A REVIEW ON ABSORPTION HEAT PUMPS AND CHILLERS USING IONIC LIQUIDS AS ABSORBENTS

Sumit K. Swarnkar¹, G. Venkataraman¹, Dereje S. Ayou², Joan Carles Bruno² and Alberto Coronas²*

¹Indian Institute of Technology Madras, Chennai, India
²CREVER, Dep. Mechanical Engineering, Universitat Rovira i Virgili, Tarragona, Spain
*Corresponding author: alberto.coronas@urv.cat

Keywords: Absorption heat pump, Absorption chiller, Absorbent, Ionic liquid.

Introduction: Absorption heat pumps and chillers are thermally activated systems that use heat, instead of an electrical driven system (compressor), to produce chilled water for air conditioning and refrigeration applications. They are widely acknowledged as a prospective candidate for efficient and economic use of solar energy, waste heat recovery methods for cooling and heating applications. The conventional working fluid (absorbent + refrigerant) combinations used in these systems include lithium bromide + water (LiBr + H₂O) and water + ammonia (H₂O + NH₃) where LiBr and H₂O are the absorbents, respectively. These conventional working pairs are characterized by some drawbacks such as low (sub-atmospheric) operating pressure, crystallization and corrosion for LiBr + H₂O system and low system performance, need for rectification process of the refrigerant stream and high driving heat source temperature for H₂O + NH₃ system. In order to overcome these drawbacks of the conventional working pairs and to extend the operating range of absorption systems for different boundary conditions, various mixtures of natural refrigerants such as ammonia (NH₃), carbon dioxide (CO₂) and water (H₂O) with Ionic Liquids (ILs) have been researched for absorption heat pump and chiller processes over years [1-22].

The objective of this paper is to present a review of the scientific literature on absorption heat pumps and chillers working with ILs and natural refrigerants (NH₃, H₂O and CO₂). It highlights both theoretical and experimental work done by several researchers on this topic, as well as on the literature survey for the thermodynamic property models used for the prediction and correlation of thermodynamic properties.

Discussion: We have discussed the performance of ILs as new absorbents in absorption systems based on system performance parameters such as energy efficiency (COP), solution circulation flow ratio (f), cooling/heating capacity and temperature lift. The influence of the working fluid mixture on the performance and application/working range of the absorption systems under different operating conditions are also discussed.

For heat pumps and chillers with ILs + NH₃: The performance of a single-effect absorption cycle using [bmim][BF₄], [bmim][PF₆], [emim][EtSO₄] and [emim][TF₂N] as absorbents for NH₃ are studied in the literature [5]. A comparison with the conventional absorbent (H₂O) was also investigated for the same cycle configuration at different cycle operating conditions. In the reviewed paper it has been found that the dependency of COP...
on the operating conditions varied for different IL absorbents for the same refrigerant. According to Kotenko et al. [5], for some ILs and operating conditions the COPs can be higher than the values for the conventional NH₃+H₂O mixture, but these COPs values decreases significantly more when the temperature lift increases in comparison with the conventional mixture. The best simulation in terms of the COP corresponds to the working mixture NH₃+[bmim][PF₆].

For heat pumps and chillers with ILs + H₂O: The functional capability of replacing LiBr by ILs as absorbent for H₂O in absorption heat pumps and chillers has been demonstrated using theoretical absorption cycle analysis as well as in few experimental works [2,6-9]. Yokozeki and Shiflett [2] used twelve ILs with H₂O in a simple cycle configuration analysis using COP and f as comparing parameters, which explains the efficiency and compactness of the system. In the analysis [mmim][{(CH₃)2PO₄} and [emim][{(CH₃)2PO₄} show the best results, with the highest COP and lowest f values. The COP result was about 85-88% that of the water+LiBr system. The results of cycle simulations indicate that IL + H₂O system could be competitive with H₂O + LiBr system particularly for optimized ILs.

For heat pumps and chillers with ILs + CO₂: A few absorption refrigeration system analyses are available in the literature. Martin and Bermejo [20] reported that the process with ILs has a lower COP than H₂O + NH₃ and H₂O + LiBr systems due to necessity of operating with a higher solution flow rate. However, near-optimum performance is obtained in a wide range of process conditions.

Summary: The absorption cycle, mainly single-effect, analysis found in the literature indicates that COP of the absorption heat pumps and chillers with the adequate ILs can be similar to the COP of the conventional working pairs. But, other advantages like low driving temperature, high temperature lift, compact size, low initial cost (no rectifier cost) and no corrosion can be brought to the system by using ILs which make ILs interesting novel absorbent for natural refrigerants. The correctness of the cycle analysis is highly dependent on the accuracy of the thermodynamic properties of working mixture. Activity coefficient and equation of state (such as cubic and PC-SAFT) models are used so far mainly for the property modelling of working fluid mixtures with ILs. The viscosity and wetting performance of ILs influences the heat and mass transfer in the absorber and desorber/generator which highly influences the cooling/heating capacity of the absorption system.

Acknowledgment: The authors gratefully acknowledge the support of the FP7-People-2010-IRSES Program (NARILAR -New Working Fluids based on Natural Refrigerants and Ionic Liquids for Absorption Refrigeration, Grant Number 269321).

References:


