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Performance of a modified zeolite 13X-water adsorptive cooling module powered by exhaust waste heat

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ABSTRACT

A modified adsorption cooling module with a working pair of 13X zeolite-water used for engineering truck air-conditioning driven by engine waste heat is presented in this paper. The cooling powers at different evaporating temperatures for the module were first tested, and the cycle operating characteristics of the module at different cooling powers were then analyzed and discussed. The performance of the cooling module is found to have a strong coupling with exterior ambient parameters such as the heat source temperature (T_{hs}), ambient temperature (T_a), air velocity (v) and air relative humidity (φ). Experiments were carried out systematically and analyzed in detail to study the effects of the ambient parameters on the module performance. Our results indicate that the demonstrated cooling module has a good performance, and the minimum evaporating temperatures corresponding to the cooling powers of 2.0 W and 10.5 W are 0.7 °C and 16.2 °C, respectively, under the conditions of T_{hs} at 325 °C, T_a at 18 °C, φ at 70%, and natural convection. Based on the presented module, a preliminary multiple module adsorption air conditioning system for engineering truck driver's cab was also proposed in this work.

1. Introduction

As a consequence of the Kyoto Protocol and its predecessor, the Montreal Protocol, environmental consideration will play an important role in the choice of a refrigeration or heat pump system [1]. Effective energy utilization is also required for prevention of global warming and decrease in the use of fossil fuels. Heat driven sorption heat pump/refrigeration systems have drawn considerable attention due to their lower environmental impact and large energy saving potential as the systems using neither ozone depleting gases nor the fossil fuel or electricity as driving source [2–5]. Zeolite-water heat pump system was originally proposed by D. I. Tchernev [6] for effective use of low temperature heat sources such as the solar heat and waste heat.

Waste heat adsorption cooling is a clean process which does not contribute at all to global warming. At present, car air conditioning systems using HFCs as refrigerants have very high HFC leakage rates (20–40% per year) [1,7,8]; moreover their annual operation time is very short. Waste heat adsorption cooling is, therefore, highly competitive from the global warming point of view even with low COP. As a good example, adsorption systems could be applied in automotive air conditioning systems in which heat recovered from the exhaust gas could be re-used as the powering source. Some studies [9–18] have been carried out in this direction, but to date no commercial product exists, which is mainly due to the need for light and compact units. This brings a great challenge for adsorptive cooling to be realized and widely applied, and technological breakthroughs are still required.

Zhu et al. [19] designed a waste-heat-powered adsorption cooling module with 400 g of zeolite and 120 g of water as the adsorbent-adsorbate pair to produce chilled water for fish preservation in a fishing boat. The adsorption cooling module was different from the conventional adsorption systems, because, as an independent and integrated micromation adsorption refrigeration unit, it had a very simple structure which was comprised of a generator/adsorber and an incorporated condenser/evaporator. No moving parts or controlling valves were included. It is noteworthy that we could easily assemble such an adsorption cooling system with different cooling power by utilizing different quantity of modules. Since that, similar adsorption modules with different adsorbent-adsorbate pairs such as silica gel and water [20], zeolite-active carbon compound and water [21], activated carbon PX21 and NH_3 [22], active carbon and ammonia [23,24], and domestic type of charcoal and methanol [25,26] were successively studied and reported in theoretical modeling and/or experimentally.

Despite the above efforts, heretofore no module is successfully applied in automotive air conditioning. In the present study,

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