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EDITORIAL

Ya-Ling HE, Ruzhu WANG, Anthony Paul ROSKILLY, Peiwen LI

Efficient use of waste heat and solar energy: Technologies of cooling, heating, power generation and heat transfer

As a research focus, energy conservation has attracted a great deal of attention in recent years due to the energy crisis and environmental pollution concerns. Many countries made great efforts on both research and implementing energy conservation technologies. Currently more than 50% of the total world's delivered energy is consumed by industry and about one sixth of the total energy consumed is wasted as low-grade heat, for example through radiation loss, exhaust gas flows, and cooling fluid circuits. Therefore, the recovery and reuse of waste heat is an effective way to significantly improve energy utilization. In addition, solar energy can provide low grade heat and is a clean and renewable form of energy. The efficient use of low grade heat from these sources can play an important role for a large number of applications.

Thermal driven cooling, heating and power generation technology provides a means to practically and efficiently use low grade heat. Performance improvement, flexible operation of hybrid systems, and low capital and operating costs are necessary to ensure low grade heat recovery and reuse technologies are attractive to end users. In this thematic special issue, seven invited papers contribute new research and knowledge on optimized cycles of heating, cooling and power generation, as well as the feasibility for waste heat reuse. Four papers focus on the development of solar systems.

A high temperature heat pump is an efficient technology to upgrade waste heat or reuse by the industrial processes. **Z.Y. Xu** and his coworkers produce a comprehensive review of thermally driven absorption heat pumps for different applications, including heat amplification and temperature lift cycles, working pairs and current projects. They conclude that large temperature lift heat pumps and open-cycle absorption heat transformers, with direct contact with exhaust gas, should be further studied and developed. Organic working pairs with good stability, no corrosion and good thermophysical properties are necessary to be studied. **H.S. Bao** and her coworkers propose a hybrid absorption-compression, high temperature heat pump for the recovery of industrial waste heat of 60°C–120°C. The cycle allows a flexible operation with energy input from waste heat and electrical power. The study gives a numerical analysis and several features such as recirculation flow ratio are presented. **B. Hu** and his colleagues present an exergy analysis for a multi-stage compression heat pump used for high temperature heating applications with R1234ze(Z) as the refrigerant, which has a low GWP value. The analysis is conducted on the basis of producing pressurized water at 120°C under different waste heat conditions. Single, double and three stage compression heat pumps are compared and this indicates a multi-stage compression heat pump has less power consumption. A three-stage compression heat pump system has obvious advantage of higher exergy efficiency. In addition to absorption and compression heat pumps, a chemical heat pump provides another way of upgrading heat with a large temperature lift. **M. Xu** and his coworkers carry out an exergy

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Ya-Ling HE (✉)
School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an 710049, China
E-mail: yalinghe@mail.xjtu.edu.cn

Ruzhu WANG (✉)
School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
E-mail: rzwang@sjtu.edu.cn

Anthony Paul ROSKILLY (✉)
Sir Joseph Swan Centre for Energy Research, Newcastle University, Newcastle upon Tyne NE1 7RU, UK
E-mail: tony.roskilly@ncl.ac.uk

Peiwen LI
Department of Aerospace and Mechanical Engineering, The University of Arizona,Tucson AZ 85721, USA

analysis on an Isopropanol-Acetone-Hydrogen chemical heat pump which can upgrade waste heat of 80°C–110°C to 200°C. The highest irreversibility is in the distillation column and reactive distillation is an effective alternative. The operating conditions could be optimized to obtain greater thermodynamic performance.

Besides using heat pump technology, waste heat can be converted to produce cooling and electrical power. **Y. Lu** and his coworkers present a simulation study for a 1 kW organic Rankine cycle using a scroll expander to recover waste heat from the cooling system and exhaust gas of an engine. They pointed out a potential solution to fully recover engine coolant energy with the penalty of reduced ORC thermal efficiency. The proposed solution has the advantages of higher power output and less rejected heat from the engine radiator compared with that of the engine ORC system only using the coolant energy as preheat source. A recuperator is suggested to be added to the ORC system when the working fluids are isentropic or dry types. When the engine is operated under rated power condition, the integrated waste heat recovery system can potentially improve the overall system performance by 9.3%.

J. Cho and his coworkers develop a small-scale, multipurpose experimental S-CO_2 system using a high-speed radial-type turbo-generator. A preliminary experiment test is conducted using R134a as a working fluid to determine the operational characteristics of the closed Rankine cycle. A turbine power of 400 W is successfully generated. **P. Gao** and his colleagues propose a solid sorption combined cooling and power system using the waste heat from the exhaust gas of a vehicle. The cogeneration system uses $MnCl_2$/$CaCl_2$-NH_3 working pairs and its feasibility is demonstrated experimentally.

