Abstract of dissertation

Evaluation and Design of Solar-assisted Desiccant Air-conditioning Systems for Residential Buildings in Hot and Humid Regions

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In hot and humid regions, a good cooling and dehumidification are considered to be an issue of increasing concern as an important aspect of indoor environment. For decades, conventional air-conditioning systems have played an exceptional role in providing us comfort and fulfilling pleasure indoor environment. However, its general drawbacks on sanitary aspects, for instances, drain water due to condensation taking place at cooling coil, improper indoor humidity control in particular of under humid climates, cause a lot of anxiety among building users. Furthermore, although it is considered to be one of the systems with relatively high energy-efficiency, the contribution on non-renewable energy consumption is still comparatively high. On the other hand, as an alternative to conventional air-conditioning system, although desiccant air-conditioning systems possess disadvantages such as relatively large in size of equipments and degradation of desiccant materials, desiccant air-conditioning systems still provide considerable benefits on many aspects. Elimination of condensation, independent handle of sensible and latent cooling loads, ability to well tackling high latent load, possibility of utilization of diverse energy source such as solar energy and so on, mechanical simplicity and sanitizing effects are among the merits to be mentioned. Having considered previously mentioned advantages obtained from solar-assisted desiccant air-conditioning systems, it has increasingly attracted interests and attentions from researchers for years.

While a development and evaluation of desiccant air-conditioning equipments have fruitfully been invested, little attention has been paid to the evaluation of solar-assisted desiccant air-conditioning systems integrated with buildings. Of particular concern is a residential building under hot and humid climates with possible relatively high latent load, which could benefit from utilization of solar-assisted desiccant air-conditioning systems. In present work, this issue is addressed as one of primary objective. Furthermore, in spite of a number of studies on particular system using rotary desiccant dehumidifier, a comparison study with the systems with other desiccant components will be comparatively considered in this study. In addition, the influence due to variety of hot and humid climates on the performance of solar-assisted desiccant air-conditioning systems and its appropriateness regarding to the climatic constraints is due to be investigated. On the other hand, besides having set objectives on evaluation, the important support required to achieve the goal is a simulation tool. Not only complicated evaluation tools for the integration of solar-assisted desiccant air-conditioning systems and residential buildings, which provide the consistency throughout the variation of

desiccant systems and buildings, but also a simplified evaluation tools for end user during implementation phrase is to be developed in current research.

In the first part, for addressing the characteristics of residential buildings under hot and humid climates, the actual humidity environment of residential buildings and its nature was studied. The actual survey on indoor humidity was conducted by means of temperature and humidity measurement for physical data and questionnaire for activity patterns. The situations regarding to humidity environment in residential buildings are then elaborated further by hygrothermal building simulations, which is specific developed and verified. As expected, the survey illustrates that it is fairly evident for the existence of excessive indoor humidity problems under hot and humid climates even under conventional air-conditioning operation. Furthermore, the nature of characteristics of space cooling load of residential buildings exhibits relatively high latent cooling load. Therefore, it can be concluded that the applications with ability to handle relatively high latent cooling load, are essential for residential buildings under hot and humid climates.

The second part extensively highlights the investigation on solar-assisted desiccant air-conditioning systems and its components. Literatures on desiccant air-conditioning systems were firstly reviewed in order to grasp the information on development and variations of desiccant air-conditioning systems up to date. The mathematical models for reproducing the system mechanism and predicting the performance of the systems were then intensively examined. A number of verifications assured the numerical simulation method for intricate desiccant components and evaporative cooler and analogy solutions for complicated desiccant components to be considerably reliable. In addition to that, the mathematical models obtained from the standard libraries of well-known TRNSYS simulation software were applied for other secondary components. The experiment and numerical analysis on continuous reactivation desiccant air-conditioning systems using common rotary desiccant dehumidifier and periodically reactivated desiccant air-conditioning systems using desiccant beds were then conducted. The results lead us to infer that the continuous reactivation desiccant air-conditioning systems incorporating indirect evaporative cooler with minority of inlet air being dehumidified can perform with high energy efficiency comparable with conventional air-conditioning system even without solar energy utilization. Furthermore, it can be taken into consideration that the periodically reactivated systems can achieve even further higher energy efficiency according to measurement and simulation results. Therefore, it can be concluded that not only advantages over healthy issues, but desiccant air-conditioning systems can also provide acceptable energy efficiency performance.

Finally, the third part intensively analyzed the performance of the integrated solar-assisted desiccant air-conditioning systems with residential buildings. Having prepared simulation tools for both building cooling load and solar-assisted desiccant air-conditioning system, the simulation on the integrated units can now be realized. Firstly, as a case study, the field measurement and simulation on the passive solar room dehumidifying system using the property of a wooden space was firstly conducted as well as its parametric study. The system is found to possess relatively high dehumidification potential to lower the humidity of bedroom during nighttime by approximately 4-5 g/kgDA of humidity ratio. However, the temperature of the bedroom achieved by the system is considered to be higher than the outdoor condition in most cases.

Sequentially, the investigation of solar-assisted desiccant air-conditioning systems for residential buildings is examined through the simulation tools. The full analysis on seasonal performance of the systems was firstly performed. And the simplified evaluation tool of the

system performance based on steady-state calculation was then introduced and verified with that of full analysis. Consequentially, among various options in solar-assisted desiccant air-conditioning systems, the passive solar room dehumidifying system using the property of a wooden space operating with indirect evaporative cooling not only solved the high indoor temperature issues, but also it produces the highest energy efficiency at average primary energy COP of 7.98, despite of the limitation of its use under mild outdoor humidity and nighttime operation in order to achieve acceptable frequency percentage of comfort conditions. Despite of relative huge in size of equipment, the periodically reactivated desiccant cooling system performs with relatively higher percentage of comfort and results in primary energy COP of approximately 1.51. However the systems are limited to nighttime operation and mild enthalpy outdoor conditions for indoor comfort reasons. Even though with comparatively lower energy efficient, the continuous reactivation desiccant cooling systems with advance cycle performs with primary energy COP of approximately 1.07 with 24 hours and 1.14 with nighttime operation with advantages, such as, guaranteed comfort condition, comparatively compact in equipment size and compatible under every climatic zones within hot and humid regions. Additionally, under continuous reactivation desiccant cooling systems, in particular of the usage under severe hot and humid climates, the variable regeneration temperature operation can significantly enhance the energy efficiency of the desiccant cooling system and make the system competitive with conventional air-conditioning system. On the other hand, with mild climate, the complementation of variable regeneration temperature over full cooling load and minimum fixed regeneration temperature over part cooling load could improve the performance of solar-assisted desiccant air-conditioning system for residential buildings. In addition, the simplified evaluation tool using contour performance chart presented a relatively consistent results comparing to that of full seasonal analysis, which brings the possibility of end user to access and conduct the evaluation with ease.

Therefore, with the advantages of the improvement over high-humidity and water drain issues in residential buildings in hot and humid regions, with proper selections in building configurations and equipments, the solar-assisted desiccant air-conditioning system is proved to be competitive in terms of energy efficiency and considered to be an alternative to current conventional air-conditioning system. It is also worth mentioning that in further study, the other technology such as heat pump or fuel cells could be taken into consideration as hybrid systems to further reduce non-renewable energy consumption. Additionally, the investigation on the potential ability to provide heating systems and hot water supplying can be further considered.