Research in low-temperature heat pump drying

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***Abstract* – Improving the efficiency of operation of drying units can be obtained by applying heat generating units of heat pump type, in which the waste heat drying agent is utilized. The research is focused on the optimization of the actual heat pump cycle in order to reduce energy consumption in heat pump dryer.**

Keywords – drying, heat pump cycles, heat pump, energy consumption, energy efficiency.

Introduction

Modern convective dryers are characterized by low energy efficiency, which is related to large heat losses with the outgoing drying agent. One of perspective ways to improve the thermal efficiency of convective dryers is the use of the energy-saving equipment such as heat pumps [1, 2].

In heat pump drying the moisture, which is removed, doesn't imposed by a drying agent in the environment and condenses on the cold surface of the evaporator and is given in a liquid form. Perceived evaporator heat of water vapor condensation by the heat pump is transformed to a higher temperature level and is returned to the process of drying, which provides a significant decrease of the specific energy consumption than the traditional dryers and helps to reduce thermal "pollution" of the environment.

The main disadvantage of traditional condensing heat pump dryers is inconsistency of the processes of forced draining of heat carrier in the heat pump and desorption of the moisture from the material in the drying chamber. These dryers' temperature parameters of heat pump cycle and, consequently, the degree of dehydration of drying agent maintained unchanged during the whole period of drying, while the characteristics of heat and humidity of drying material are changed. In this mode, the sufficient speed of the process and optimal energy consumption are not provided throughout the whole period of drying, which leads to unnecessary energy consumption.

The aim of studies is to optimization of heat pump operation to minimize energy consumption during convection drying.

Results and Discussion

In the process of heat pump drying the amount of current energy consumption largely depends on the moisture content of drying agent and its drying temperature conditions in the evaporator of the heat pump: the higher the moisture content and temperature of dehydration, the lower specific energy consumption for the removal of moisture from it [3]. However, the dependence of the intensity of desorption of moisture from the material from the moisture of drying agent is reversible: with the increase of moisture content – drying process slows down.

The results of analytical studies of the heat pump cycle energy performances of heat pump drying process based on thermal and humidity parameters of drying agent were received and the optimum regime parameters of dehydration were defined. It is shown that energy consumption in heat pump drying depends on the moisture content and the temperature of the heat drying agent. The more the heat drying agent is dehumidified, the more energy for moisture removal is consumed. The energy consumption increases dramatically when dehumidification is deeper than d = 15 g/kg d.a. Also, the amount of energy consumption for dehydration increases with increasing drying temperature. Therefore, for heat pump dryers optimum drying temperatures are 50 ... 55 °C. At rational operation modes of the heat pump specific energy consumption for moisture removal can be reduced in 1,3-1,5 times.

It is shown that the recovery of the cold using an air-to-air heat exchanger (recuperator) reduces the current energy consumption during heat pump drying. The waste drying agent, which comes in the heat pump evaporator, is partially cooled by already cooled drying agent in heat exchange. It is allows, depending on the efficiency of the recuperator, to reduce the power imputs in drying by 1,5-2 times.

On the basis of the analysis of technological schemes of convection dryers with heat pumps and the results of analytical studies of heat pump drying processes, the experimental convective dryer with a heat pump system for preparation of heat carrier was developed. And energy-saving technological processes of thermal and humidity treatment of the heat carrier with heat recovery of the waste drying agent are proposed.

On the basis of the experimental data on drying kinetics of plant materials at different drying agent humidity the operational parameters of the heat pump dryer are studied. Decrease in drying agent humidity promotes increase in moving force of mass transfer that results in considerable reduction of drying time. However at the maintenance of low air humidity by the heat pump value of energy consumption is decreased. It takes place, because at low humidity considerable part of cold is used non-productively on cooling of dry air mass.

In the experimental heat pump drying plant the primary energy consumption was reduced to 0,7-0,9 kW·h per kg of removed moisture.

Conclusion

1. On the basis of analytical researches of heat pump cycles modes of moisture removal provided a minimum specific energy consumption for the drying process are determined.

2. The use of research results in the experimental heat pump drying plant has allowed to reduce the primary energy consumption to 0,7-0,9 kW·h per kg of removed moisture.

3. Using of the recuperative heat exchanger allows to reduce energy consumption in drying in 1,5-2 times.

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