Applied Thermal Engineering 47 (2012) 119–125

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Design, fabrication, and experimental demonstration of a microscale monolithic modular absorption heat pump

Matthew D. Determan, Srinivas Garimella*

Sustainable Thermal Systems Laboratory, George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA

ARTICLE INFO

Article history:
Received 3 August 2011
Accepted 19 October 2011
Available online 29 October 2011

Keywords:
Absorption
Miniaturization
Heat transfer
Mass transfer
Microchannel

ABSTRACT

The first ever conceptualization, design, fabrication and successful experimental demonstration of a thermally activated microscale absorption heat pump for miniaturized or mobile applications is reported here. Several-fold enhancements in coupled heat and mass transfer possible in microscale passages remove significant hurdles that have hindered the implementation of thermally activated heat pumps. Cooling capacities of 100 W–10 s of kW are possible through minor changes in component geometry. These mass-producible miniaturized systems can be packaged as monolithic full-system packages or as discrete, distributed hydronically coupled components integrated into buildings. A 300 W nominal cooling capacity ammonia–water absorption heat pump with overall dimensions of 200 × 200 × 34 mm and a mass of 7 kg was fabricated and tested over a range of heat sink temperatures from 20 to 35 °C with 500–800 W of desorber heat input to yield cooling duties of 136–300 W.

1. Introduction

Thermally activated systems have the ability to produce useful cooling from waste heat streams such as engine exhaust or directly from the combustion of liquid fuels. They offer independence from the constrained electricity supply landscape, and also are ideal candidates for the utilization of energy from already combusted fossil fuel that is currently exhausted at high thermal availabilities. Applications that could benefit from miniaturization of absorption system technology include waste heat recovery and upgrade for heat-driven chillers and heating and air-conditioning systems, water heating and cogeneration systems, vehicular, marine and refrigerated transport of food, medicines, vaccines, and other perishable items. Specifically, thermally driven systems can provide space cooling and heating, and can be readily configured to provide the other essential building energy requirement, water heating. Furthermore, if designed as part of a combined heating and power (CHP) systems through the use of microturbines and fuel cells, they would supply the requisite electrical power too. This integrated energy system would combine all of the essential energy intensive functions of a building into one package. Until recently, such systems were restricted to large facilities or campuses due to an unavailability of small-scale thermally activated heating and cooling systems.

Few concepts for miniaturized or mobile thermally activated cooling systems exist in the literature, and even in such cases, successful fabrication and testing has been elusive. Grzyll and Balderson [5] developed a 19.9 kg adsorption system using calcium oxide that provided 150 W for 4 h. Rahman [8] investigated the use of a Brayton cycle to provide mobile cooling for soldiers. The system was estimated to have dimensions of 0.47 × 0.279 × 0.368 m. No estimate of the mass of the system was provided. No prototype was developed in this study, and no experimental results were presented. Salim [9] proposed a thermally activated mobile ejector refrigeration system for use in automobile cooling. The system used waste heat from the engine coolant at 90 °C, and from the exhaust gas (220–990 °C depending on driving conditions) to drive the refrigeration cycle. A high pressure vapor stream is expanded through a convergent–divergent nozzle to induce a secondary flow of refrigerant from the evaporator. While the system still requires power to drive a pump, it is a small fraction of the power required to drive the compressor in current automobile vapor compression systems. A thermodynamic model of the proposed system was described and COPs of 0.5–1.04 were predicted for several heat input methods. However, in this case also, experimental results were not reported. Wang et al. [11] analyzed a combination of a Rankine power cycle and a vapor compression cycle for use as a portable cooling system. The high COP of the vapor compression cycle is utilized while also taking advantage of the heat-actuation provide by the incorporation of a Rankine power cycle.

Ernst and Garimella [2–4] designed and fabricated an R134a vapor compression refrigeration system for completely

* Corresponding author. Tel.: +1 404 894 7479.
E-mail address: sgarimella@gatech.edu (S. Garimella).

1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2011.10.043