Advances in refrigeration and heat transfer engineering

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This special edition of Science and Technology for the Built Environment (STBE) presents selected high quality papers that were presented at the '15th International Refrigeration and Air Conditioning Conference' held at Purdue University during July 14-17 2014. All papers received additional review before being finally accepted for publication in this special issue of Science and Technology for the Built Environment. Altogether, 22 papers made it into this special issue that cover a wide range of topics, including advancements in alternative refrigerants, heat exchangers/heat transfer, nano-fluids, systems design and optimization and modeling approaches. Although CO_2 may perhaps have been the most researched and popular refrigerant during the past decade, R32 is being seriously considered lately as an alternative and environmentally friendly refrigerant for small systems due to its low Global Warming Potential (GWP).

Advances in Alternative Refrigerants

There are four papers in this category. Bansal and Bo (273) presented a technical assessment of environmentally friendly refrigerants (e.g., R32, a mixture of R32/R125 with 90%/10% molar concentration, R600a, R290, R1234yf, R1234ze and R134a) as alternatives to R410A for window air conditioners. R32 offers the best efficiency improvement over R410A in addition to 67.5% lower GWP. Majurin et al. (251) evaluated material compatibility of unsaturated hydro-fluorocarbon (known as hydro-fluoro-olefin, or HFO) refrigerants, and HFO refrigerants blended with R-32, to characterize equipment reliability risks associated with the use of next generation low GWP fluorinated refrigerant candidates. Bella et al. (282) presented a performance comparison of R410A with that of R32 in a packaged air-to-water unit using a scroll compressor and the effect of the circuit length in the finned coil of a packaged air-to-water reversible unit. R32 was found to be an acceptable refrigerant. Lawrence and Elbel (228) simulated the performance of a two-phase ejector and compared it with experimental data of R134a and CO_2

from previous studies. It was found that CO_2 ejectors can achieve somewhat better performance than R134a ejectors.

Advances in Heat Transfer and Heat Exchangers

There are a number of interesting papers covering a variety of subject areas including macro and mini-channels, micro-channels and microfins, and traditional areas such as condensation heat transfer.

Chien et al. (254) presented a modified general correlation to predict the saturated flow boiling heat transfer of R410A in horizontal macro and mini-channels. The experimental data included various tube diameters of 1.5, 3.0, 6.61 and 7.49 mm, mass fluxes of 100 – 600 $kg \cdot s^{-1} \cdot m^{-2}$, heat fluxes of 10 – 40 $kW \cdot m^{-2}$, saturation temperature of 5 – 15°C and vapor quality from 0.2 to 1. Lopez-Belchi et al. (270) determined experimental heat transfer coefficients of R32 in mini-channels and compared them with R410A data. The influence of saturation temperature (30, 35, 40, 45, and 50°C), flow velocity (from 100 to 800 $kg \cdot s^{-1} \cdot m^{-2}$), and vapor quality (from 0.05 to 0.9) on heat transfer coefficient and frictional pressure gradient were investigated. Khovalyg et al. (261) examined the flow boiling of R134a in 0.54 mm square parallel mini-channels with a particular focus on analyzing transient pressure drop of individual channels in a wide range of heat and mass flux conditions. They found better two-phase flow distribution between parallel mini-channels. Zou et al. (218) presented experimental results of R410A and R134a distribution in the vertical header of a reversible outdoor microchannel heat exchanger, where the distribution results of R410A and R134a were generalized with coefficient of variation, a flow regime map and a distribution function. Kondou et al. (253) investigated the condensation and evaporation of R744/R32/R1234ze(E) flow in a horizontal microfin tube. The condensation and evaporation heat transfer coefficient of R744 /R32/R1234ze(E) (9/29/62 mass%) was found to be lower than that of other mixtures, including R744/R32/R1234ze(E) (4/43/53 mass%) and R32/R1234ze(E) (40/60 mass% and 30/70 mass%). Rückert and Schmitz (244) measured the dynamic heat transfer coefficient of R134a in a small diameter horizontal pipe (i.e. an evaporator) of a cooling cycle that had a receiver tank filled with R134a, a pump and a condenser as other components. A numerical model was developed and validated with the experimental data. Pisano et al. (274) discussed the methodology to validate condensation heat transfer and pressure drop correlations in a finned-tube heat exchanger for a wide range of key parameters such as air velocity, condenser temperature, refrigerant mass flow rate and condenser sub-cooling. Col et al. (280) investigated the condensation heat transfer and pressure drop of mixtures of R1234ze(E) and R32 (23/77% and 46/54% by mass) in a single microchannel with 0.96 mm diameter, and analyzed the heat transfer penalization due to the mass transfer resistance occurring during condensation of these zeotropic mixtures.

