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Reduction of the Total Drying Time in Mixed Fluidized Layer

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The article deals with drying of fluidized bed ionex-exchanger by mixed fluidized layer and its influence on the total drying time. The goal is to demonstrate a positive effect of mixed bed, to find the optimal parameters (type of stirrer, speed and size of stirrer). Experiments are conducted at drying chamber in batch operation. The objective is to evaluate finally the effect of mixing on total drying time. We proved a decrease of drying time up to 40 %.

1. Introduction

Drying is a highly energy-intensive process. It is a sphere, where reserves can be found at the time of high prices for energies and strong cost-saving pressure. In practice, drying processes are used as little as possible and as one of the final solutions of the given process. Unfortunately, however, certain process conditions can only be solved by drying. This article concerns finding reserves in fluid drying of particles in a batch mode, where the particles are highly sticky due to surface tension of the liquid on the particles; this liquid cannot be removed by a different type of drying, such as centrifuging.

Fluid drying is a type of a drying process with a very intensive transfer of heat and mass between the dried particle and the air-flow in which the particle is carried during fluidization. The surface tension of the liquid, which covers the surface of the dried particle at the start of the process, makes the particles very sticky with each other and the walls of the drying chamber. A batch mode of this process and the small amount of the dried material in a single batch eliminates usage of a vibro-fluid dryer, because these dryers are usually designed for a continuous operation. A solution lies in a fluid drying process with a stirred fluid layer, where the stirring process continuously breaks clusters of particles and wipes off particles stuck to the walls of the drying chamber.

The chart in Figure 1 illustrates a drying curve for 350 g of wet ionex dried in a fluid chamber with air at 120 °C, moving at the speed of 2.5 m/s. Over the first eighty minutes, the dried material forms a compact cluster of particles caused by surface tension of water, which covers the surface of the particles at the beginning of the drying process. This fact results in a drying process without transition of particles into fluidization. The fluidization occurs after eighty minutes of drying. The period between 80 and 104 min represents the first drying phase, where the decrease of moisture in the particles is constant. After 104 min of the drying process, the drying passes into the second phase of fluid drying, where the speed of moisture removal drops.

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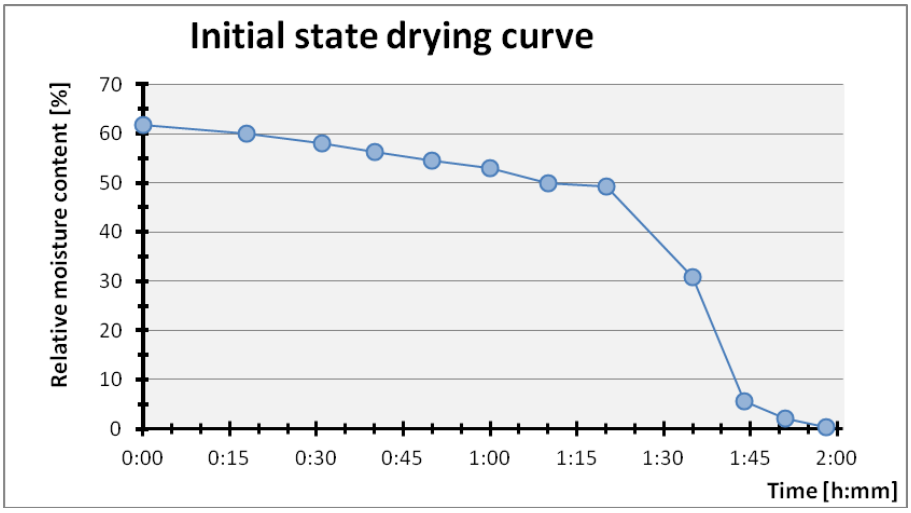

Figure 1: Initial drying curve

2. Materials and methods

2.1 Spherical ionex particles

As a model material, we used spherical particles of ionex (cation exchanger, anion exchanger). Among other applications, this material is used in membrane technology for water treatment. Ionexes are usually synthetic high-molecular organic substances based on styrene, polyacrylate, phenol formaldehyde resin etc.

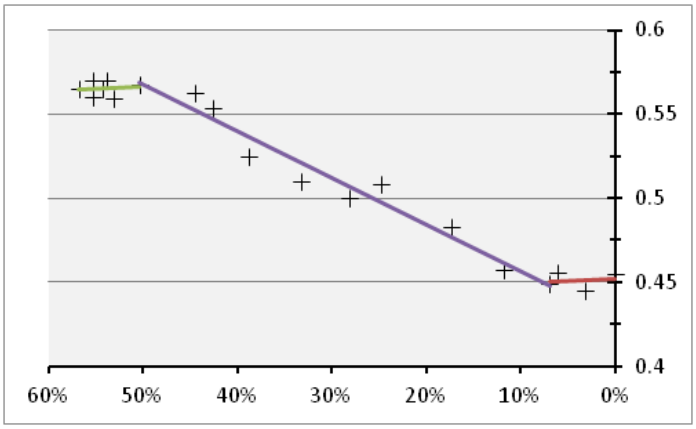

Figure 2: Dependence of the particle diameter on the relative humidity of the particle

We used Marathon-A cation exchanger shaped as spherical particles 450-550 □m in diameter as a model material. This material is peculiar for its volume expansion, which depends on the amount of moisture in the material - see Figure 2.

