DEVELOPMENT OF A NOVEL ENERGY EFFICIENT ADSORPTION DRYER WITH ZEOLITE FOR HEAT SENSITIVE PRODUCTS

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Abstract—Drying is a basic operation in wood, food, pharmaceutical and chemical industry. The operation is important to enhance the preservation properties of agriculture crops and pharmaceutical products, to reduce the costs for transportation, to increase consumer convenience of food products, and to obtain desired water content in raw material feed for next unit process in industry.

Currently several drying methods are used, ranging from traditional to modern processing: e.g. direct sun drying, convective drying, microwave and infra-red drying, freeze and vacuum drying. However, the current drying technology is often not efficient in terms of energy consumption (energy efficiency of 20-60%) and has a high environmental impact due to combustion of fossil fuel or wood as energy source.

This work discusses on the development of adsorption drying with zeolite to improve the energy efficiency as well as product quality. In this process, air as drying medium is dehumidified by zeolite. As a result humidity of air can be reduced up to 0.1 ppm. So, for heat sensitive products, the drying process can be performed in low or medium temperature with high driving force.

The study has been conducted in three steps: designing the dryer, performing laboratory scale equipment (tray, spray, and fluidised bed dryers with zeolite), and evaluating the dryer performance based on energy efficiency and product quality. Results showed that the energy efficiency of drying process can reach 70-80% in which is 15-20% higher than that of conventional dryer.

Index Term—adsorption, drying, energy efficiency, zeolite, heat sensitive

I. Introduction

Drying is a basic operation in wood, food, pharmaceutical and chemical industry. The operation is important to enhance the preservation properties of agriculture crops and pharmaceutical products, to reduce the costs for transportation, and to increase customer convenience of food products. A large part of the total energy usage in industry is spent in drying. For example 70% of total energy spent in the production of wood products, 50% of textile fabrics, 27% of paper, 33% of pulp production is used for drying [1]. In food and pharmaceutical industry the energy consumption for drying is around 15% of the total energy usage in this sector. Energy spent for drying varies between countries and ranges between 15-20% of the total energy consumption in industry [2].

Currently several drying methods are used, ranging from traditional to modern processing: e.g. direct sun drying, convective drying, microwave and infra-red drying, freeze and vacuum drying. However, the current drying technology is often not efficient in terms of energy consumption (energy efficiency of 20-60%) and has a high environmental impact due to combustion of fossil fuel or wood as energy source [3].

The sources of fossil fuel are limited, the price of energy increases, the worldwide industrial energy usage rises, and increase of greenhouse gas emission becomes a global issue due to climate change; the need for a sustainable industrial development with low capital and running cost especially for energy becomes more and more important. In this context the development of efficient drying methods with low energy consumption is an important issue for research in drying technology.

Innovation and research in drying technology during the last decades resulted in reasonable improvements, but breakthrough solutions with respect to the energy efficiency are scarce. Therefore it can be noted that innovation in drying technology tends to reach a saturation level and a further significant reduction in energy consumption seems not feasible [3]. Positive results are obtained in adsorption dryer with zeolite to speed up drying rate and to improve energy efficiency, while other new developed drying processes cannot compete with traditional drying method in terms of energy efficiency and operational cost [4,5].

This paper presents the development of adsorption drying with zeolite to improve energy efficiency. The work focuses to answer on the following questions: 1. how the conceptual configuration of the dryer system with zeolite? 2. how the effectiveness of the system configuration? 3. how to design and construct the dryer system with zeolite?

II. Methodology

To answer the questions, the research was conducted as illustrated in Figure 1.

![Figure 1: Schematic Diagram of Research](http://www.foxitsoftware.com)
III. RESULTS AND DISCUSSION

3.1. Energy efficiency based on conceptual design

Table 1 presents the results for the single and multi stage adsorption drying systems indicating that the energy efficiency of adsorption dryer is higher than that of conventional dryer. For all cases, extending the number of stage increases the efficiency.

<table>
<thead>
<tr>
<th>Options</th>
<th>Number of stages</th>
<th>Energy efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional dryer</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>Adsorption Dryer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single stage</td>
<td>1</td>
<td>72</td>
</tr>
<tr>
<td>Cross-current</td>
<td>2</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>Co-current</td>
<td>2</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>82</td>
</tr>
<tr>
<td>Counter-current</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>90</td>
</tr>
</tbody>
</table>

Results given in Table 1 show that the different process configurations gives different efficiency results. In the co-current system, the input air contacts the fresh feed in the first dryer and both streams go in the same direction through the system. The driving force between product and air (temperature and humidity) decreases along the stages. As a result, more energy and air is required for drying and energy efficiency is the below that of the others configurations [6].

In the counter-current dryer, the air and product flows are in the opposite direction; fresh product is contacted with the air in the last stage of adsorbers. The advantage of this system is the ability to use the air from last stage to preheat fresh product. Furthermore, heat and mass transfer in each stage is enhanced which is reflected by the enhanced energy efficiency. The efficiency of counter-current is the highest and goes up to 88%, for a three stage system with energy recovery. Therefore, the counter-current dryer is more favorable option. The difference between a three and four stage system is moderate and will probably not justify the extended equipment costs [6].

3.2. Energy efficiency based on experiment

The experiment was conducted to prove the concept. Initially, the adsorption dryer with zeolite was constructed in single stage system with adsorption-regeneration working in shift. The results showed the energy efficiency is close to that of the concept. The energy efficiency increases corresponding to the increase of the ratio between the air flow for drying and air flow for regeneration. At a ratio 4:1 the efficiency is 70-72% which is similar to the calculations results in the previous study using a steady-state model [7].

The shift time of adsorption-regeneration also affects the energy efficiency. In this work, the best performance is obtained for shift time 60 minutes. Main reason is that for a shorter shifting time, the zeolite is not sufficiently regenerated, which lowers the efficiency of the zeolite for air dehumidification during operational time [7].

IV. CONCLUSION

Two approaches involving conceptual design and experimental set up steps have been conducted to realize adsorption dryer with for improving energy efficiency. All results indicate the same energy efficiency improvement where the best results are obtained for a ratio between the air flow for drying and the air flow for regeneration 4:1. The positive results will boost the development of novel dryers for efficient energy usage and retaining product quality for industrial application.

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