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Design Of Hybrid Heat Pump Dryer - Dehumidifier For Drying Of Agricultural Products

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Evaporator and condenser in a heat pump system can act as a condenser and heater in drying – cooling system. Dehumidified cooled air and heated air are into two chambers interchangeably at intermittent times. Thus two units of dryer – dehumidifier are obtained. This paper describes the conceptual design of a hybrid heat pump dryer – cooler. A brief description of the components of the hybrid dryer – dehumidifier is given followed by explanation on the operational sequence of the drying – dehumidification process.

1. Introduction

Drying is one of the most common preservation methods to prolong the shelf life of agricultural and bio-origin products. It is an energy intensive process. Therefore, the need to develop efficient and cost effective drying processes remains important. Most industrial dryers used in food, agricultural industries are of conventional type where the energy efficiency is low. Nowadays, the industrial players are facing pressure on the operating cost as the fuel price is skyrocketing in recent years. The need to research and develop, design and invent cost effective and efficient dryers to process agricultural products has become increasing important over the years.

Agricultural products are bio-origin, thus they are heat sensitive. High temperature processing will destroy or change the chemical and biochemical properties of the products. In the process of dehydration and drying of agricultural products, low temperature is preferable. Heat pump dryer is one of the low temperature dryers besides freeze dryer that can be used to dry heat sensitive products.

Advantages offered by heat pump fluidized bed dryer are: low energy consumption due to high specific moisture extraction rate (SMER), high coefficient of performance (COP), drying temperature can be regulated within the range of -20°C to 110°C, environmental friendly and high product quality.

Islam and Mujumdar (2004) have classified many types of heat pump dryers. Much research works have been done on various types of heat pump dryer, viz, fluidized bed heat pump dryer (Alves-Filho & Strommen, 1996; Strommen, 2002). Klocker et al. (2002) presented the design of a batch cabinet heat pump dryer using CO2 as the working fluid. Alves-Filho (2002) proposed a new type of fluidized bed heat pump

dryer that uses CO2 as the refrigerant. Chua et al. (2002) studied the effect of different temperature profile on the quality of the dried product. Chen et al. (2002) developed a dual purpose heat pump dehumidifier dryer.

A hybrid heat pump dryer – cooler has been designed. This paper presents the design of this unit operation, its operational sequence as well as the brief description of the components.

2. Heat Pump System

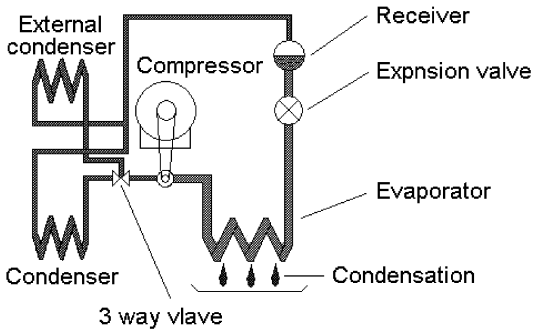

Figure 1. Heat pump system

An ordinary heat pump drying system consists of evaporator, compressor, condenser, and an expansion valve. The working fluid (refrigerant) at low pressure is vaporized in the evaporator by receiving heat from the surrounding of the evaporator. Withdrawal of heat from the surrounding of the evaporator causes temperature of the air at the surrounding decreases. If the temperature of air is below the dew point, condensation occurs. The air is cooled and dehumidified. Thus evaporator acts a condenser or dehumidifier to the air.
The working fluid then goes to compressor. The compressor raises the enthalpy of the working fluid and discharges it as superheated vapor at high-pressure. The superheated vapor is then condensed in a condenser. Heat is removed from the working fluid and transferred to the process air that is around the condenser. As a result, the temperature of the air around the condenser increases. The air is heated. Thus the condenser acts as a heater to the air. The working fluid is then throttled using an expansion valve to the low-pressure line and enters the evaporator to complete the cycle.

3. Conventional Design of Heat Pump Dryer

Conventional heat pump dryer uses a heat pump system to dehumidify and heat the process air. By means of this, the dehumidified heated air has lower relative humidity and thus able to absorb more moisture from moist solids. This in turn allow higher rate of moisture removal to be achieved.

