Optimization Design Research of a Filtering, Washing, and Drying Three in One Dryer

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Abstract: In response to the contamination of active pharmaceutical ingredients in the pharmaceutical process, it is difficult to meet safety requirements Technical difficulties such as FDA and drug GMP requirements. Most manufacturers have vague positioning when it comes to equipment functional requirements, resulting in phenomena such as insufficient or excessive equipment functionality. A new type of "three in one" equipment has been developed, which integrates filtering, washing, and drying functions. Starting from the working principle of the equipment, the design, structural type, control, etc. of the equipment have been optimized to achieve intelligent production of the dryer and meet the GMP requirements of the pharmaceutical industry. The equipment is fully enclosed, automated, completely isolated from people and materials, and has wide adaptability. It is the preferred equipment for processing high toxic and highly active products, providing a certain reference and reference for the development, design, and application of new centrifuges.

Keywords: "Three in One" Equipment; Optimize Design; Drying Machine; GMP

In order to avoid pollution during the drying process of raw materials, a drying equipment that integrates functions such as loading and unloading, filtering, drying, and washing, and can work continuously is needed. The three in one dryer (i.e. filter washing dryer) is widely used in fields such as medicine, chemical industry, and food that require solid-liquid separation, washing, and drying quality requirements due to its advantages of simple operation, environmental protection, high degree of automation, and small footprint.

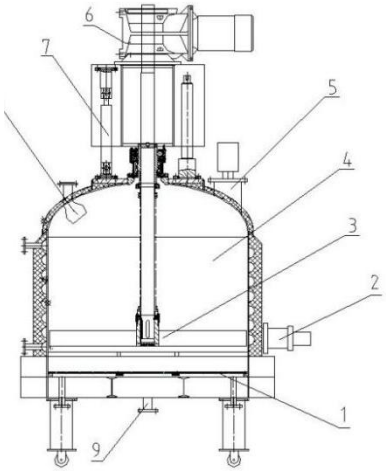
1 The Principle of a Three in One Dryer

Filtering, washing, and drying are very important unit operations in industries such as chemical, pharmaceutical, and food. They are generally completed by multiple equipment such as filters, pulping tanks, and dryers. The operation of a three in one dryer generally consists of three steps: filtration, washing, and drying. In order to achieve high-quality filtration of solid-liquid mixtures, the three in one dryer cleverly utilizes gas pressurization, effectively utilizing the combination of pressure difference and porous filtering media to achieve precise separation of solids. This filtering method not only improves filtration efficiency, but also ensures filtration accuracy, thus meeting the high-quality filtration needs in various industrial applications.

1.1 Filtering Process

The selection of pressurized gas is crucial in the filtration process of a three in one dryer. Common pressurized gases include compressed air and inert gases. Compressed air is widely used in various filtration scenarios due to its wide range of sources and low cost. However, in certain special circumstances, such as handling flammable, explosive, or oxidizing materials, compressed air may pose safety hazards. Therefore, in these situations, inert gases such as nitrogen and argon become more suitable choices. They not only have stable chemical properties, but are also less likely to react with materials, ensuring the safety of the filtration process. Gas pressure is another key factor affecting filtration efficiency. The magnitude of

pressure directly determines the filtration speed and filtration accuracy. Generally speaking, the higher the pressure, the faster the filtration speed, but it may also cause deformation or damage to the filtering medium, thereby affecting the filtration accuracy. Therefore, when setting the pressure, it is necessary to comprehensively consider the characteristics of the mixture, the performance of the filtering medium, and the required filtration accuracy. By adjusting the pressure reasonably, the three in one dryer can achieve high-precision solid-liquid separation while ensuring filtration efficiency.



