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Experimental study of ice slurry performance in a standard fan coil

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ABSTRACT

A commercial fan coil has been experimentally studied in this work in order to assess its behaviour when ice slurry is used as secondary refrigerant. Experimentally obtained results have been compared to theoretical prediction obtained using the correlations proposed in previous papers in order to verify them. Several reasons have been reported to explain the deviation of fan coil behaviour from that expected and which make the direct application of ice slurry inappropriate in the fan coil studied.

In order to avoid those problems and to establish a comparison between two secondary refrigerants with similar cold storage capacity, ice slurry *direct application* has been compared to ice slurry *indirect application* – only carrier fluid, without ice particles, flowing through the fan coil. The most remarkable conclusion obtained is that *indirect application* improves the behaviour of the fan coil studied for all the cases analysed, overcoming the problems reported for *direct application*.

Etude expérimentale sur la performance des coulis de glace dans un ventilo-convecteur classique

Mots clés : Conditionnement d'air ; Ventilo-convecteur ; Expérimentation ; Transfert de chaleur ; Chute de pression ; Coulis de glace

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Nomenclature

A	heat transfer area (m^2)
d	ice particle mean diameter (m)
D	pipe diameter (m)
d/D	diameter ratio of ice particles over inside tube diameter (–)
h	heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
h_m	mass transfer coefficient ($kg\,m^{-2}\,s^{-1}$)
h_s	sensible heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
i	specific enthalpy ($J\,kg^{-1}$)
i_{fg}	saturated water vapour enthalpy ($J\,kg^{-1}$)
k	thermal conductivity ($W\,m^{-1}\,K^{-1}$)
L	pipe length (m)
$\dot{m}$	mass flow rate ($kg\,s^{-1}$)
$\dot{Q}$	heat transfer rate (W)
ΔT_m	effective mean temperature difference (K)
U	overall heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
W	humidity ratio of moist air ($kg\,kg^{-1}$)

Greek symbols

φ	ice mass fraction (–)
η	fin efficiency (–)

Subscripts

cf	carrier fluid
ext	exterior surface of the pipe wall
f	fin
fb	fin base
in	fan coil inlet
int	interior surface of the pipe wall
out	fan coil outlet
p	primary surface, not covered by the fins
w	water

1. Introduction

The use of secondary refrigerants comes from the interest in reducing the charge of primary refrigerant either due to its hazardous characteristics or the high global warming potential of the fluids used. Nevertheless, this second reason enters into conflict with the increase in energy consumption associated with the use of secondary refrigerants. In this context, the use of ice slurry would be interesting if it is able to bring down the energy consumption in the secondary refrigerant distribution system, where ice slurry is often used to cool both liquids and gases.

The main research efforts have been directed at studying ice slurry behaviour when it is used in liquid to liquid heat exchangers, whereas its application to air cooling systems has been treated by only a few authors (Field et al., 2003; Nørgaard, 2005; Rivet, 2001; Kalaiselvam et al., 2008). The applications where the use of ice slurry to cool air is more attractive include supermarket display cabinets or food cold stores (Nørgaard, 2005).

Field et al. (2003) analysed the behaviour of ice slurry in a supermarket display cabinet where the original evaporator was replaced by an evaporator that did not have an expansion device. When compared to chilled propylene glycol, the ice slurry delivered a high average cooling power, although it also increased the pumping power.

Nørgaard (2005) experimentally analysed ice slurry behaviour in a closed air circuit loop containing air conditioning equipment. The author found that, when compared to single-phase fluid, ice slurry increases the capacity of the air cooler by approximately 5–10%. For low flow velocity, the pressure drop for ice slurry is almost equal to that of the single-phase fluid whereas as flow velocity increases, the pressure drop for ice slurry becomes twice or more as high as for the single-phase fluid, increasing the pumping power similarly to that described by Field et al. (2003).

Rivet (2001) analysed the behaviour of an ice slurry supermarket indirect cooling system compared to that obtained for a single-phase system. Contrary to Field et al. (2003) and Nørgaard (2005), Rivet reports savings on pumps and distribution systems, although these savings are dependant on energy price policy and, in any case, do not compensate for the extra cost of generation and accumulation.

Kalaiselvam et al. (2008) numerically analysed the heat transfer and pressure drop characteristics of a tube-fin heat exchanger in ice slurry HVAC system. The authors obtained that the increase in heat transfer rate by the usage of ice slurry is 7.4% over conventional chilled water systems. The ice slurry usage increased the pressure drop in tubes, but the authors did not provide information about the increase in pressure drop.

In previous works (Illán and Viedma, 2009), the authors found that the use of ice slurry slightly improves the behaviour of a concentric tube liquid to liquid heat exchanger, compared to that obtained for single-phase refrigerant. Nevertheless, from the above literature review, it is not clear if the use of ice slurry also improves the behaviour of air coolers. The first aim of this work is to experimentally assess the behaviour of a commercial fan coil when ice slurry is used as secondary refrigerant and to compare experimental results to the predictions obtained using the basic correlations proposed in Illán (2008) and Illán and Viedma (2008a,b) to calculate pressure drop and heat transfer characteristics for ice slurry flowing through horizontal pipes.

The second objective is to evaluate whether the use of ice slurry provides advantages in air coolers compared to a single-phase secondary refrigerant. The behaviour of the studied fan coil will be analysed for different ice slurry flow conditions and compared to the behaviour obtained when a heterogeneous storage is used and only carrier fluid flows through the heat exchanger.

2. Experimental procedure

2.1. Experimental set-up

The air cooler used in these experiments was a Ciatesa KCN-75 fan coil. The coil had 8.8 mm inner diameter copper tubes