Figure 2 shows a typical heat pump fluidized bed dryer. The fluidized bed drying chamber receives wet solids and discharges dried product. Processed air is dehumidified near the evaporator and it is heated to higher temperature near the condenser. The air is then charged into the fluidized bed chamber from the bottom. Moisture is transported from the solids into the air when contacting between the two phases occurs.

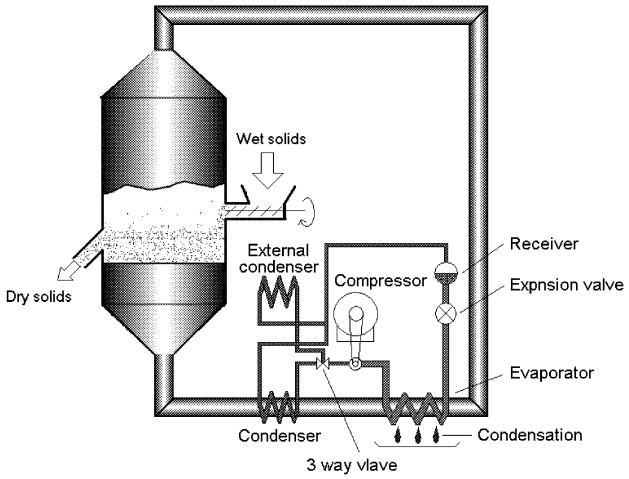

Figure 2. schematic diagram of a heat pump fluidized bed dryer (Law & Mujumdar, 2006)

4. Conceptual Design of the Hybrid Heat Pump Dryer – Dehumidifier

A heat pump dryer – dehumidifier can be obtained by having a heat pump system serving two units of processing chamber.

Since evaporator and condenser of a heat pump system can act as a condenser and a heater respectively in a drying – dehumidification system. Both components can be used to construct a dryer cum dehumidifier. The system can be used to service two processing chambers. One chamber having the dehumidified cooling air as the processing air whereas the other chamber has heated air as the processing air. If the cooling air and heated air are used interchangeably in a chamber, the chamber becomes a dryer cum dehumidifier.

Figure 3 shows the conceptual design of a hybrid dryer – dehumidifier. Here a heat pump is used to service two processing chambers. Diverter valves are use to direct the dehumidified air and the heated air into the path of cooling and drying systems respectively. For the drying system, heated air after exhausted from the chamber will be discharged completely from the drying system. Whereas part of the dehumidified air

will be recycled back to the dehumidification system and part of it will be discharged from the system.

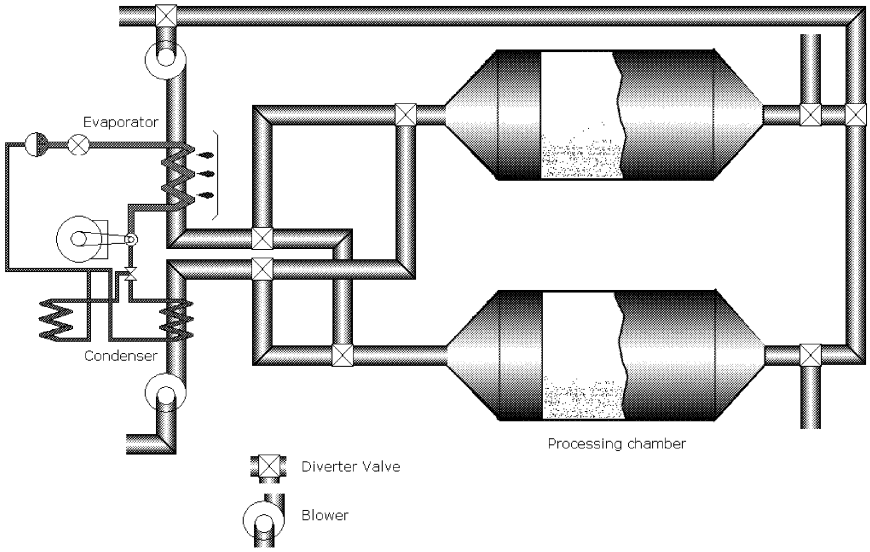

Figure 3. Schematic diagram of a heat pump hybrid dryer - cooler

The operational sequence of drying – cooling system is illustrated in Figure 4 and Figure 5.