1. Filtering device; 2. Discharge device; 3. Mixing device; 4. Tank body; 5. Dust capture device; 6. Transmission device; 7. Hydraulic system; 8. Washing device; 9. Drainage device

Figure 1. Structural Diagram of Multifunctional Filtering and Drying Equipment

Fig.2 Schematic Diagram of the Overall Structure of the Equipment

Filtering accuracy is one of the important indicators for evaluating filtering effectiveness. It determines whether solid particles can be effectively intercepted during the filtration process. In practical applications, the selection of filtration accuracy needs to be balanced based on the particle size distribution of raw materials and the requirements of filtration rate. If the accuracy is too high, although it can effectively intercept smaller particles, it may cause blockage of the filtering medium, thereby reducing the filtration efficiency; If the accuracy is too low, although it can improve the filtering speed, it may lead to excessive particle loss and affect product quality. Therefore, when setting the filtration accuracy, it is necessary to fully consider the characteristics of raw materials and production needs to achieve the best balance between filtration efficiency and filtration accuracy.

In addition, the three in one dryer also focuses on optimizing the selection of filtering media during the filtration process. As a key component of solid-liquid separation, the material, pore size, and structure of the filter medium have a significant impact on the filtration effect. In order to meet the filtration needs of different materials, the three in one dryer adopts various types of filtration media, such as metal mesh, ceramic membrane, polymer materials, etc. These filtering media each have their own characteristics and can be selected based on the material characteristics. At the same time, regular cleaning and replacement of filter media are also important measures to ensure the stability of filtration effect.

In practical applications, the gas pressure filtration technology of the three in one dryer has shown significant advantages. It can not only efficiently separate solid particles from the mixture, but also flexibly adjust pressure and accuracy based on material characteristics. This has made the three in one dryer widely used in various fields such as chemical, food, and pharmaceutical. By continuously optimizing and improving filtration technology, the three in one dryer will continue to provide high-quality filtration solutions for industrial production.

By using gas pressure, the three in one dryer achieves high-quality filtration of solid-liquid mixtures. In terms of selecting pressurized gas, adjusting pressure, and setting filtration accuracy, the three in one dryer has demonstrated a high degree of flexibility and adaptability. This enables it to perform excellently in various industrial scenarios, providing strong guarantees for the smooth progress of the production process. The washing process adopts a special spray device, which is divided into fixed and rotating types, which can fully wash the filtered solid. After the solid

enters, the uniform distribution of the cleaning liquid inside the tank of the equipment is achieved through the rotation and axial movement of the blade, in order to fully wash the impurities adhered to the surface of the grain solid that have not been completely separated. Select the corresponding washing solution and cleaning frequency according to the requirements of the process and the characteristics of the raw materials.

1.2 Drying Process

The drying process of a three in one dryer has its unique features compared to traditional dryers. It cleverly combines vacuum and hot air drying methods to meet the needs of different materials. When dealing with easily oxidizable or heat sensitive raw materials, vacuum drying becomes the preferred choice. This is because in a vacuum environment, the oxygen content is extremely low, which can effectively prevent the oxidation of raw materials. At the same time, a low-temperature environment can also protect the thermal sensitivity of raw materials.

The setting of heating temperature is crucial for the drying effect. Thermally sensitive raw materials require strict control of heating temperature to avoid damage or qualitative changes. For other raw materials, increasing the heating temperature appropriately can accelerate the drying process and improve production efficiency. In addition, the length of heating time is also a key factor affecting the drying effect. The drying speed may vary depending on the structural shape of the raw materials. For raw materials with complex structures and large surface areas, it is necessary to extend the heating time appropriately to ensure sufficient drying inside. By precisely controlling the heating temperature and time, the three in one dryer can achieve high-quality drying of raw materials while maximizing the preservation of their original properties.

1.3 Washing Process

By using a specially designed washing mechanism, the cleaning solution is evenly distributed inside the three in one filter to ensure a good cleaning effect as much as possible. And under the stirring and mixing action, the filter cake and washing solution can be fully mixed, forming a slurry like suspension, and the filter cake can be fully washed. And users can choose the number of washes based on the separation of materials.

2. Defects of Traditional Three in One Dryer

The three in one dryer has been widely used in chemical, pharmaceutical and other fields due to its unique design concept and functional combination. This device can achieve automatic filtration, washing, drying, and discharge of the entire process sealing, effectively solving a series of problems in the use of traditional equipment.

Firstly, the combination of traditional single function equipment usually occupies a large space, while the three in one dryer achieves multi-functional integration, greatly reducing the equipment footprint and improving the utilization of production space. Secondly, due to the easy leakage and pollution at the connection points between traditional equipment, the fully sealed design of the three in one dryer effectively avoids these problems, ensuring the purity of the product and the safety of the production environment. In addition, the improvement of automation level also makes the production process smoother and reduces the interference of human factors.

However, no device is perfect, and the three in one dryer also has some undeniable drawbacks. Its complex structure makes the equipment prone to sealing problems. For example, to ensure the normal operation of the filtration device, a certain safety gap is usually set between the blades and the filter screen. But this design can also easily lead to residual raw material powder on the filter screen, increasing the difficulty of cleaning. In addition, long-term use of dry double-sided mechanical seals may cause damage to the sealing components, leading to leakage. Bellows may also leak under long-term compression, which requires regular maintenance and replacement. During the discharge process, if the sealing performance of the equipment is poor or the operation is improper, leakage problems may also occur. This not only affects the quality of the product, but may also cause pollution to the production environment. Therefore, for the use and maintenance of the three in one dryer, it is necessary to strictly follow the operating procedures and conduct regular inspections and maintenance to ensure the normal operation of the equipment and the smooth progress of production.

Although the three in one dryer has many

advantages, there are also some shortcomings that we need to pay attention to and solve during use. For special occasions such as aseptic production processes, there are also high requirements for the blades of the mixing shaft. For example, in order to ensure that the blades do not adhere to the raw materials, it is necessary to make the complex curved blades smooth enough, and their shape needs to ensure special angles to evenly roll the raw materials and ensure normal washing and drying. At the same time, special devices are equipped to keep them flat and timely scrape off the raw materials, which makes the manufacturing and processing of the blades difficult .

When dealing with solvent crystallization raw materials, the three in one dryer has been widely used due to its multifunctional and integrated design. However, some problems have also been exposed in the actual production process, such as low drying efficiency, residue, leakage, and the need for manual intervention. In order to solve these problems, many engineers and scholars have conducted in-depth research and improvement, among which the new flipping multifunctional filtering, washing, and drying machine designed by Liu Guangtao is an important attempt.

The new flipping multifunctional filtering washing and drying machine has been specially designed for the drying station and discharge station of the traditional three in one dryer. At the drying station, by fully contacting and drying the raw materials through transfer, not only does it increase the contact area between the raw materials and hot air, improve drying efficiency, but it also reduces the residue of the raw materials during the drying process. This design is particularly effective for solvent crystallization raw materials, as these materials often have difficulties in uniform drying. At the discharge station, the new machine utilizes the gravity of the raw materials to automatically discharge, avoiding the problem of manual intervention required by traditional three in one dryers. This not only reduces the difficulty of operation and labor intensity, but also reduces production errors caused by human factors. In addition, the design of automatic discharge also improves production efficiency, making the entire production process smoother and more efficient.

In addition to improving the equipment structure, upgrading the control system is also an important way to improve the performance of the three in one dryer. The traditional three in one dryer control system often can only achieve the generation of a single, large batch of raw materials, which is difficult to meet the requirements of personalized and small batch generation in modern production. To solve this problem, Dong Bin designed a flexible drying machine system.

The core control equipment of the system adopts Siemens S7-300 PLC, which is a high-performance and reliable industrial control equipment that can meet the needs of complex control logic and precise control. Based on a flexible control strategy, Dong Bin wrote control programs for multiple functions and unit processes of the dryer. These programs can flexibly adjust parameters such as the type of raw materials and production batch to meet personalized and small batch production needs. In terms of control program writing, Dong Bin not only utilizes the powerful functions of S7-300 PLC, but also combines S7-GRAPH graphical programming language to make control logic more intuitive and easy to understand. At the same time, through the WinCC upper computer monitoring software, operators can monitor the operating status and production data of the dryer in real time, and timely discover and handle problems during the production process. The application of flexible drying systems not only improves production efficiency and product quality, but also reduces production costs and energy consumption. It enables the three in one dryer to better meet the needs of modern production and create greater value for enterprises.

