated quickly from the material to achieve drying purpose.

These rake teeth are used to turn the raw material forward or backward, allowing the raw material to move through the various spaces of the cylinder (center or top and bottom) so that it can make full contact with the clamping cylinder. The speed and duration of rotation of the mixing shaft are determined according to the type of raw material, its moisture content and the degree of dryness required for the finished product, etc. After mixing, the raw material ensures that the moisture in all its parts evaporates fully and uniformly.

In addition, the design of auxiliary settings knock stick, knock stick is generally placed in parallel with the position of the mixing shaft, usually equal length with the cylinder, play a role in clearing raw materials. For example, some drugs after drying the finished product is easy to pile up adhesion in the rake teeth or cylinder wall, it can be crushed with a percussion rod, then to facilitate the clearance of the residual material inside the equipment. Sealing structure is the more important structure of the whole device, because the vacuum of the device will affect the vacuum of the device, and

directly affect the quality of the output of the finished product, and even contamination of the finished product. For example, if the mixing process, due to vacuum problems make part of the outside air into the device, will make the moisture content of the finished product has been dried to rise rapidly, and the impurities in the air will contaminate the finished product.

5. Control Design of New Harrow Dryer

The PID control system is mainly composed of a controller part, a sensor part, an actuator, and an input and output interface. The control system block diagram is shown in Figure 3 .

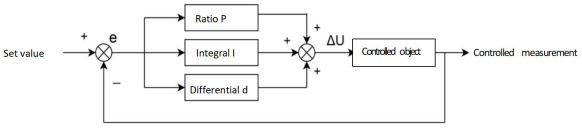

Figure 3. Block Diagram of PID Control System

PID control is a superposition of deviation, integral of deviation over time and differential of deviation over time. They are proportional control, integral action and differential output respectively. In analogue control, the mathematical expression for PID control is as follows:

$$U = P(e + \frac{1}{I}\int_0^t edt + D\frac{de}{dt}) + U(0) \quad (1)$$

Where, U - controlled quantity; P - proportionality coefficient; I - integral time constant; D - differential time constant; e - deviation; U(0)-the controlled quantity when the deviation is zero.

By choosing appropriate proportionality coefficients, integration times and differentiation times according to the characteristics of the controlled system, the static-free PID control, which is the most widely used in analogue control and solves the problems of stability, speed and accuracy of control, is obtained.

Using the above control design, the moisture of the material and the temperature of the heat conduction medium were PID design. Among them, it is to compare the actual measured value of the moisture content of the material produced with the target pre-set value, to compare and analyse the temperature before and after the heat-conducting medium, and to exceed the pre-set value, to carry out control interventions until it reaches the pre-set expected value.

6. Conclusion

For the traditional vacuum harrow dryer heat transfer area is small, low yield, and the shaft is solid, the internal can not pass into the heating medium and so on, the research proposes a new type of jacket and conical screw belt composite heating vacuum harrow dryer, through the setting of the hollow shaft, pass into the heat transfer medium, increase the contact area of the material when heated, shorten the drying time, increase the yield, improve work efficiency, solve the existing vacuum harrow dryer Solve the existing vacuum harrow dryer with small heat transfer area and low output.

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