Analysis of the Results of Research on Spray Drying of Starch Suspension

The spray dryer is very often applied in chemical and food-processing industries. This drying method includes suspension - spraying with the contents about 30 to 65% of dried substance. The drying period in most cases is only several seconds. The drying agent is the warm air. A model of momentum, heat and mass transfer in the atomization - swirler zone was proposed. To verify the model an extensive experimental investigation was performed on water evaporation at different initial air temperatures, feed rates, flow rates of the drying agent and different parameters of atomization and initial particle size distribution. Good agreement between experimental results and theoretical data was achieved. The model was verified experimentally on the basis of results of investigations on drying of a 40% mass solution of starch and water.

Keywords: Spray, Dryer, Starch, Drying, Temperature

1. INTRODUCTION

Different suspension of certain products react with uneven drying, which depends on the properties of the material that is dried. It is very difficult to recommend a unique technique of the spray driers. In comparison with other systems, spray drying requires a relatively small storage space. Service and maintenance are very simple and is performed with little labor. These advantages, as well as a economical heat transfer provides the optimal cost of the final dried product. Drying time is often only a few seconds, and can successfully dry heat sensitive products such as vitamins, chemical and food products and other, which better submit to a high temperature in a short period of time, but to lower temperatures for a longer period of time [1-3].

For substances such as suspension of various materials with over 30 to 65% of dry matter, spray drying kilns is quality solution to the problem of drying. There have been many attempts at formulating a mathematical description of spray drying since the 1950s. In spray drying there are many phenomena, which are difficult to represent in the form of a mathematical model. For many years polydispersity of spray, entrainment effects, or problems of internal heat and mass transfer in the disperse phase have been inadequately considered in such models. Practically, models of the process that have been created since the beginning of the 1970s were concerned only with the plug flow of a drying agent [4-6]. Drying systems based on the principle of heat transfer by convection, such as spray driers and pneumatic dryer have been treated in the literature [7-14].

2. EXPERIMENTAL APPARATUS AND DETAILS

Inlet air drying is done by fans (3). Air over the absorb–

Table 1. The basical characteristics of the spray drying chamber

<table>
<thead>
<tr>
<th>Name</th>
<th>Units</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter chamber spray dryer</td>
<td>(mm)</td>
<td>5000</td>
</tr>
<tr>
<td>Elevation spray drying chamber</td>
<td>(mm)</td>
<td>5500</td>
</tr>
<tr>
<td>Cyclone diameter</td>
<td>(mm)</td>
<td>1400</td>
</tr>
<tr>
<td>Power fan</td>
<td>(kW)</td>
<td>18.5</td>
</tr>
<tr>
<td>Air flow</td>
<td>(m³/h)</td>
<td>9750 - 14400</td>
</tr>
<tr>
<td>Atomizer (swirler)</td>
<td>(kW)</td>
<td>0.75</td>
</tr>
<tr>
<td>Electric motor rpm</td>
<td>(min⁻¹)</td>
<td>3800</td>
</tr>
</tbody>
</table>

Figure 1. Schematic of the experimental plant spray dryer: 1-chamber spray dryer, 2-cyclone, 3-fan, 4-heater, 5-air outlet, 6-supply of material, 7-swirler (atomizer), 8-drive axle, 9-rotary feeder, 10 - measuring point

Axle (8), is given by electric propulsion. Spray nozzle rotates at a large number of rpm n = 3800 min⁻¹.
and thus has made dispersal of the liquid solution in small droplets. Aerosols are derived in the form of a rotating disc diameter of 320 mm, with a paddle. Extensive spray speed is 63.5 ms⁻¹.

In contact with hot gas – air drying is done in dispersed droplets and intensive exchange of heat and mass is carried out. Air flow to the fan (3), can be regulated, so that it can be achieved at the drying air velocity of V = (0.17 to 0.24) ms⁻¹.

Dried material is using a rotary feeder (9), and transported as a finished product. Air with dust particles is drained with piping (5) and the cyclone (2). The cyclone (2), the complete separation, after which they are using fans (3), is performed by taking the air into the atmosphere.

3. EXPERIMENTAL RESULTS AND DISCUSSION

One of the main sources of error in spray drying simulation is an imprecise specification of initial process parameters, for example, spray cone angle and particle size distribution. The parameters were carefully determined for each swirl insert and for each feed rate.

Experimental investigations of water evaporation were carried out for three feed rates (98, 135, 157 kg h⁻¹), three values of air temperature (80, 100, 130 °C). An example of the initial particle size distribution obtained at feed rate of 98 kg h⁻¹ is shown in Figure 2.

![Figure 2. Initial particle size distribution](image)

Both in this case and for other values of initial atomization parameters a characteristic log-normal particle size distribution was obtained. The experimental investigations show that the character of the distribution does not change as a function of the distance to the atomizer - swirler in all experimental runs.

All theoretical calculations made negligible changes in the air and material temperature in cross-section of atomized material spray, which was confirmed experimentally.

Increasing temperature in the cross section spray dryer is slightly, Figure 3. The absence of an air temperature gradient in the spray cross-section can be explained by the design of the experimental set-up and by the process parameters. The air velocity profile in the tunnel of a dryer is flat and the turbulence is low. In the study carried out by [15, 16] a temperature distribution along the spray dryer radius was observed, and obtained similar results.

As simulation calculations show, the particle of a diameter corresponding to 95% cumulative percentage undersize did not contact the walls of the tunnel dryer, which was in agreement with experimental observations (in all experimental trials no wetting of the tunnel wall was reported).

![Figure 3. Comparison of theoretical and experimental results Initial particle size distribution](image)

Fig. 2, shows a comparison between the theoretical and experimentally calculated changes in the temperature of air, material and evaporation rate as a function of the distance from the atomizer for the same feed rate and air flow velocity. A theoretically calculated spray radius is also plotted on the same graph. A rapid drop in the air temperature and then its characteristic rise are related to entrainment effects.

An increase in the amount of air in the spray caused by its expansion causes the temperature to rise despite intensive evaporation, until the moment when a balance occurs between the heat used for evaporation and the heat supplied into the spray by the entraining air.

After this time, a drop in the air temperature as a function of the distance to the atomizer is observed. Similar profiles of particular functions were obtained in many studies [17-19].

Experimental results, shown in Figure 4, illustrate changes in the evaporation rate along the tunnel of a dryer for different temperatures of the drying agent. Air temperature has a decisive effect on the evaporation rate. No significant influence of the drying agent velocity on the shape of the curves discussed was observed. Particles achieve a zero relative velocity after a short
period of time which limits convective heat transfer between the continuous and disperse phases.

Figure 4. Evaporation at different air temperatures

Lack of air circulation zones in the tunnel causes the spray to compact and move parallel to the tunnel of dryer walls. Very good agreement between theoretical and experimental results is worthy of note.

Figure 5. Effect of sauter mean on evaporation rate

The final figure discussed, Figure 5, shows the effect of the initial particle size distribution on the evaporation rate at the same air temperature and feed rates.

The analyses of the results show that the character of initial particle size distribution has a remarkable influence on the whole evaporation process. Particles with a smaller Sauter mean diameter are evaporated much faster than particles having larger mean diameters.

In the case where the initial particle size distributions are similar, the feed rate is the parameter that determined the evaporation rate [20]. Good agreement between theoretical and experimental results was also obtained in this case.

4. CONCLUSIONS

As part of this work the experimental and theoretical study of spray drying for drying starch solution was carried out. Comparison of theoretical and experimental results was performed. It shows the evaporation at different temperatures. It also shows the influence of particle size on the intensity of evaporation.

Determined parameters of drying regime on the basis of research of operating conditions, can be considered optimal parameters, given that the experimental drying process produced good quality of dried material.

The model presented in this paper can be used to predict many subtle phenomena that occur during spray drying, in particular in complex air flow. In all theoretical simulations of the drying process of evaporation, a reasonable agreement with the experimental data was reached.

The research results have practical value, because it is based on experimental data. In this way, the research results can be useful for researchers, designers, producers and users of these and similar drying systems.

REFERENCES


tly of Mechanical Engineering, Belgrade, 2008.


АНАЛИЗА РЕЗУЛЬТАТА ИСТРАЖИВАЊА НА СПРЕЈ СУШАРИ ЗА СКРОБНЕ СУСПЕНЗИЈЕ

Д. Толмач, С. Првуловић, Ј. Толмач, С. Станков

Спременом сушаром се врло често користе у хемијској и прехранбеној индустрији. Ова метода укључује сушење суспензија са садржајем 30-65% суве материје. Период сушења је у већини случајева само неколико секунди. Агенс сушења је топли ваздух. Предложен је модел преноса топлоте и масе у зони атомизации. Да би се проверили модели, извршено је експериментално истраживање испаравања воде на различитим температурама, капацитетима и притоку агенса сушења при различитим параметрама атомизације и почетне расподеле величина честица. Добијено је добро слагање између експерименталних резултата и теоријских поставки. Модел је експериментално верификован на основу резултата истраживања при сушењу 40%, масеног раствора скроба и воде.