In summary, engineers have proposed a series of effective solutions to the problems encountered by the three in one dryer in processing solvent crystallization raw materials through equipment structure improvement and control system upgrade. The implementation of these plans not only improves the performance and production efficiency of the dryer, but also provides strong support for the sustainable development of the enterprise.

3. Design and Improvement of Key Parts of the Three in One Dryer

The three in one dryer, as an integrated drying equipment, plays a crucial role in the treatment of solvent crystallization raw materials. However, due to its more complex structure

compared to traditional dryers, it also brings a series of issues that need attention and improvement. The structure of a three in one dryer mainly includes multiple parts such as the main body of the dryer, discharge device, mixing device, heating and drying device, filtering device, lifting device, sealing device, spraying device, transmission device, and electromechanical control system. Each part carries specific functions and together constitutes this efficient and complex equipment.

Firstly, the main body of the dryer is usually welded from the cylinder and the head, forming a closed space for accommodating the raw materials to be dried. The cylinder is generally made of high-temperature and corrosion-resistant materials to ensure that it can withstand high temperature and chemical erosion during the drying process. On the head, various process joints are installed, which are designed according to specific process requirements. For example, the mixing shaft interface is used to connect the mixing device, the feed port is used to add raw materials to the dryer, the cleaning solution interface is used to introduce cleaning solution to clean the equipment, the pressure gauge port is used to monitor the internal pressure of the equipment, the spray head interface is used to install a spray device to wet or wash the raw materials, and the safety valve is used to automatically release pressure when the internal pressure of the equipment is too high, ensuring equipment safety.

The discharge device is another important component of the three in one dryer, which is responsible for discharging the dried raw materials from the dryer. The design of unloading devices usually takes into account the characteristics of raw materials and production needs, in order to achieve an automatic, fast, and complete unloading process. Common discharge devices include valve type discharge devices and rotary discharge devices, which can choose appropriate discharge methods based on the particle size and flowability of raw materials.

The mixing device is a key component in a three in one dryer to achieve uniform mixing and dispersion of raw materials. By rotating the mixing shaft, the mixing device can thoroughly mix and flip the raw materials inside the dryer, thereby improving drying efficiency and quality. The design of the mixing device usually takes into account the characteristics of the raw materials and the requirements of the drying process to ensure that the raw materials can be uniformly heated and dried during the drying process.

The heating and drying device is the core part of the three in one dryer, which is responsible for providing the heat required for drying. The heating and drying device usually consists of a heat source, a heat exchanger, and a control system. The heat source can be steam, electric heating, or gas, etc. The heat is transferred to the raw materials inside the dryer through a heat exchanger to achieve the purpose of drying. The control system is responsible for precise control of the heating and drying device to ensure the stability and efficiency of the drying process.

The filtering device is used to filter the raw materials during the drying process to remove impurities or particles. This helps to improve the purity and drying effect of the raw materials. The design of filtration devices usually takes into account the characteristics of raw materials and the requirements of filtration efficiency to ensure effective removal of impurities and maintain the normal operation of the dryer.

The lifting device is used to adjust the height and position of the main body of the dryer to adapt to different production environments and operational needs. Through the lifting device, it is convenient to install, maintain, and inspect the dryer.

The sealing device is a very important part of the three in one dryer, which ensures the sealing of the dryer during operation, prevents the leakage of raw materials and the entry of external impurities. The design of sealing devices usually takes into account factors such as the working pressure and temperature of the dryer to ensure its good sealing performance and durability.

Spray devices are used to wet or wash raw materials during the drying process, which helps improve the drying effect of raw materials and enhance product quality. Spray devices are usually designed based on the characteristics of raw materials and process requirements to ensure uniformity and effectiveness of spraying.