Advances in NanoFluids

There are two papers that uncovered the fundamental understanding of nanolubricants and their effectiveness. Cremaschi et al. (283) presented experimental data of solubility and miscibility of three types of Al_2O_3 nano-lubricants with refrigerant R410A. Nanolubricant did not increase the two-phase pressure drop as compared to POE lubricant and at low and medium mass flux the pressure drop of nanolubricant was lower than the corresponding two phase pressure drop of refrigerant R410A and POE oil mixture. Fedele et al. (278) tested several nanolubricants, formed by Polyolester (POE) or mineral oil, as the base fluid, and titanium oxide (TiO_2) or single wall carbon nano-horns (SWCNH), as nanoparticles, in a dedicated heat pump system. However, contrary to some published data, no improvement was detected with 0.05 to 0.5 wt% of TiO_2 or 0.1 wt% of SWCNH in tested commercial oils.

Advances in System Design and Optimization

There are three papers that address some of the challenges and insights of future energy efficient system design and their usefulness, including an energy efficient refrigerator, separate sensible and latent cooling systems and a multi-functional variable refrigerant flow system (MFVRF). Mrzyglod and Holzer (201) presented challenges to design an energy efficient refrigerator that may consume less than 10 W electrical power. The design must overcome issues related to low cooling capacity demand, start/stop cycles and additional power consumption by control accessories. Nawaz et al. (279) studied the mass diffusivity of solid silica aerogels and silica aerogel coatings on metal foam substrates for separate sensible and latent cooling (SSLC) air-conditioning systems integrated with a solid desiccant based dehumidification device. Lee et al. (326) presented experimental results of a MFVRF system in heat recovery mode with a water heating system. The MFVRF system performance was increased by 18% in the heating main mode and cooling main mode tests. Field testing revealed that the hourly performance factor of the system could be improved from 2.18 to 3.16 due to heat recovery operation.

Advances in Modelling

The saying that "*there is nothing more practical than a good working theory*" qualifies here admirably. There are three very interesting papers covering topics such as Modelica-based dynamic modeling, slip ratio correlation and a two-dimensional numerical model for a mini-channel evaporator. Ling et al. (201) developed two Modelica based dynamic models to simulate the heat pump cycle for two drop-in refrigerants, R32 and the R32-based blend D2Y60, during steady state and transient operations. Both models were based on an efficiency-based compressor model, two control volume-based heat exchanger models, a control volume-based valve model, a segmented pipe model and a lumped-capacitance accumulator model. Laughman et al. (287) studied effect of the flow assumptions and specific slip ratio correlations on both the equilibrium operating point and the transient behavior of the cycle through both simulations and experiments. It is shown that equivalent simulations with different slip ratio correlations each have different equilibrium mass inventories. Hassan et al. (268) developed a two-dimensional numerical model for a mini-channel evaporator accounting for the variation of wall temperature and moist air properties in both longitudinal and transverse directions. Predictions from the current model differed with the ε-NTU approach due to the assumptions in the latter, such as no variation in moist air temperature and humidity ratio along the direction between tubes, no account for partially wet fin conditions, and constant average saturation line slope within a specific evaporator segment. Huang et al. (220) studied the design optimization of variable geometry Micro-Channel Heat Exchangers (MCHXs) for an automotive R134a and R290 condenser and a CO_2 gas cooler in air-conditioning systems to maximize capacity and reduce cost. The optimization study shows a 35 percent reduction in material and 43 percent savings in envelope volume for a variable geometry gas cooler for the same performance compared to a baseline conventional geometry design. In a subsequent study, Huang et al. (229) presented an air-to-fin heat and mass transfer model for a variable geometry MCHX operating under dry, wet and partially wet conditions. The proposed model allows for the most comprehensive and accurate analysis of microchannel evaporators and condensers.