2.2 Experimental

As mentioned above, the main difficulty of this problem is the initial phase of the drying process, where the particles stick to each other or to the walls because of the surface tension of liquid on the surface and inside the particle. The main task is thus specification of suitable properties of the stirrer. The stirrer must be able to break clusters of the dried particles and wipe the particles off the walls so

effectively that the initial drying phase with sticky particles is minimized and the particles are not broken. To pinpoint the course of the drying process, we developed experimental equipment for fluid drying with a stirred layer. The experimental equipment is illustrated in Figure 3.

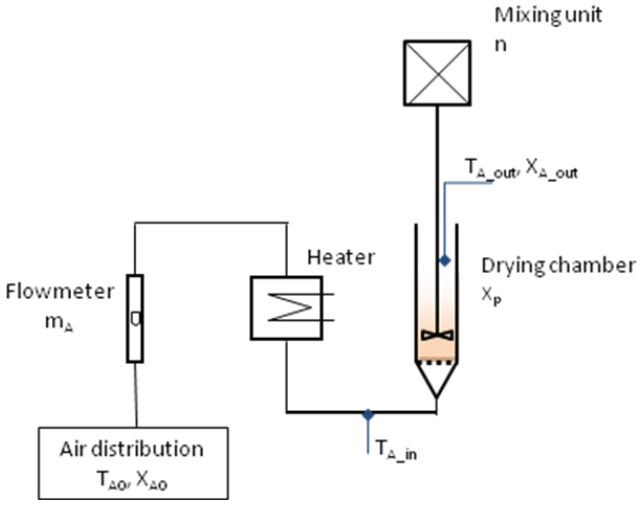

Figure 3: Chart of the experimental equipment

Pressurized air of a known temperature and humidity is brought from a central air distributor. The air flow is controlled by a control valve and measured with rotational flowmeter. The air behind the flowmeter is heated by a heater with resistance wires manually controlled by a transformer. The temperature of the heated air is measured before the fluid chamber with a contact thermometer. A U-manometer is installed at the fluid chamber inlet for monitoring loss of pressure in the fluid bed. The fluid chamber is a glass cylinder Ø 90×570 mm. The sensor for measuring humidity and temperature of the drying air is located 300 mm above the bottom of the chamber. The stirring unit with adjustable speed is located above the chamber.

3. Results and discussion

3.1 Influence of the stirrer's position

Designing an optimized stirrer concerned its attachment in the drying chamber. We tried two main versions, i.e. an eccentric location (see Figure 4) and a centric location of the stirrer (see. Figure 5). The assumptions and subsequent experiments show that the optimized stirrer must be located centrically in the tank and its diameter must be 0.95-0.97 of the drying chamber's inner diameter. The stirrer should not be located higher than 5 mm above the grid. The main reason for a centric arrangement is occurrence of undesired vibrations of the whole stirring aggregate, impacts of the stirrer against the chamber walls and a subsequent degradation of the dried material. The size of the stirrer is determined by a necessity to wipe the stuck material off the walls and homogenization of the entire batch. If the stirrer's diameter is smaller, a layer of wet material accumulates on the walls of the drying chamber, thus increasing the speed of the drying air above the particle flight velocity. Location of the stirrer immediately above the drying grate is determined by the thickness of the accumulated layer of the wet material, which blocks access of air into the chamber, thus causing overheating of the material and local increase of the air speed above the particle flight velocity. The dried particles have a strong tendency towards creating a fountain or spurting type of fluid layer, which is not as beneficial for transfer of mass as a laminar or fluid type of layer.

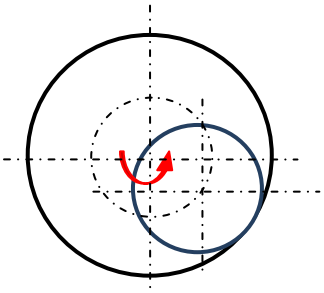

Figure 4: Eccentric location of the stirrer

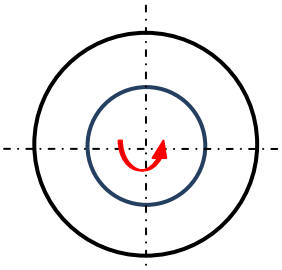

Figure 5 - Centric location of the stirrer

3.2 Influence of the stirrer speed

The experiments proved a hypothesis that the efficiency to break clusters of particles is not sufficient if the speed is low and the cluster of particles rotates together with the stirrer. Conversely, if the speed of the stirrer is too high, the stirrer obstructs setting of the fluid layer and constantly disturbs it. This effect affects the drying period in the first and second drying phases, prolonging them 1.2 - 1.8 times in comparison with unstirred condition; this is also true for a low stirrer speed.