The transmission device is the connection and transmission part between the various components in the three in one dryer, which is responsible for transmitting power to the various devices, so that they can work together. The design of transmission devices usually considers the smoothness and reliability of equipment

operation to ensure the smooth progress of the entire drying process.

The vacuum drying part is the core technical link in the three in one dryer, which is mainly composed of a vacuum pump and a vacuum valve. Through precise control and coordination of the electronic control system, it ensures the smooth progress of the drying process. The function of a vacuum pump is to create a low-pressure environment inside the dryer, allowing water to quickly evaporate at lower temperatures, thereby achieving efficient drying of raw materials. The vacuum valve plays a role in controlling the internal vacuum degree of the dryer. By adjusting its opening, the pressure inside the dryer can be precisely controlled to meet the drying needs of different raw materials.

In summary, as an integrated drying equipment, the three in one dryer has a complex structure but powerful functions. Through in-depth understanding and optimization of its various components, the performance and production efficiency of the equipment can be further improved to meet the needs of modern chemical production. The mixing device mainly consists of a mixing power device (motor and reducer), a sealing structure, a mixing shaft and blades, etc., which play a role in mixing raw materials. In the pharmaceutical industry, in order to meet GMP requirements, a dry mechanical sealing structure with both ends is generally adopted, and a corrugated pipe protective sleeve is set outside the main shaft to effectively isolate the shaft from the raw materials and prevent foreign objects from entering and causing pollution. According to actual needs, there are two types of mixing shafts: solid and hollow, which are controlled by the electromechanical system for forward and reverse rotation as well as up and down reciprocating motion. When rotating forward, thoroughly stir the raw materials to make them more uniform; When reversing, flatten the raw material by squeezing. Among them, the hollow stirring shaft can pass through the heating medium to heat and dry the raw materials. Similarly, according to the type of shaft, propeller blades can also be divided into solid and hollow types, and their shapes can be divided into S-shaped and flat propellers. For example, when there is a requirement for sterility, an S-shaped hollow structure propeller is generally selected.

At the pressure gauge on the head, the operator can conveniently check the pressure inside the dryer. This design not only facilitates real-time monitoring by operators, but also provides convenience for equipment maintenance and upkeep. By observing the reading of the pressure gauge, the operator can determine whether the working status of the vacuum system is normal. If there are abnormalities, they can be dealt with in a timely manner to avoid adverse effects on the drying process.

The filtering device is another important part of the three in one dryer, which consists of a filtering medium and a bottom support structure. The selection of filter media has a decisive impact on the filtration effect. According to the characteristics of the raw materials and filtration requirements, different filter media can be selected, such as filter cloth, metal sintered plate, and metal filter screen. These filter media have different pore sizes and filtration accuracies, which can effectively remove impurities and particles in the raw materials and improve the purity of the product.

The bottom support structure adopts a non dead angle GMP design, ensuring the stability and reliability of the filtration device. The design without dead corners can effectively avoid the formation of dead corners during the filtration process, thereby improving the filtration efficiency and quality. Meanwhile, GMP design also meets the production requirements of the pharmaceutical and food industries, ensuring the safety and hygiene of products.

Most sprinkler devices use a rotating sprinkler head that can rotate 360 degrees. This design allows the sprinkler head to evenly spray cleaning solution or wetting agent into the interior of the dryer, thereby achieving uniform wetting and washing of raw materials. The rotary sprinkler head has the advantages of wide spraying range and good spraying uniformity, which can ensure that the raw materials are fully pretreated before drying, improve drying efficiency and product quality.

4. Design of Control System for Three in One Dryer

The electromechanical control system is the "brain" of the three in one dryer, responsible for controlling and monitoring the entire equipment. The electromechanical control system includes an electrical control cabinet and hydraulic/pneumatic control devices. Through programming and setting, it can accurately control and manage the operating parameters,

process flow, and fault information of the dryer. This enables operators to conveniently monitor the operational status of the equipment, promptly identify and address potential issues, ensuring the stable operation and production efficiency of the equipment.

