



Investigation of moisture condensation on papermaking plant envelopes in high humidity environment by orthogonal analysis and CFD simulation

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ABSTRACT

The objective of this study is to investigate the problem of moisture condensation on papermaking plant envelopes in high humidity environment. In this study, orthogonal experiment method is combined with CFD simulation to explore how moisture condensation varies with governing factors, such as the thermal parameters of building envelopes, temperature and humidity distributions or ventilation and air distribution. The criteria used by our work to determine whether the condensation will occur on envelopes are to calculate the temperature differences between the inner surface and the air dew point near the envelopes. Specifically, the temperature differences have a linear relationship with the governing parameters, and a first-order linear regression equation is derived, which is validated by data from investigation and measurement. This research provides theoretical support and measurement data for solutions of the envelope condensation problems and anti-condensation design of HVAC systems in papermaking plants.

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1. Introduction

Condensation problems in papermaking plants can be traced to high emissions of heat and moisture from papermaking process, which makes the indoor environment hot and humid. Hot and humid environment has bad impact on the health, comfort and productivity of the building occupants [1–3]. In addition, moisture contributes to the deterioration of building materials and has an impact on HVAC systems and therefore on the whole building energy performance [4–6]. Surface condensation and extra moisture in the air increased the risk of developing microbial vegetation in the plants, which was bad for the quality of paper produced. The severe condensation problems occurring both in summer and winter in most Chinese papermaking plants make the owners of the plants' and the building design community recognize the need for moisture control and for a better understanding of an available analysis method.

One way of controlling indoor relative humidity amplitudes without adding energy costs to buildings is to use the moisture buffering capability of building materials of absorbing or releasing moisture from/to the adjacent environment [7]. In recent times, several researchers have studied the use of various hygroscopic materials to moderate indoor humidity levels [8–14] and demonstrated the

benefits from inside relative humidity variation control provide by hygroscopic materials [15,16]. The recent project IEA Annex [17] contributed to a deeper understanding of that process. However, through the investigation of 9 production lines in 5 papermaking workshops in China during the last three years, it was found that different geometries and materials of enclosure did not have a significant impact on the condensation problem under such huge moisture emission (0.004–0.006 kg/m³ s of water) all the year round. The moisture source of special occasions like papermaking plant is mainly from the production process, which is quite different from the dwellings discussed by Lucas [18]. Materials with good moisture absorption and adsorption can provide a possibility to control the indoor humidity in a residential space, in which the moisture transport is governed by the air infiltration, rainwater leakage or the occupants [19]. But in papermaking plants, large release of moisture throughout a year may cause the hygroscopic materials invalid. Therefore, this paper makes use of whole building simulation to predict the surface condensation based on the measurement data, neglecting modeling moisture transfer in building materials.

As computing power increases, many numerical models are used for heat, air and moisture transfer simulation. In IEA/ECBCS Annex 41 [17], numerical models have been used to simulate heat and moisture transfer between indoor air and hygroscopic materials during transient changes in indoor humidity. Lucas [18] used CODYRUN, which is a multi-zone and multi-model software for simulation of building thermal environment, to determine the

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