3.3 Design of an optimized stirrer for a minimum drying period

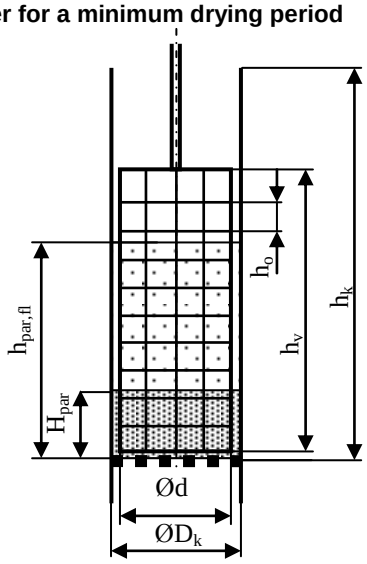

Figure 6: Wire stirrer

Based on experiments with standardized stirrers, we designed a prototype stirrer called "Wire Stirrer", which is illustrated in Figure 6. The stirrer is made of stainless steel wire 0.4-0.6 mm in diameter. It is designed for a centric arrangement. The stirrer diameter is (0.95-0.97) D_k and it is 2.8-5x higher than the rest position of the material layer. The estimated speed is about 50 min^{-1}, and the peripheral speed of the blade is 0.225 - 0.26 ms^{-1}.

We made experiments with sizes and shapes of apertures in the stirrer. The sizes of square apertures were 2.5x2.5 mm, 10x10 mm and 25x25 mm; rectangular apertures were 25x2.5 mm and 25x10 mm, positioned upright and sideways. The experiments showed that if the apertures are small, the stirrer fails to break a cluster of large particles, which rotates together with the stirrer. If the apertures are too large, the cluster is broken regularly, but only into insufficiently small clusters. The orientation and shape of apertures had no effect on breaking the cluster.

3.4 Influence of individual phases of the drying process

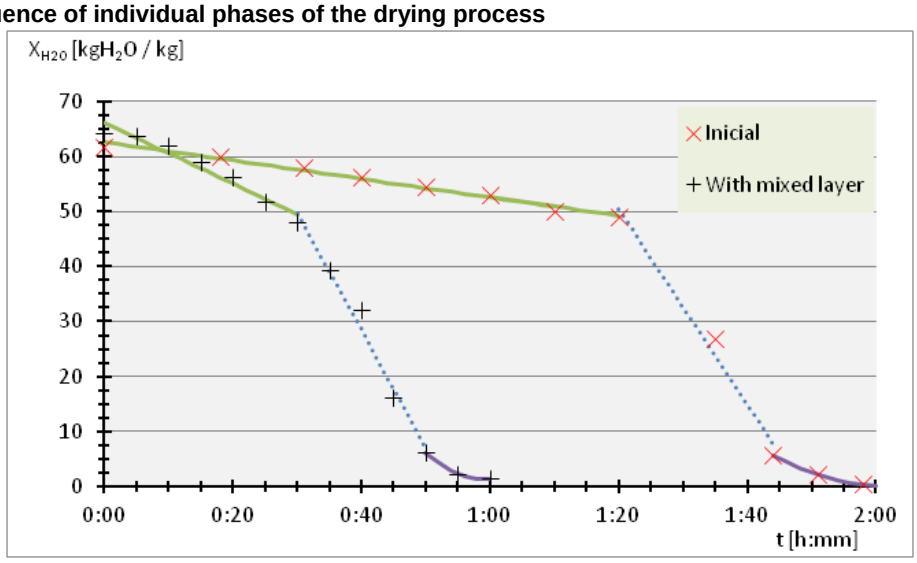

Figure 7: Comparison of drying curves

The drying curves with stirred and unstirred fluid layer are compared in Figure 7. It is clear from this chart that the wire stirrer has the main impact on the initial phase of the drying process (dotted line in Figure 7). Thus in a fluid layer without the stirrer the sphere of ionex oscillates in a range of particles' relative humidity from 65 - 50 %. The particles stick to each other and the walls and do not reach the fluid condition. In a version with a stirred fluid layer, the total drying period of the initial sphere drops from eighty to thirty minutes, i.e. by 60 %. It is also clear that the stirrer has no negative impact on the speed of moisture removal from the material in the first and second drying phases.

4. Conclusion

We designed a stirrer for minimizing the total drying period during fluid drying of sticky ionexparticles 250 - 1000 μm in diameter. The total drying period decreased from 111 min to 55 min, reaching the desired moisture of the material, i.e. 2 %. Then the total drying period in this model example is 50 % shorter.

Acknowledgements

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List of symbols

dm	Stirrer diameter	[mm]
Dk	Drying chamber diameter	[mm]
s	Pitch of the stirrer	[mm]
hv	Height of the stirrer	[mm]
h	Width of the stirrer	[mm]
h0	Size of the aperture	[mm]
hpar	Level of the fluid layer in the rest condition	[mm]
hpar,fl.	Level of the fluid layer during fluidization	[mm]

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