# COMPARATIVE STUDY OF THREE DIFFERENT ADSORBENT-ADSORBATE WORKING PAIRS FOR A WASTE HEAT DRIVEN ADSORPTION AIR CONDITIONING SYSTEM BASED ON SIMULATION

**[1]H. R. Ramji, [2]S. L. Leo, [1]I. A. W. Tan & [1]M. O. Abdullah**
[1]Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, East Malaysia
[2] International College of Advanced Technology Sarawak (ICATS), Jalan Canna, Off Jalan Wan Alwi, Tabuan Jaya, 93350 Kuching, East Malaysia
E-mail: amomar13@gmail.com ; amomar@feng.unimas.my

**ABSTRACT**

In a previous study, a laboratory prototype of a thermal-driven adsorption air conditioning system employing activated carbon as adsorbent and methanol as the refrigerant was successfully developed. The experimental results employing the prototype obtained a COP of 0.19 and cooling capacity *Q* of around 320 kJ. The cooling power *P* yielded ~ 0.64 kW and it was able to produce chilled air temperature $T_{chill,out}$ of around 22 °C. In the present study, further works are conducted via simulation to carry out "what-if" analysis viz. to determine the optimal adsorbent-adsorbate working pair based on the prototype. Three types of refrigerants, coupled with activated carbon, were considered in this study, namely (1) methanol (similar to the experimental works); (2) ammonia; and (3) water. The simulation results obtained showed that activated carbon-water pair produced the best cooling compared to activated carbon-methanol and activated carbon-ammonia working pairs, as far as present study is concerned. The methanol and ammonia showed a COP of 0.37 and 0.4, respectively. The average $T_{chill,out}$ produced by methanol was around 15 °C while the temperature produced by ammonia was slightly higher around 19 °C. The cooling capacity *P* for methanol and ammonia showed a value of 0.65 kW and 0.50 kW, respectively. Activated carbon-water pair simulated to yield a higher COP of 0.58 with *Q* at 480 kJ mainly due to high heat of evaporation, which was able to produce average $T_{chill,out}$ of 12 °C with cooling power of approximately 1 kW.

**Keywords:** *Adsorption air conditioning system; Activated carbon; COP; Cooling power; Simulation; Waste heat.*

## 1. INTRODUCTION

The recent European Union directive on mobile air conditioning (MAC) phases out system using HFC-134a as refrigerant on the EU market from 2008 onwards (Reference). This leads to other alternative systems such as adsorption air conditioning system. Air conditioning technology is required to evolve due to the new environmental regulations which are concerning about the depletion of the ozone layer thus causing global warming. As a result, this trend has led to a strong demand for a new air conditioning technology (see e.g. Leo SL, Abdullah MO, 2009) [1]. As far as automobiles are concerned, unfortunately, no working adsorption cooling system has been practically run due to various restrictions - in particular due to sizing and cooling capacity limitations (Abdullah et al, 2011) [2].

There were several prototypes of adsorption refrigeration systems reported in literature, most of which were for ice making industry and others were designed for air conditioning purposes. Wang et al. (2001) [3] have reviewed an adsorption refrigerator driven with a heat source temperature of 100 °C. The refrigerator could obtain specific refrigeration power for 5.2 kg-ice /day per kg activated carbon with SCP of 150 W/kg adsorbent and a COP close to 0.5. In another study done by Wang et al. (2001) [3] on adsorption solar ice maker, 5-7 kg-ice/day per square meter solar collector could be produced continuously in well lighted condition, making use of solar energy.

Meanwhile Tso et al. (2012) [4] had developed a chiller system powered by waste heat employing activated carbon-sodium silicate/calcium chloride. The outcome was chilled water temperature of 9 °C utilizing waste heat temperature of 85 °C as driving source. A COP and SCP of 0.65 and 380 W/kg-adsorbent were obtained respectively in their study. The corresponding adsorption-desorption cycle time of the operation showed that one full cycle could be completed optimally in 360 seconds.

Xia et al. (2009) [5] had performed an analysis on an adsorption chiller employing silica gel-water pair with a methanol evaporator for cooling purposes. They obtained a COP of 0.39 with the heat source temperature of 82.5 °C, cooling water temperature of 30.4 °C and the temperature of the chilled water produced was 12 °C.

Meanwhile, Sato et al. (1997) [6] had presented a multiple-stage adsorption air conditioning system for vehicles. Although the efficiency of the multiple-stage adsorption system was improved, the size of the system also increased