REVIEW ON SPRAY DRYING TECHNOLOGY

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ABSTRACT

Spray drying is an important unit operation in manufacturing process for powders. It is also a challenging one involving a complex balance between production costs and product quality. Spray drying is the process of contacting an atomized stream to be dried with a gas stream that is at a higher temperature than the liquid stream. The higher temperature of the gas stream causes evaporation of the liquid from the droplets, forming particles. In spite of such a variety of applications, the mechanisms of spray drying to form particles is not completely understood. One of the reasons for this is that the spray drying process, characterized by rapid and simultaneous heat and mass transfer between the droplets of the feed solution and the heating gas, is complex to describe in a mathematical model as many of the model parameters are not readily measurable.

Key words: *Spray Drying, Different Types of Spray Dryer, Recent Advancement in Drying,*

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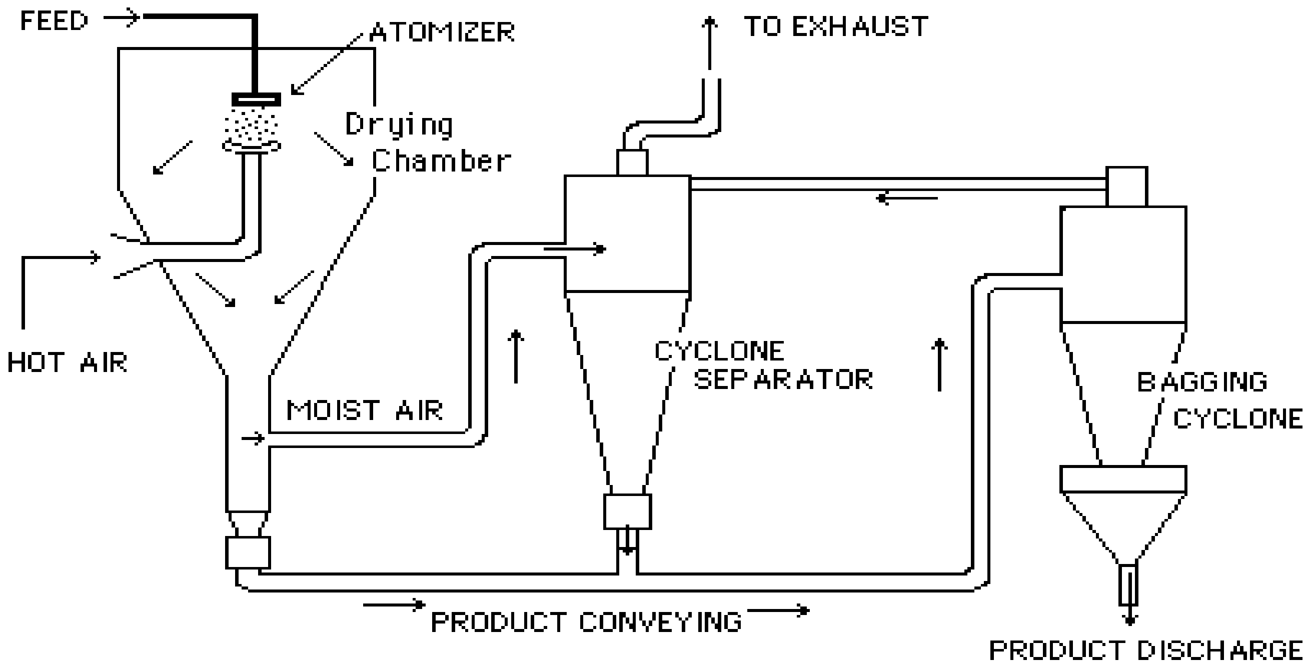
1. Introduction

