IMAT ICSERA 2021

7th International Conference on Saving Energy for Refrigeration and Air-Conditioning (ICSERA)

1st November 2021 | Universiti Teknologi Malaysia

UTM UNIVERSITI TEKNOLOGI MALAYSIA

50 SAREK since 1971 대한설비공학회 The Society of Air-conditioning and Refrigerating Engineers of Korea

Message from the Chairman of ICSERA2021

The scientific community's grave concerns about the finite energy resources and environmental degradation have paved the way for research into reducing our demand for energy and its negative impacts to our surroundings. Air-conditioning and the refrigeration industry is a major contributor to these concerns. In addressing these issues, researchers and academics involved in the air-conditioning and refrigeration sector, be it directly or indirectly, get together at the International Conference on Saving Energy for Refrigeration and Air-Conditioning (ICSERA) and regularly exchange ideas and research, as well as discuss a myriad of related and relevant matters. ICSERA conferences have been regularly held in Korea and Indonesia. This is the first time the conference is being held in Malaysia, and Universiti Teknologi Malaysia (UTM) is honoured to host the event at the Johor Bahru main campus on November 1st 2021, in collaboration with the Society of Air-conditioning and Refrigerating Engineers of Korea (SAREK).

Due to the Covid-19 pandemic, the7th ICSERA is to be held completely virtual. With a total of 56 papers that have been accepted from Malaysia, Korea, Japan, Vietnam, Indonesia, and Nigeria, selected manuscripts will be published in the International Journal of Air-conditioning and Refrigeration (IJACR), Journal of Thermal Analysis and Calorimetry (JTAC), Evergreen Journal, and Jurnal Mekanikal based on the standard review process. Sincerest appreciation goes to the Plenary and Keynote Speakers who have shared their knowledge and experience – Professor Ruzhu Wang, Professor Oh Jong-Taek, and Professor Patrice Estellé.

On behalf of the organizing committee, it is hoped that much will be gained from this year's ICSERA despite the uncertainties of the future with the pandemic. We must continue our efforts to save energy and protect the environment that we share. And last but not least, thank you to all the authors and the hardworking committee members of both the ICSERA2021 and IMAT2021 as the conference would not have been possible without the participation of every one of you. *Terima kasih*.

Normah MOHD-GHAZALI, Ph.D., C.Eng.
Chairman of ICSERA2021
Professor
School of Mechanical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia (UTM)

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Prof. THU, Kyaw, Kyushu University, Japan.

8:30 – 8:45	Housekeeping announcement & Welcoming remarks				
8:45 – 8:55	Opening Speech by Chair of IMAT – Prof Ng Kim Choon, Prof Idrus AlHamid, Prof Mazlan Wahid				
8:55 - 9:00	Address by President of SAREK - Prof Kim Min Soo				
9:00 – 9:10	Opening Speech by Chair of ICSERA – Professor Normah Mohd-Ghazali				
9:10 – 9:20	Officiating Speech by Chair of School of Mechanical Engineering				
9:20 – 9:25	UTM – montage				
9:30 – 10:20	**PLENARY – PROFESSOR RUZHU WANG "Adsorbents for energy conversion and management, and its cross to energy-water-air nexus" (Chair: Prof Normah Mohd-Ghazali)**				
10:20 – 10:35	TEA				
10:35 – 11:05	**KEYNOTE 1 – PROFESSOR OH JONG-TAEK "An up-to-date review of flow condensation heat transfer inside mini-micro scale channel" (Chair: Prof Normah)**		**KEYNOTE 2 – PROFESSOR PATRICE ESTELLE "Graphene-based nanofluids for energy and cooling applications" (Chair: Prof William Chong Woei Fong)**		
PARALLEL SESSIONS	**7**	**8**	**9**	**10**	**11**
Chairperson	**7A.** Prof Agus/Dr Atiqah (UMP)	**8A.** Prof Kyaw Thu/Dr Ken	**9A.** Prof Ahn Joon/ Prof William Chong	**10A.** Prof Jae Dong Chung/ Dr Faisal	**11A.** Dr Ibtisham/ Dr Mohsin
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11:50 – 12:10	50	57	12	16	24
12:10 – 12:30	10	3	29	56	55
12:30 – 12:50	11	62	4	21	14
12:50 – 1:10	26	36	23	9	61
1:10 - 2:30	LUNCH BREAK				

