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Antoine Dalibard

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Advanced control strategies of
solar driven adsorption chillers

Dipl.-Ing. Antoine Dalibard

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Abstract

This thesis reports on improvements in controlling solar driven adsorption chillers. Since simulation is used as main research method, a part deals with the modelling of the main system components. The control problematic is investigated in a first approach considering the chiller alone and in a second approach on the system level.

The modelling of solar collectors, adsorption chillers and closed wet cooling towers is presented first in a state of the art overview. An existing solar collector model is improved so it can be used in transient conditions with small time steps. A model for adsorption chillers which uses physically relevant lumped parameters is being developed and presented. Different heat recovery concepts are integrated in the model as well as the mass recovery between the two adsorbers at the end of the cycle. Finally, an existing model for wet closed cooling towers is further developed in order to increase the model accuracy during wet to dry regime switching phases. All the models are implemented in the transient simulation platform TRNSYS and compared with measurement data of a system in operation.

The potential for performance improvement of the chiller through the control of internal parameters is investigated. The adsorption/desorption duration has a strong influence on both cooling capacity and efficiency of the chiller. Therefore it is a crucial parameter which needs to be controlled in order to improve the chiller efficiency during operation. Different ways of performing heat recovery have been investigated. Concepts with internal circulation (with no connections to heat source and/or heat sink) show the best results since the chiller COP can be significantly improved (in the best case 35 % in comparison with the reference case without recovery) without decreasing the cooling power. The heat recovery shall not last too long since, above a certain duration (that depends on the heat recovery concept used), no more COP improvement is possible and increasing further the duration leads only to a cooling capacity reduction. The concept of mass recovery is also a good way to increase the chiller efficiency. A proper adjustment of the mass recovery duration allows to increase both COP and cooling power (15 % and 3 % respectively in comparison with the reference case). In the case of combined heat and mass recovery, mass recovery should be applied first in order to take advantage of the higher pressure difference between the two adsorber beds. In the best case, up to 45 % COP increase can be expected with only 6 % of cooling capacity reduction (compared to the reference case) if both the heat and mass recovery durations are properly adjusted.

Then, the improvement potential of controlling the adsorption/desorption duration during chiller operation is investigated. The chiller model is used to produce a performance map of the chiller by varying the three inlet temperatures and the adsorption/desorption duration. Then, the characteristic equations of sorption chillers have been modified in order to account for varying

operating conditions over a wide range of inlet temperatures and adsorption/desorption durations. Two ways of controlling the chiller adsorption/desorption duration have been presented and investigated. The first control strategy consists in sequencing several ON/OFF controllers in order to adjust stepwise the adsorption/desorption duration. The second strategy uses the modified characteristic equations to adjust the adsorption/desorption duration in a way that the chiller matches the required cooling load. The two control strategies have been simulated with different cooling load and temperature profiles. Both controls allow a good cooling power modulation and significant thermal COP improvements (up to 13 % in comparison with the case of constant adsorption/desorption duration). The control strategy using the modified characteristic equations allows a more efficient chiller operation.

Finally, a method to control solar driven adsorption chillers by adjusting dynamically several control variables is proposed. The first control goal with the highest priority is to adjust the chiller cooling capacity according to the building cooling load. The second goal is to minimize the system power consumption and is achieved by the use of an optimization algorithm. Based on the developed method, several control strategies that act on different control variables (hot and cooling water temperatures, adsorption/desorption duration) are investigated through simulations of a solar cooling system. The implementation of these advanced controls is simulated first on daily basis and then the best strategies are investigated over the whole cooling season. The modified characteristic equations can be used to control the chiller cooling capacity accurately. The adjustment of the cooling water temperature by the control of the cooling tower fan speed is crucial to enhance the overall performance (50 % primary energy savings increase over the whole cooling season compared to the reference control without dynamic set-point control). With the used control approach, controlling the hot water temperature and/or the adsorption duration without controlling the cooling water temperature leads to a poor electrical performance (in comparison to the reference control) although it increases the solar fraction. The highest primary energy savings are achieved when both hot and cooling water temperatures are controlled together with the chiller adsorption/desorption duration. Up to 25 % additional primary energy savings compared to the cooling water temperature control alone is achieved for a specific day with part load conditions. This increase is about 4 % over the whole cooling season but might be higher with a fine tuning of the controller at extreme part load conditions.

This work contributes to extend the knowledge on modelling and controlling solar cooling systems with adsorption chillers. With the developed models, helpful tools are made available for simulating and controlling such systems. The understanding of adsorption chiller heat and mass recovery processes has been brought further and new possibilities for control improvement are opened for future research. A method to control dynamically different control variables with the use of optimization algorithms has been proposed and tested in a simulation environment. This approach has to be developed further and implemented in real systems.