PERFORMANCE ANALYSIS OF ABSORPTION HEAT TRANSFORMERS USING IONIC LIQUIDS WITH 2,2,2-TRIFLUOROETHANOL AS WORKING FLUID PAIRS

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Introduction: Enormous energy is dissipated as low temperature waste heat in the industry. Absorption heat pumps can recover low temperature waste heat from various industrial processes and upgrade it to deliver useful heat for heating and hot water supplies. The relative freedom from noise and vibrations and, above all, the possibility to use waste heat and renewable energy heat sources such as solar energy to energize the systems are prevailing arguments in favour of sorption systems. The drawbacks which are most often quoted are heavy weight and large footprint, lack of understanding of the process, and, above all, the relatively high first cost.

Unlike electrical driven heat pumps, absorption heat pumps can also work as heat transformers. The purpose of an Absorption Heat Transformer (AHT) cycle, also known as Absorption Heat Pump Type II, is to use heat at an intermediate temperature level (T_m), for example, 60 - 80ºC and to upgrade a portion of it to high temperature heat (T_h), for example, at 110ºC or higher and transfer this heat out of the cycle. It is important to note that a heat transformer is driven by recovery waste heat only, i.e. no primary energy is needed in the form of high temperature heat (absorption heat pumps) or electrical energy (compression heat pumps) apart from a small amount of electricity for pumps. The most used working fluid for absorption heat transformers has been water + lithium bromide (H_2O + LiBr) due to the excellent properties (no toxicity or flammability, high latent of water as a refrigerant, no need for rectification to separate the mixture, etc). But the use of corrosion inhibitors is necessary and also the crystallisation problems have prevented a greater use of absorption heat transformers and their application has been restricted mainly to absorption chillers for cooling applications.

The objective of this work is to study the performance of AHTs using two working fluid pairs composed of Ionic Liquid(ILs): 2,2,2-trifluoroethanol (TFE) + 1-ethyl-3-methylimidazolium tetrafluoroborate ([emim][BF4]) and 2,2,2-trifluoroethanol + 1-butyl-3-methylimidazolium tetrafluoroborate ([bmim][BF4]), where TFE is the refrigerant and the ILs ([emim][BF4] and [bmim][BF4]) are the absorbents [1-6].

Simulation: A modified single-effect (SEAHT) and double-effect absorption cycle (Double AHT) configurations (Fig. 1 and Fig. 2) were selected for analysing the performance of the two working pairs. The thermodynamic model of the cycles developed based on the thermodynamic properties of the working pairs and on the mass and energy balances of each component in the cycle were built using the software Engineering Equation Solver (EES).

The cycle performance has been analysed in terms of the Coefficient of Performance (COP), Exergy Efficiency (ECOP) and the Gross Temperature Lift (GTL), that is, the difference between the output heat and the waste heat input temperatures, as a function of the solution concentration, heat exchanger efficiency and sink and input temperatures. The presented performance analysis is compared with those using more conventional working fluid pairs.

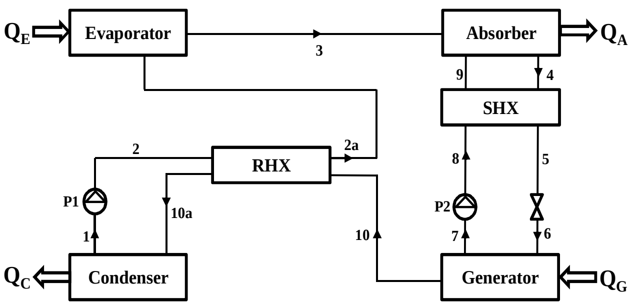

Figure 1. Schematic diagram of modified SEAHT[7].

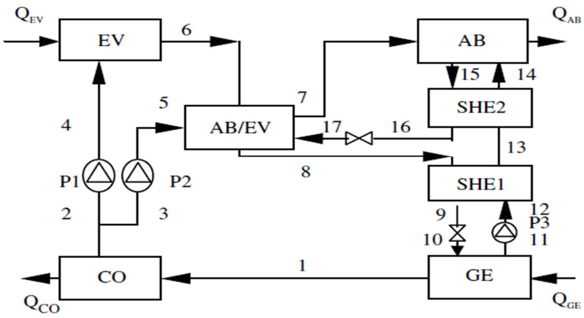

Figure 2. Schematic diagram of Double AHT[8].

Results and discussion: The coefficient of performance and exergy efficiency values of the new working fluid pairs (TFE + [emim][BF4] and TFE + [bmim][BF4]) are lower than those of H_2O + LiBr. When the condensing and generator/evaporator temperatures and concentration difference between the strong and weak solutions are 35^{o}C, 70^{o}C and 7.5% respectively for the cycle configuration in Fig.1, the COP reach similar values 0.455, 0.464 and 0.488 for TFE + [emim][BF4], TFE + [bmim][BF4]) and H_2O + LiBr but the available output heat per unit mass of refrigerant for the mixture of TFE with the ILs is much lower than that of the conventional working pair (H_2O + LiBr). For instance for the same conditions the useful output heat for TFE + [emim][BF4], TFE + [bmim][BF4] and H_2O + LiBr are 209.5kW, 213.6kW and 2369kW respectively. The ECOP and internal GTL values for the above operating conditions considered for modified single-effect cycle configuration (Fig.1) are 0.541 and 38 ^{o}C for TFE + [emim][BF4], 0.547 and 39 ^{o}C for TFE + [bmim][BF4], 0.693 and 25 ^{o}C for H_2O + LiBr.

Summary: The results of this work will be not only relevant for the recovery of industrial waste heat but also for thermal solar applications where in winter season the outlet temperature from the solar collectors could be upgraded up to a level suitable for the use of this heat in conventional heating supply systems in buildings. Even though the COP values of the systems with TFE + [emim][BF4] and TFE + [bmim][BF4] are lower than H_2O + LiBr systems the advantage of high working pressure, wide solution field/operating range, no crystallization and more weak corrosion tendency make these working pairs one of the potential candidate for replacing the conventional working fluid pairs. A modified single-effect cycle configuration is more convenient to reach high cycle performance (COP) due to the subcooler existing in the refrigerant circulating side of the cycle whereas the double absorption heat transformer (Fig.2) is more suitable for high temperature lift.

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