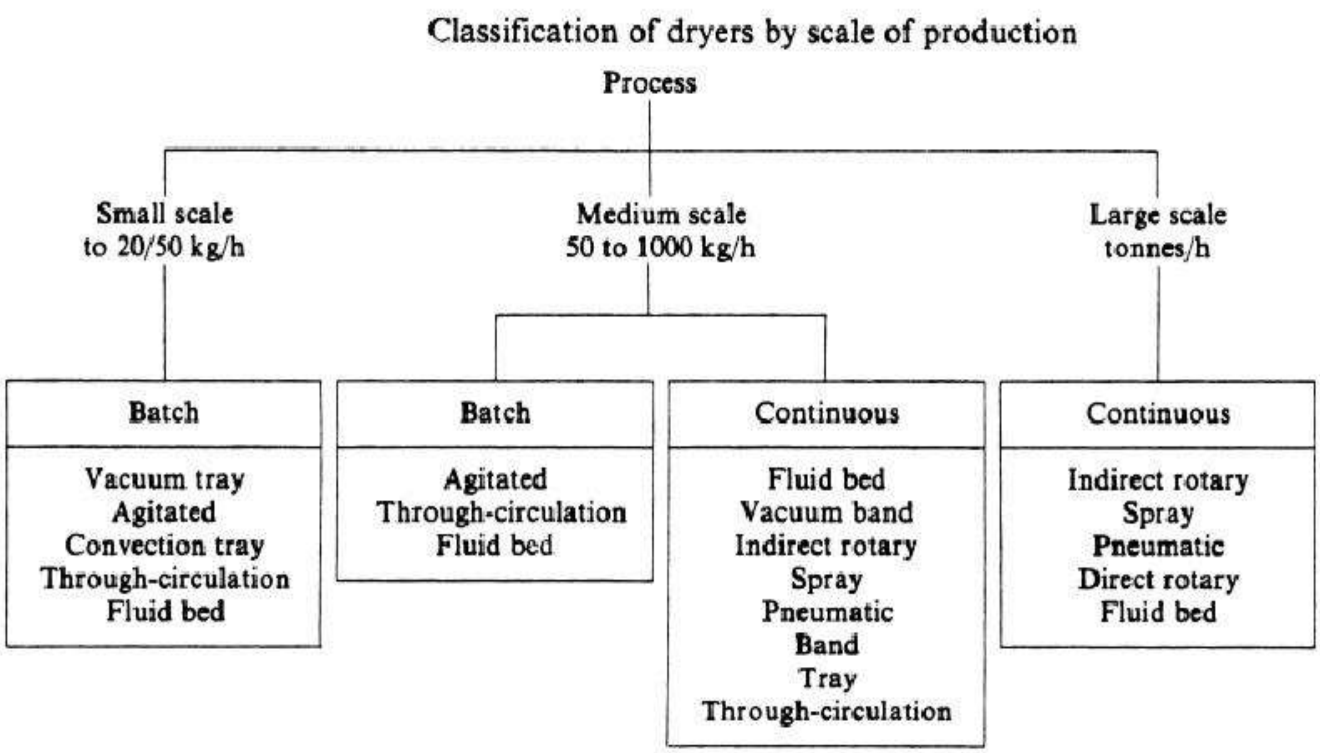
Spray drying is the process of contacting an atomized stream to be dried with a gas stream that is at a higher temperature than the liquid stream. The higher temperature of the gas stream causes evaporation of the liquid from the droplets, forming particles. Spray drying has been used extensively in the food industry for example the manufacture of milk powder; the pharmaceutical industry to form powders for palletization [1] [2]; and the agricultural industry to produce different granular materials, to name a few examples. Recently, the use of this process to manufacture hollow, micron and sub-micron particles has also been demonstrated. In spite of such a variety of applications, the mechanisms of spray drying to form particles is not completely understood. One of the reasons for this is that the spray drying process, characterized by rapid and simultaneous heat and mass transfer between the droplets of the feed solution and the heating gas, is complex to describe in a mathematical model as many of the model parameters are not readily measurable. Such difficulties also limit the regulation of the spray dryer operation to tailor the end point properties (mechanical, thermal, size, density, etc.) of the particles [3]. Spray drying chambers typically are vertical vessels with a cylindrical cross section and a conical bottom.

