Test Platform and Methodology for Model Parameter Identification of Sorption Heat Pump Modules

Corey BLACKMAN[1,2]*, Chris BALES[1], Eva THORIN[2]

[1]Dalarna University, Solar Energy Research Centre, Borlänge, Sweden
[2]Mälardalens University, School of Business, Society & Engineering, Västerås, Sweden

*Corresponding Author
Contact Information (+46733167042, cbl@du.se)

ABSTRACT

Sorption heat pumps are employed in various heat-driven cooling and heat pumping applications. These heat pumps may be driven by solar energy, natural gas, biogas, geothermal energy or waste heat. Given that a plethora of heat sources and sorption materials can be exploited for different applications, various sorption heat pump modules have been developed. The sorption modules are pre-engineered sorption components for increased ease of sorption system development, improved cost effectiveness and reduced system complexity for various applications. However, in the design of sorption modules, component and system modelling and simulation are useful in the process of determining the optimal candidate of several possible sorption working couples for a given application. A test platform has been developed and a test methodology devised for the rapid characterisation of the transient behaviour of the sorption modules. The testing apparatus was used to derive various model parameters to be used for validation of a dynamic sorption module component model. The test method was analogous to that employed for dynamic testing and performance modelling of electrochemical accumulators (i.e. electric batteries) given the similarities between them and sorption modules (also known as thermochemical accumulators). The model parameter identification was based on various heating and cooling power performance parameters as a function of state of charge (SoC) of the sorption modules. A 7-step procedure was used to characterise the performance of the sorption modules based on experimental data. A reference performance for charge and discharge of the sorption modules was measured followed by several measurements at 'off-reference' conditions. Performance curves for 'off-reference' conditions were then correlated to reference conditions to generate performance curves that describe the transient cooling and heating power delivery of the sorption module at any point within the test range. Results showed that the discharge performance of the sorption modules could be predicted within a reasonable margin of error with a test run sequence of 39 cycles.

1. INTRODUCTION

A sorption heat pump module or simply sorption module is a pre-engineered sorption component designed for increased ease of sorption system development and reduced system complexity for various applications. A sorption module comprises two cylindrical vessels with integrated jacket-type heat exchangers. Within the cylindrical vessels, a proprietary matrix material is employed, where one or both matrices is infused with a salt (alkali halide) capable of absorbing and desorbing a refrigerant such as ammonia or water. If only one of the vessels of the sorption module contains salt, the salt containing vessel is designated the name of reactor (R) with the other vessel, which only contains matrix material, denominated as condenser-evaporator (CE) [1]. In the case where both cylindrical vessels house a salt infused matrix the vessels are both considered reactors and are labelled reactor A (RA) and reactor B (RB). The sorption modules operate like thermal batteries where they are 'charged' with thermal energy from a heat transfer fluid (HTF) and 'discharged', delivering thermal energy in the form of heating and cooling. Consequently, a testing methodology similar to that used for electric batteries was employed [2]. A test platform was developed, capable of carrying out a wide range of tests at different HTF temperature levels with minimum manual intervention. The test platform is purposed to characterisation of the transient behaviour of the sorption modules for sorption component and system modelling and simulation in a time effective and reliable manner. The model is to be used in dynamic simulations of sorption heat pumps.

2. TEST SETUP

The test platform comprises two hydraulic loops; loop A and loop B. Loop A was connected to the R or RA where HTF supply temperatures could be set from 20°C to 120°C ± 0.2°C and 121 to 200°C ±1°C. Loop B had

HTF supply temperature set points between 5°C and 80°C ± 0.2°C and was connected to the CE or RB heat exchanger of the sorption module. The fluid flow rate in the Loop A was measured with an Omniflo FTO-4 turbine flow sensor (measurement uncertainty ± 0.75 l/h). Inlet and outlet temperatures of the R, RA, CE and RB heat exchangers were measured using PT100 resistance temperature sensors (4-wire, class A, uncertainty ± 0.1°C) with probes that were placed directly into the fluid stream. All data was recorded with a datalogger at a 1 second time interval and results subsequently exported as 90 second averages for graphing. All piping as well as the sorption modules were insulated with 50mm thick rock wool insulation.

3. METHODOLOGY

Sorption modules containing various sorption materials were tested in the automated test apparatus. The modules were cycled through a number of cycles where input fluid temperatures, flow rates and SoC were varied.

3.1 Test Sequences
The test sequences carried out for each sorption module covered a set of 39 cycles where 1 cycle corresponded to charge immediately followed by discharge of the sorption module. During charge, the difference between supply temperature to the R or RA and that to the CE or RB is defined as the driving temperature difference (ΔT_D). While during discharge the difference between supply temperature to the R or RA and that to the CE or RB is defined as the temperature lift (ΔT_L). SoC during charge was defined as the ratio of total heating energy rejected from the sorption module compared to maximum heating energy rejection at reference conditions. During discharge the SoC was the ratio of total delivered cooling energy from the sorption module to maximum cooling energy delivery at reference conditions. For each sorption module, the following was carried out:

1. Three complete reference cycle measurements with fixed flow rate, driving temperature difference and temperature lift. That is, 3 complete cycles carried out under identical reference conditions.
2. A set of 4 complete 'off-reference' cycle measurements with fixed HTF flow rate and driving temperature difference but at 4 different temperature lifts. Each cycle with a unique temperature lift point was run 3 times for a total of 12 cycles.
3. A set of 4 complete 'off-reference' cycle measurements with fixed HTF flow rate and at reference temperature lift but at 4 different driving temperature differences. Each cycle with a unique driving temperature difference point was run 3 times for a total of 12 cycles.
4. A set of 4 incomplete cycle measurements (where SoC is lower than 100% at the end of charge) with fixed HTF flow rate at reference driving temperature difference and reference temperature lift. Each cycle with a unique SoC point was run 3 times for a total of 12 cycles.

3.2 Model Parameter Identification
1. Average performance curves of reference and 'off-reference' measurements at each unique driving temperature difference, temperature lift and SoC point were plotted.
2. Curve fitting of the sorption module performance curves were carried out and curve coefficients correlated to the reference curves.
3. Correlations were derived to characterise the effects of driving temperature difference, temperature lift and SoC on the reference performance curves.
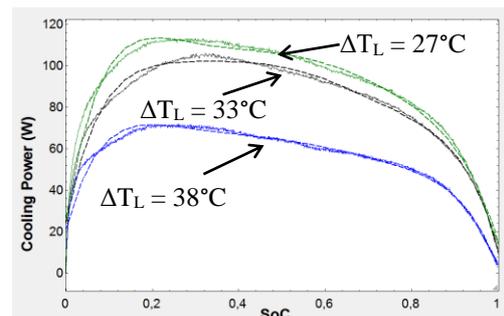
Figure 1 - discharge curves showing measured cooling power (solid lines) and curve fits (dashed line) at temperature lifts of 27°C, 33°C and 38°C.

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