Department of Systems Engineering and Engineering Management and BEETRU of Division of Building Science and Technology

Seminar Series

Prediction of Heat and Mass Transfer in defrosting an unresolved step in refrigeration system design

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Abstract
An important problem in the refrigeration industry is the formation and removal of frost layers on sub-freezing heat exchanger surfaces of air coolers. The frost layer is a porous structure of ice and air pockets that grows on the finned surfaces of the heat exchanger. Frost directly diminishes the performance and efficiency of the entire cooling system by presenting resistances to the air flow and heat transfer. To return the system to pre-frosted performance, the frost layer is melted by heating the surfaces of heat exchanger. This method is inherently inefficient, with the majority of the applied energy being lost to the surrounding environment.

This seminar presents a validated model for heat and mass transfer in frost melting based on local conditions at the fin surface. Non-invasive measurements of frost thickness and profile are taken from digitally reduced in plane photos of the frost layer through time. This visual method eliminates disturbances caused by contact measurements at the frost-air interface. The thermophysical properties and porosity of the frost are also estimated from digital image analysis. The visual techniques used to measure the change in frost thickness and porosity, the change in frost thickness during melting, and the change in the water droplet size during dryout, when combined with temperature and heat flux measurements, allow for a detailed analysis of the frost growth and defrost processes. New heat and mass transfer models are constructed from these measurements, and we analyze the defrost process through its distinctly defined stages: vapor diffusion, liquid permeation, and dry out.
Frost porosity at the start of defrosting has a significant impact on the vapor diffusion stage wherein a large portion of the applied heat to the surface is absorbed by the frost layer. Frost with low porosity (high density) absorbs more of the applied heat and exhibits higher defrost efficiency. The second stage of defrost is dominated by melting and permeation of the melt liquid into the overlying frost. Digitally computed frost front velocity is found to vary with the supplied heat transfer rate and frost porosity, which compares well to the visual measurement. Higher heat transfer rates result in larger melt velocity and thus shortened defrost time. Lower frost porosity has the effect of increasing the defrost time. Defrost efficiency for this stage is nearly 100% with little heat lost to the surroundings. Evaporation dominates the final stage of defrost. This stage inherently has the low defrost efficiency, as most of the supplied heat is lost through sensible heat exchange with the ambient air. A new heat transfer model for the wetted surface is proposed to capture both sensible and latent heat exchange effects. Latent heat exchange is correlated to an area reduction of the water droplets, which is expressed by a mass transfer coefficient.

About the Speaker
Dr. Frank Kulacki is Professor of Mechanical Engineering at the University of Minnesota. He received his education in mechanical engineering at the Illinois Institute of Technology and the University of Minnesota. His current research and scholarly interests include coupled heat and mass transfer in porous media, two-phase flow in micro-channels, natural convection heat transfer, heat transfer in metal foams, hybrid renewable energy systems, thermal energy storage technology, energy policy, management of technology, and the adaptation of computer-based technologies in engineering education. He has published 170 technical articles, 14 book chapters and reviews, 33 educational/professional articles, 29 technical reports, edited some 20 books and conference volumes and has resented more than 200 seminars and invited lectures. He is Editor of the SpringerBriefs in Thermal Engineering and Applied Science which has gained twenty titles in the past two years. He is the author of the audio visual digital text “Heat Transfer and Fluid Mechanics – A First Course”. His advisees include 20 doctoral students, 43 master’s degree students and 13 undergraduate research scholars. Twelve of his graduate students hold academic positions, including one university presidency.

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All are Welcome!

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