In the first interval, drying is carried out in the lower chamber while cooling is carried out in the upper chamber. Figure 4 shows the paths of the heated air and the dehumidified cooled air.

In the second interval, drying is carried out in the upper chamber while cooling is carried out in the lower chamber. Figure 5 shows the paths of the heated air and the dehumidified cooled air.

In the subsequent intervals, heated air and cooling air are supplied to the processing chambers interchangeably. When a chamber is undergone drying operation, the other one has dehumidification.

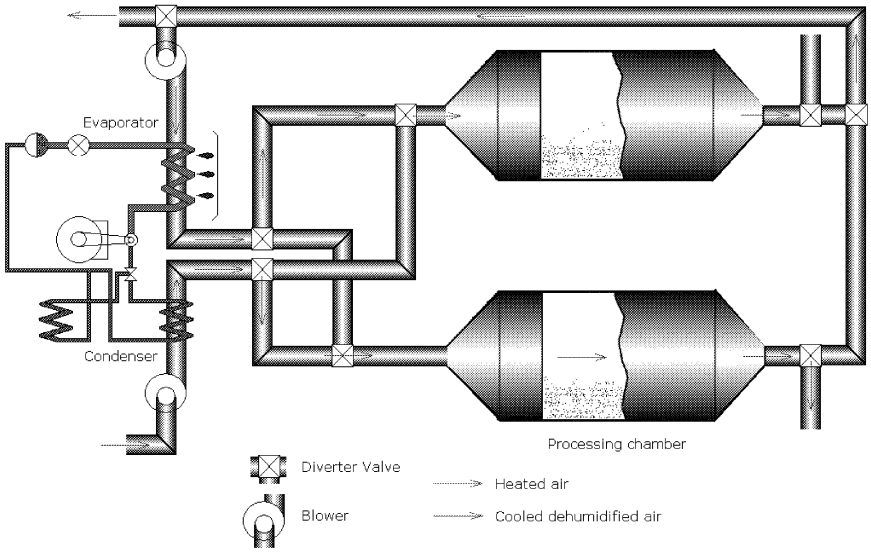

Figure 4. Schematic diagram of a hybrid dryer – cooler for the first interval

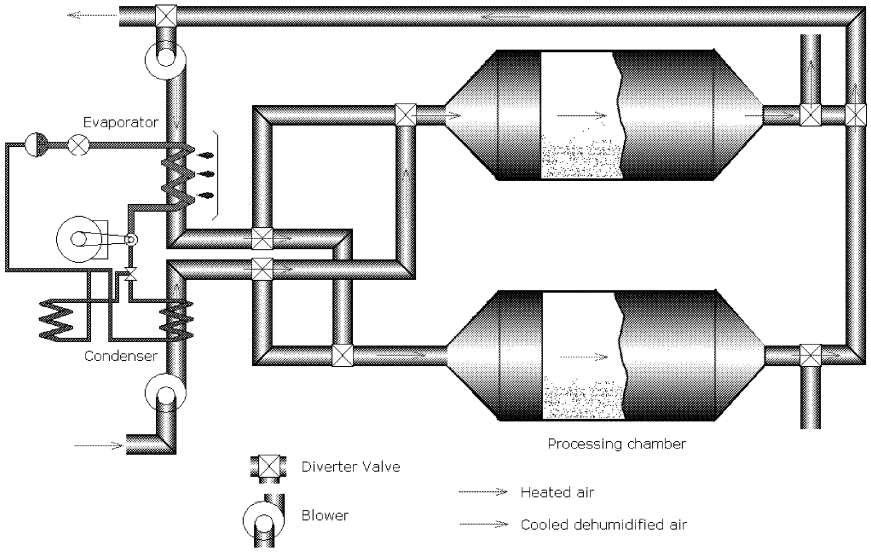

Figure 5. Schematic diagram of a hybrid dryer – cooler for the second interval

5. Conclusion

A heat pump system can be used to service two processing chambers. The evaporator of the heat pump system acts as a condenser in the drying – dehumidification system. Whereas the condenser acts as a heater in the drying - dehumidification system. Dehumidified cooled air and heated air are supplied into the chamber interchangeably. Thus drying cum dehumidification can be carried out in each chamber.

6. Acknowledgement

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7. References

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