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Performance analysis of a new humid air dehumidifier

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Abstract

A new humid air humidifier was designed and built. It is composed with two identical stages. The condensation is achieved on vertical tubes. Many configurations are tested. A thermodynamic model has been established. This model predicted the performances of each stage. The results showed that the flow rate of pure water produced by dehumidification and the exchanged heat power increase with increasing mass flow rates of dry air and cooling water, temperature and absolute humidity of inlet moist air in the dehumidifier. The high quantity of water vapor in air makes a thick film of condensate on cooling tubes. This reduces the flow rate of condensate and thermal power exchanged. So, the use of multistage condenser as dehumidifier is must but not sufficient for optimum efficiency.

Keywords: Dehumidifier; multistage; efficiency;

1. Introduction

In a desalination system by humidification-dehumidification (HDH) of air, the dehumidifier has an important effect on the productivity of the unit. The presence of air, which is a non-condensable gas (NCG), with vapor water, causes local reduction of performance, reduction of efficiency and hence a HDH cost increase. The nature of dehumidification operation causes the NCG concentration to increase upstream. This increase of NCG concentration will causes a difficulty against the migration of water vapor molecules from the gas phase to the cooled surfaces. So, the mass transfer rate of water vapor condensation decreased. Besides, a film of liquid water is made up on the cooled surface under the condensation of water vapor causes an additional thermal resistance. Consequently, the heat transfer is reduced. Thus, an expensive area of heat and mass transfers is wasted. The technological

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characteristics and the operating conditions are the most important factors of dehumidifier efficiency. This calls for a rigorous analysis that may lead to the optimization criteria needed for the design and exploitation of the dehumidification system.

Nomenclature

Cpas	calorific capacity of dry air	(kJ / kg. K)
Cpcw	calorific capacity of cooling water	(kJ/ kg. K)
Cpv	calorific capacity of vapor	(kJ/ kg. K)
Lv0	evaporation latent heat at 0°C	(kJ/ kg)
mas	mass flow rate of dry air	(Kg/h)
Mcond	mass flow rate of condensate	(kg/h)
mcw	mass flow rate of cooling water	(kg/h)
T	air temperature	(°C)
X	absolute humidity of moist air	(kg water vapor / kg dry air)
ΔT	temperature difference	(°C)

Indices

a	air
cw	cooling water
1, in	inlet
2, out	outlet
V	vapor
as	dry air

2. Literature survey

Humidification and dehumidification (HDH) of air is a very important process widely used in desalination of water. The humidification of the air depends on the operating conditions and the humidifier technology. The air dehumidifier has a direct influence on the productivity of the process. In this article, a new dehumidifier is designed and realized. The thermodynamic model developed allowed to identify the important operational variables as well as to quantify the relative influence on each parameter on the dehumidifier efficiency. The review of the literature shows that there are five modes of condensation are generally listed [1]:

Film condensation where the liquid constituted by the condensed vapor, also called condensate, forms a continuous film on the cold surface. This type of condensation is most commonly encountered in industrial equipment. Homogeneous condensation: the condensate appears as droplets which remain suspended in the gas flow, which then constitutes a mist. This occurs, for example, when a gas undergoes isothermal compression upon passage of an expansion in a pipe. Drip condensation replaces film condensation under certain circumstances; when the cold surface has been treated to be non- wet and the surface tension of the liquid is small. This configuration greatly increases the exchange coefficient. Direct contact condensation occurs when a cold liquid, usually the liquid associated with the vapor to be condensed, is brought into direct contact with the vapor. Condensation of vapor mixture will form immiscible liquids. Condensation of water vapor and hydrocarbons engenders this kind of behavior. The majority of the work focuses on the heat transfer kinetics and material in a steam condenser. Signe et al. [2] showed the influence of condenser technology on the amount of pure water produced. They have proved that the condensation of a mixture of several different vapors affects the performance of the process. Semiat et al. [3] shows that the presence of an incondensable gas in a vapor to be condensed directly affects the kinetics of heat and material transfer in the condenser. The variation of the absolute humidity of the air as a function of the temperature is indicated in fig.1. According to Duminil M. [5], to dehumidify the air one can opt either in an isothermal way (Zone 5) or in an adiabatic way (zone 6).