For solar systems, heat collection and heat transfer issues are important to improve system performance and to make system operation reasonable and stable. **S. Tang** and his colleagues review different approaches for solar fuel production from spectrum-selective photo-thermal synergetic catalysis. The meaning of synergetic effects, the mechanisms of spectrum-selectivity and photo-thermal catalysis are introduced and a number of experimental or theoretical works are sorted by the chemical reactions and the sacrificial reagents applied. The studies are summarized based on the operating conditions, spectrum-selectivity, materials and productivity. They suggest that the optimizations on materials and structure of catalysts and deeper understanding of the reaction mechanism, especially the photo-thermal synergy effects are necessary to be given more academic attentions. On the performance of direct steam generation solar power tower plant, **Y. Luo** and his coworkers study the impacts of solar multiple and thermal storage capacity, which are two key design parameters for the sensitivity analysis of the annual plant performance and the economic assessment. The analysis gives the effects of site, solar field equivalent electricity size and investment costs on the minimum levelized cost of electricity, optimal solar multiple and thermal storage capacity, which is based on the reference cases. **T.J. Wang** and his colleagues present an experimental study on a quartz tube falling particle receiver. Silicon carbide particles are proposed to be the heat transfer fluid when the temperature is higher than 600°C in which case molten nitrate salt becomes chemically unstable. Particle receivers have the potential to increase the maximum temperature of the heat-transfer media to over 1000°C. Experiments are carried out to test the dynamic thermal performance of the receiver. The experimental study focuses on the effect of particle diameter, particle inlet temperature, particle flow rate and type of the quartz tube on outlet particle temperature. It provides a novel strategy for the development of a high temperature heat transfer fluid. **B.J. Lougou** and his coworkers conduct a numerical analysis of radiation heat transfer and temperature distributions for a solar thermochemical reactor used for syngas production. Finite volume discrete ordinate method and P1 approximation for radiation heat transfer are employed. The study reveals that the temperature drop due to the boundary radiation heat loss could not be neglected for the thermal performance analysis of the solar thermochemical reactor.

We hope these papers will provide you with a good overview of the technologies which can be utilized for the efficient use of waste heat and solar energy. The coverage is limited but we hope that it inspires more research exploration in this extremely important field.

Editor's bio sketches:

Dr. Ya-Ling HE is a Chair Professor at Xi'an Jiaotong University and the Academician of Chinese Academy of Sciences. Currently, she is the Vice President of Chinese Association of Refrigeration and the Chairman of Academic Committee of Xi'an Jiaotong University. In 2010, she was rewarded the Science and Technology Awards of the Ho Leung Ho Lee Foundation. She is also a Chief Scientist for the National Basic Research Program (973 Project) of China, an Associate Editor of *Applied Thermal Engineering* and a member of the Scientific Council of ICHMT. She was also the Vice President of Commission B1- International Institute of Refrigeration. She has published about 380 SCI journal papers with a total citations more than 9000 times. Her major interests are in the following fields: Energy-saving theories and new methods in efficient utilization of energy, development and utilization of new energy, new energy storage technologies, advanced refrigeration and cryogenic techniques in high-tech fields, capture, control and utilization of

CO_2 in energy and power system, fluid flow and heat transfer in micro systems, numerical principle and its applications in fluid flow and heat transfer processes, and thermal science problems in aeronautical and aerospace engineering. E-mail: yalinghe@mail.xjtu.edu.cn

Dr. Ruzhu WANG is Chair Professor and Director of the Institute of Refrigeration and Cryogenics at Shanghai Jiao Tong University. He graduated from Shanghai Jiao Tong University in 1984 and 1987 with bachelor and master degrees. He received a Ph.D from Shanghai Jiao Tong University in 1990. He had been appointed as the Director of Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University since 1993. Currently he is also the Director of Engineering Research Center of Solar Energy, MOE China. He has published over 350 SCI journal papers, with more than 9000 citations. He has written 9 books on refrigeration technologies and solar energy. His major research contributions are in adsorption refrigeration, heat pumps, CCHPs and solar energy systems, heat transfer to superfluid helium, and green building energy systems. Due to his most noteworthy contributions to refrigeration globally, he was honored to receive the J & E International Gold Medal from the Institute of Refrigeration in 2013. E-mail: rzwang@sjtu.edu.cn

Professor (Dr) A.P. ROSKILLY is Director of the Sir Joseph Swan Centre for Energy Research at Newcastle University, UK. He is an Associate Director of the UK Centre for Energy Systems Integration, an Associate Member of the Interdisciplinary Centre for Storage, Transformation and Upgrading of Thermal Energy (i-STUTE), a member of the Science Board of the Energy Storage Supergen Hub, and the National Contact for the European Energy Research Alliance Joint Programmes on Energy Efficiency in Industrial Processes (EEIP) and Energy Systems Integration (ESI). Professor Roskilly has published over 130 SCI journal articles in the past 5 years and has received almost 2800 citations for his research papers over this period. He has performed a number of academic journal editorial roles and is currently an Associate Editor of *Applied Energy*. Professor Roskilly has 30 years' experience in the design, control, and operational optimisation of energy systems. His personal research group undertakes fundamental and applied research into various aspects of power generation and thermal energy systems including technology development and environmental impact assessment of alternative fuels for thermal power plants; combined heat and power systems; tri-generation; thermal power system configurations, chemisorption and PCM storage system development. E-mail: tony.roskilly@ncl.ac.uk

Dr. Peiwen LI is a full Professor in Department of Aerospace and Mechanical Engineering at the University of Arizona, USA. He obtained his Ph.D. focused on thermo-science for energy and power engineering from Xi'an Jiaotong University 1995, China. He is ASME member since 2003. His recent research work focuses on thermal energy storage technologies, property measurement and evaluation of high temperature heat transfer fluids for solar thermal energy application, electrochemical and heat/mass transfer processes in fuel cells and electrolysis cells, fuel processing and reforming for hydrogen production, and heat transfer and fluid flow in industrial processes. His team has developed high temperature (up to 800°C) thermal storage and heat transfer fluids for concentrated solar thermal power systems. He has authored/co-authored one book, 5 book chapters, 95 peer reviewed journal articles and 95 peer-reviewed conference articles. He is an active associate editor of journal *Solar Energy* and *AIMS journal of Energy*.