2.Typical Spray Drying System

The diagram shows a schematic representation of a typical spray drying system for milk powder. For spray drying, it is usual to pump a concentrate of the liquid product to the atomizing device where it is broken into small droplets. These droplets meet a stream of 2 hot air and they loose their moisture very rapidly while still suspended in the drying air. The dry powder is separated from the moist air in cyclones by centrifugal action. The centrifugal action is caused by the great increase in air speed when the mixture of particles and air enters the cyclone system. The dense powder particles are forced toward the cyclone walls while the lighter, moist air is directed away through the exhaust pipes. The powder settles to the bottom of the cyclone where it is removed through a discharging device. Sometimes the air-conveying ducts for the dry powder are connected with cooling systems which admit cold air for transport of the product through conveying pipes. Cyclone dryers, such as shown here have been designed for large production schedules capable of drying ton-lots of powder per hour.



3.Classification of Dryer



3.1Batch Dryers

Batch dryers are commonly used to dry small quantities or when the drying times are very long (of the order of several hours, days, or even months as in the case of some certain wood drying applications). They are common in the pharmaceutical industry for the former reason while they are used in the wood industry and for freeze drying of ultra-heat- sensitive products in the pharmaceutical and biotechnological industries for the latter reason. Some dryers can operate in both batch and continuous modes, e.g., fluid beds. On the other hand, most continuous dryers cannot operate in the batch mode, e.g., spray, rotary, flash dryers. There is a limited choice of dryers for batch drying.

It will be apparent that batch operated equipment is usually related to small production runs or to operations requiring great flexibility. As a result, the batch type forced-convection unit certainly finds the widest possible application of any dryer used today[5].

The majority of designs employ recirculatory air systems incorporating large volume, low pressure fans which with the use of properly insulated enclosures, usually provide thermal efficiencies in the region of 50 to 60%. However, in special applications of this type of dryer that call for total air rejection, this figure is somewhat lower and is largely related to the volume and temperature of the exhaust air. Capital investment and installation cost are relatively low. The use of fan systems minimizes both power requirements and operating costs. In contrast, labor costs can be high.

Batch type fluidized bed dryers have, therefore, superseded forced convection units in many cases – notably in the drying of pharmaceuticals and for the processing of certain thermoplastics. These machines generally are available in a range of standard sizes with batch capacities from 50 to 200 lbs./h (23 to 90 kg/h), although much larger units are made for special applications.

3.2Continuous Dryers

For the drying of liquids or liquid suspensions, the evaporator of choice is usually either a drum dryer or a spray dryer. A typical film drum dryer with a 4 ft. (1.2 m) by 10 ft. (3 m) long drum will evaporate about 600 lb./h (270 kg/h) of water. A typical spray dryer as shown in Figure 5 will evaporate 22,000 lb./h (10,000 kg/h). Where tonnage production is required, the drum dryer is at a disadvantage. However, the thermal efficiency of the drum dryer is high in the region of 1.3 to 1.5 mass units of steam per mass unit of water evaporated (65 to 75% efficiency) and for small to medium production runs, it does have many applications. Drum dryers are usually steam heated, although work has been done to developed units for direct gas or oil heating. Completely packaged and capable of independent operation, these dryers can be divided into two broad classifications: single drum and double drum. It must be emphasized that the method of feeding the product to the dryer is of paramount importance to selection or design. There are, of course, certain materials which are temperature-sensitive to such a degree that their handling would preclude the use of an atmospheric drum dryer. In such cases, special sub-atmospheric equipment may provide the answer, although the capital cost in relation to output generally would restrict its use to premium grade products[6].