The control system of the three in one dryer is undoubtedly the "brain" of the entire equipment, playing a crucial role in automated operation, precise control, and optimized management. This advanced system deeply integrates modern control algorithms, sensor technology, and an intuitive human-computer interaction interface, enabling the entire drying process to be carried out in a stable, efficient, and safe state.

The application of control algorithms makes the operation of the three in one dryer more precise. It can automatically adjust parameters such as temperature, humidity, and wind speed according to the different characteristics and drying needs of materials, ensuring the best drying effect. Sensor technology provides real-time feedback to the system, allowing devices to constantly understand their own operating conditions and make corresponding adjustments. The design of the human-computer interaction interface not only makes the operation simpler and more intuitive, but also enables users to understand the various parameters of the drying process and the operating status of the equipment at any time, facilitating timely management and adjustment. The control system of the three in one dryer is an important guarantee for its stable operation, efficient work, and safe operation, providing strong support for modern production.

The data acquisition module is responsible for real-time collection of temperature, humidity, flow rate and other parameters during the drying process, and transmitting the data to the control algorithm module for processing. The control algorithm module calculates corresponding control instructions based on preset process requirements and real-time data, and outputs them to the executing mechanism through PLC. The human-computer interaction module provides a friendly operating interface, making it convenient for users to set parameters, monitor status, and handle faults.

The hydraulic/pneumatic control system and electrical control system (often using PLC) are the core control components of the three in one dryer. The hydraulic/pneumatic control system is responsible for driving the lifting and rotation of the mixing shaft, as well as the lifting and lowering of the chassis, to ensure the uniform mixing and dispersion of raw materials during the drying process. The electronic control system achieves precise control of the entire drying process through PLC, including automatic loading and unloading of materials, control of heating and drying temperature and time, automatic cleaning, and other functions. The introduction of PLC greatly improves the automation level of equipment, reduces the difficulty and error of manual operation, and improves production efficiency and product quality.

The electronic control system plays a crucial role in the automatic separation, filtration, and drying process of raw materials. Through precise programming and sensor monitoring, the electronic control system can achieve automatic identification and separation of raw materials, adjust drying parameters according to the characteristics and drying requirements of the raw materials, and achieve the best drying effect. At the same time, the electronic control system also has fault diagnosis and self-protection functions. In case of abnormal situations, it can quickly cut off the power or take corresponding protective measures to ensure the safe and stable operation of the equipment.

In addition, the three in one dryer is equipped with a chain protection mechanism to ensure personnel safety and equipment stability during equipment operation. For example, when a certain part of the equipment malfunctions or is abnormal, the interlocking protection mechanism will automatically trigger, causing the equipment to stop running or take corresponding protective measures to prevent the fault from expanding or causing more serious consequences. This design greatly improves the safety and reliability of the equipment, providing strong guarantees for the smooth progress of the production process.

5. Conclusion

A highly efficient, stable, and safe drying system is composed of key components such as vacuum drying section, filtration device, spray device, hydraulic/pneumatic control system, and electrical control system (including PLC). The precise coordination and collaborative work of these components enable the three in one dryer to achieve efficient drying and separation of raw materials, improve production efficiency and

product quality, while also reducing production costs and energy consumption. At the same time, the system also has automatic fault diagnosis function, which can timely alarm and indicate the fault location when a fault occurs, making it easy to quickly troubleshoot. In terms of safety and reliability design, multiple safety protection measures have been adopted, including over temperature protection, overload protection, undervoltage protection, etc. The system is equipped with comprehensive monitoring functions, and various parameters of the drying process and the operating status of the equipment can be viewed in real time through the interface. The fault diagnosis module can automatically determine the possible types of faults based on the collected data and analysis results, and provide corresponding handling suggestions. In practical applications, the three in one dryer has been widely used in industries such as pharmaceuticals, chemicals, and food, becoming one of the indispensable and important equipment in the production process

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