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Novel compact sorption generators for car air conditioning

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ARTICLE INFO

Article history:
Received 31 October 2008
Accepted 22 November 2008
Published online 13 December 2008

Keywords:
Activated carbon
Air conditioning
Adsorption system
Ammonia
Automobile
Design
Prototype
Heat recovery

ABSTRACT

A prototype compact generator using the activated carbon–ammonia pair based on the plate heat exchanger concept has been designed and built at Warwick University. The novel generator has low thermal mass and good heat transfer. The heat exchanger uses nickel-brazed shims and spacers to create adsorbent layers only 4 mm thick between pairs of liquid flow channels of very low thermal mass. The prototype sorption generator manufactured was evaluated under EU car air conditioning test conditions.

The prototype sorption generator is described and its experimental performance reported. While driven with waste heat from the engine coolant water (at 90 °C), a pair of the current prototype generators (loaded with about 1 kg of activated carbon) operating out of phase has produced an average cooling power 1.6 kW with about 2 kW peaks. The typical average COP obtained is 0.22.

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Nouveau générateur compact à sorption pour le conditionnement d'air automobile

RÉSUMÉ

Mots clés
Charbon actif
Conditionnement d'air
Ammonica
Automobile
Système à adsorption
conception
Essai

Un prototype du générateur compact, basé sur le concept des échangeurs de chaleur à plaques et utilisant la paire charbon actif-ammoniac, a été conçu et construit à l'Université de Warwick. Le nouveau générateur a une faible inertie thermique et un excellent transfert de chaleur. L' échangeur utilise des plaques ayant des micro-canaux et des intercalaires brasés au Nickel pour créer des couches d'adsorbant de 4 mm d'épaisseur entre les paires de plaques à l'intérieur desquelles circule le fluide liquide. Le prototype du générateur à sorption ainsi fabriqué a été testé suivant des conditions prescrites par la Norme Européenne de la Climatisation Automobile.

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doi:10.1016/j.ijrefrig.2008.11.010

Prototype
Récupération de chaleur

Le prototype du générateur à sorption est décrit et ses performances experimentales présentées. Une paire dudit prototype (contenant chacun 1 kg the charbon actif), operant avec déphasage et ulisant des pertes thermiques en provenance de l'eau de refroidissement de moteur (à 90 °C), a produit une puissance frigorifique moyenne de 1.6 kW avec une valeur maximum de 2 kW. La valeur typique du COP moyen est de l'ordre de 0.22.
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Nomenclature

Abbreviations

COP	coefficient of performance in cooling
MACS	mobile air conditioning system
NH_3	ammonia
PLATEX	plate type heat exchanger
SCP	specific cooling power
SOPLATEX	sorption plate heat exchanger

Symbols

A	surface area (m^2)
K-value	flow rate corresponding to a pressure drop of 1 bar ($m^3\,h^{-1}$)
T	temperature (°C)
TEV	thermostatic expansion valve
U	overall heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)

Subscripts

A	adsorption
C	condensation, condenser
E	evaporation, evaporator
G	generation, generator

1. Introduction

In 2005, the first experimental prototype of a compact generator using the monolithic carbon–ammonia pair was developed at Warwick University. The compact generator was based on the concept of a plate heat exchanger (PLATEX) as illustrated in Fig. 1. The main objectives were to demonstrate the manufacturing feasibility of a compact generator based on PLATEX and to evaluate its thermal performance when mounted on a full cooling machine. The mechanical and thermal behaviour of the prototype were satisfactory but the cooling performance obtained (SCP ~0.150 $kW\,kg^{-1}$ carbon and COP ~0.120) were poor but predicted well by a theoretical model (Critoph and Metcalf, 2004). The performance limitations were mainly due to the design and manufacturing process of the prototype (Tamainot-Telto, 2005). Design improvements were later carried out on the configuration, reducing the thermal mass and enhancing the heat transfer (Critoph, 2006). A new manufacturing process for a fully welded compact generator that withstands both high pressure (up to 30 bar) and high temperature (up 200 °C) is now established.

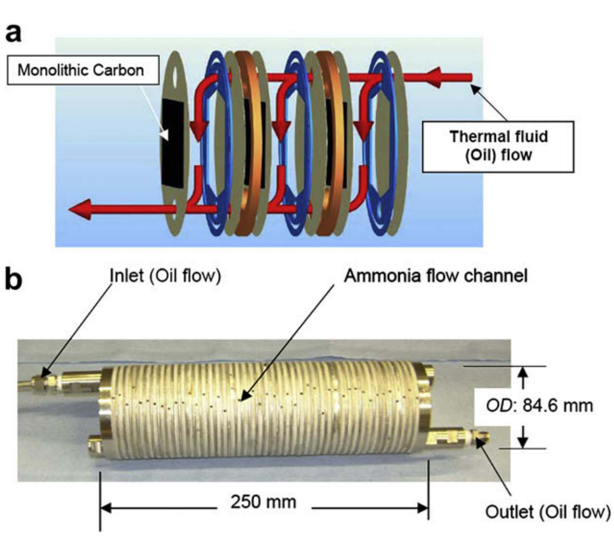

Fig. 1 – Compact sorption generator – (a) concept based on plate heat exchanger (PLATEX), (b) first experimental prototype (SOPLATEX) (Tamainot-Telto, 2005).

2. Novel sorption generator

The novel sorption generator is a nickel-brazed stainless steel design with 29 layers of active carbon adsorbent each 4 mm thick. By incorporating the carbon adsorbent in thin layers, conduction path lengths through the material are reduced and the area for fluid heat transfer is increased which enables rapid temperature cycling and thus a high SCP. The separating stainless steel plates are constructed from chemically etched shims with 0.5 mm square water flow channels on a 1 mm pitch. These channels give a high heat transfer coefficient and a large heat transfer area, further improving heat transfer performance. The square design ensures equal flow path lengths in every channel and therefore even heating and cooling of the adsorbent. The internal pressure (up to 20 bar when condensing at 50 °C) is withheld by the stainless steel shims which act as supporting webs to the outer wall, which only needs to be 3 mm thick despite being straight. The open end of the front face as shown in Fig. 2 is used to insert and remove the adsorbent in order that a range of adsorbents can be tested. Fig. 3 shows both a conceptual drawing and a photograph of the unit fitted with water manifolds and pressure flanges prior to testing. The top and bottom 'ammonia flanges' are necessary due to the open face and would be unnecessary in an eventual completely enclosed unit. The end pressure flanges are necessary to prevent

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