As an alternate, the spray dryer offers an excellent solution to a host of drying problems. Many materials, such as dairy and other food products, which would suffer from thermal degradation if dried by other methods, can often be handled by spray drying (due to the rapid flash evaporation and its accompanying cooling effect). The continuous method of operation also lends itself to large outputs and with the correct application of control equipment, to low labor costs.

4.Critical Parameters of Spray Drying

a) Inlet temperature of air: higher the temperature of inlet air, faster is the moisture evaporation but the powder is subjected to higher temperature, which may distort the chemical/physical properties of heat sensitive product (Michael, 1993).

b) Outlet temperature of air: it govern the sizing of powder recovery equipment, higher is the outlet air temperature larger will be the size of powder recovery equipment and conveying ducts and plenums (Maury et al ., 2005). Outlet air temperatures control final moisture content of powder.
c) Viscosity: high viscosity hinders correct drop formation. As the viscosity is lowered, less energy or pressure is required to form a particular spray pattern.
d) Solid content: care must be taken with high solid loadings (above 30%) to maintain proper atomization to ensure correct droplet formation.
e) Surface tension: addition of a small amount of surfactant can significantly lower the surface tension. This can result in a wider spray pattern, smaller droplet size, and higher drop velocity.
f) Feed temperature: as the temperature of a solution to be sprayed is increased, the solution may easily dry as it brings more energy to the system.
g) Volatility of solvent: a high volatility is desirable in any drying process. Unfortunately, choices are limited today. In many cases, these restrict the solvent choice to water.
h) Nozzle material: most pharmaceutical applications use stainless steel inserts. However, tungsten carbide nozzles are often available and have excellent resistance to abrasion and good corrosion resistance for most feedstock [7].

5.Innovation in Spray Drying

Drying R&D has seen nearly exponential growth over the past three decades. Initially driven by the need to conserve energy in this highly energy-intensive operation found in almost all industrial sectors, now the focus is on product quality, environmental impact, safety issues, new products, and processes etc. Drying provides challenging areas for multi- and cross-disciplinary research of fundamental as well as applied nature coupling transport phenomena with material science. Innovations trigger technological changes, which may be revolutionary or evolutionary. From our experience, we know that the latter are more common. They are often based on adaptive designs, have shorter gestation periods, shorter times for market acceptance, and are typically a result of ‘‘market-pull’’—something the marketplace demands, i.e., a need exists currently for the product or process. These usually result from a linear model of the innovation process (an intelligent modification of the dominant design is an example). Revolutionary innovations, on the other hand, are few and far between, have longer gestation periods, may have larger market resistance and are often a result of ‘‘technology push,’’ where development of a new technology elsewhere prompts design of a new product or process for which market demand may have to be created. They are riskier and often require larger R&D expenditures as well as sustained marketing efforts. The time from concept to market can be very long for some new technologies[8].

Sterile spray drying for stable injectable liquid formulation

Soluble glass microspheres forming a monodisperse suspension in anhydrous fluorocarbon liquid because the microspheres are solid, their density can be precisely controlled to match that of the surrounding liquid (Buckton et al., 2002; Roser, 2005). Such suspensions are physically stable and the particles neither settle nor float in the liquid phase.

Foam spray drying

In this method liquid food is foamed, such as milk or coffee, before spraying it into the drier. The result is faster drying rate from the expanded foamed droplet surface area, and lighter density dried product. This is known as foam-spray drying (Hanrahan & Webb, 1961)[7].

Spray drying for the production of crystalline products

Spray drying is known to produce predominately amorphous material due to the almost instantaneous transition between liquid and solid phases. However, spray drying can also be used to obtain crystalline products (Shoyele & Cawthorne, 2006). To achieve such a goal, the product is fed in a crystalline suspension, instead of a solution, to the drying chamber. Feeding the crystals in the right form allows spray drying to fine tune crystal size distribution and final content of residual solvents (Jorge & Felipe, 2004).

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