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Modeling of a fan-supplied flat-tube heat exchanger exposed to non-uniform frost growth

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Highlights

- A pseudo 3D model of a fan-supplied MCHX under frosting conditions is presented.
- A new approach with respect to air pressure loss prediction is proposed.
- A new correlation is developed to model frost effects on the friction factor.
- The model predicts the experimental data with an RMS deviation less than 3.8%.

Abstract

Reversible heat pumps for electric vehicles are being developed by the car industry to address cabin heating and improve energy efficiency compared to electric heaters. For this new application, the front, louvered-fin, microchannel heat exchanger (MCHX or flat-tube heat exchanger) of the A/C system happens to operate as an evaporator under frosting conditions. MCHX are particularly sensitive to frosting, and a model is required to improve the design. This paper presents a dynamic pseudo 3D model of a fan-supplied MCHX which predicts non-uniform frost growth, air pressure losses, airflow rate and thus, thermal performances. The air pressure losses are computed considering the maximum frost thickness along each air channel. A correlation was developed to take into account frost effects on the friction factor. The model was validated against ad hoc experimental data and was also able to predict experimental data from the literature.

Keywords: microchannel heat exchanger; louvered fins; performance prediction; airflow blockage; thermal-hydraulic performance; frost

Nomenclature

A_0	air-side heat transfer area [m^2]	**Subscripts**	
A_c	airflow cross section area [m^2]	*air*	related to moist air
c_p	specific heat at constant pressure [J.K^{-1}.kg^{-1}]	*avg*	average value between segment inlet and outlet
D_{a-b}	mass diffusivity of species *a* in *b* [m^2.s^{-1}]	*dry air*	related to dry air
D_{eff}	effective mass diffusivity [m^2.s^{-1}]	*eff*	effective value related to frost
f	friction factor [-]	*ext*	exterior
F_S	fin spacing [m]	*fan*	fan
h	enthalpy [J.kg^{-1}]	*fin*	fin
h_{conv}	convective heat transfer coefficient [W.K^{-1}.m^{-2}]	*fr*	frost
h_{mass}	convective mass transfer coefficient [m.s^{-1}]	*front*	frontal