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Chairperson	**7B.** Prof Idrus AlHamid/Dr Atiqah	**8B.** Dr Arnas/Dr Ken	**9B.** Prof William Chong	**10.** Dr Faisal	
ICSERA SESSIONS	**7B. - Refrigeration System**	**8B - Modelling AC/Ref/Cooling**	**9B - Energy Conservation & Utilization**	**10B - Cooling & Envir Analysis**	**11 - Others**
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3:45 – 4:05	25	8	59	15	
4:05 – 4:25	49	40	52	60	
4:25 – 4:45	58	20	32	38	
4:45 – 5:00	TEA				
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6:00 – 6:20	Closing Remark				

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KEYNOTE 2 **10:35 – 11:05**	Graphene-Based Nanofluids for Energy and Cooling Applications	 Professor Patrice Estellé

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11:30 – 11:50 2.	An optimization approach in the development of a new correlation for two-phase heat transfer coefficient of R744 in a microchannel	Wan Muhammad Zaid Wan Zaidi, Normah Mohd-Ghazali and Yushazaziah Mohd-Yunos
11:50 – 12:10 50.	Flow condensation heat transfer of propane refrigerant inside a horizontal micro-fin tube	Pham Quang Vu, Thi Thu Ha Nguyen and Jong-Taek Oh
12:10 – 12:30 10.	The impact the multiport mini-channel tube cross sectional geometry on condensation pressure drop of R410A	Lieu Hoang, Nurlaily Agustiarini, Vu Pham Quang and Oh Jong-Taek
12:30 – 12:50 11.	Condensation heat transfer coefficient R410A inside multiport mini-channels tubes with different cross-sectional geometry	Hieu Hoang, Nurlaily Agustiarini, Vu Pham Quang and Oh Jong-Taek
12:50 – 1:10 26.	Investigation of new refrigerant blends as R410A alternatives for air-cooled split air conditioner	Wenbin Ng, Haslinda Mohamed Kamar and Nazri Kamsah

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3:45 – 4:05 25.	Heat transfer performance in a plate-type condenser of absorption refrigeration system	Ammar Syed Muhammad and Chan Woo Park
4:05 – 4:25 49.	Experimental evaluation of refrigeration effect of cellulose evaporative cooling pads	Hung Nguyen Tien, Jong-Taek Oh, Vinh Nguyen Dinh and Chien Nguyen Ba
4:25 – 4:45 58.	An experimental test of a reciprocating magnetic heat pump system at room temperature using irregular-shaped gadolinium particles	Jongmin Choi, Seungyeon Lee and Min Soo Kim
5:00 – 5:20 35.	Sources of leakage in refrigeration and air conditioning systems and technical solutions to prevent the leaks	Salman Muradi and Shazwin Mat Taib
5:20 – 5:40 28.	Efficiency of precision air conditioning on temperature and cooling load change	Supriyadi Supriyadi, Adam Darmawan and Sentot Novianto
5:40 – 6:00 37.	Experimental study of flow condensation heat transfer of ammonia inside a multiport mini-channel tube	Pham Quang Vu, Tran Van-Tuan and Oh Jong-Taek

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	Professor Kyaw Thu (KU) / Dr Ken (UTM)	
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11:30 – 11:50 43.	Desiccant air conditioning (DAC) systems and their prospects for energy savings in tropical climates: the Philippines scenario	Marco Lao, Frantisek Miksik, Jie Lin, Kyaw Thu and Takahiko Miyazaki
11:50 – 12:10 57.	A feasibility study on the ED-assisted liquid desiccant regeneration method	Jeong Kuk Hong, Inchan Hwang and Min Soo Kim
12:10 – 12:30 3.	Energy consumption estimation for a hydrothermal energy used in building by ECO2	Seungrok Oh, Rin Yun, Hoseong Lee, Yujin Nam and Chang Yong Park
12:30 – 12:50 62.	Fault diagnosis of air conditioner using based on physical model	Chaeyeon Lee and Youngsoo Chang
12:50 – 1:10 36.	Condensation heat transfer characteristics of R1234yf inside the multiport mini-channel tube	Pham Quang-Vu, Phung Anh-Xuan and Oh Jong-Taek

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3:45 – 4:05 8.	Numerical study for the temperature uniformity evaluation of gasket plate heat exchanger	Jeonggyun Ham, Gonghee Lee and Honghyun Cho
4:05 – 4:25 40.	TRNSYS simulation of thermal environment according to outdoor conditions in desiccant cooling space driven by gas engine cogeneration	Joon Ahn and Ji Hyeok Kim
4:25 – 4:45 20.	Two-phase heat transfer microchannel system Identification with particle swarm optimization (PSO) approach	Hanim Mohd Yatim, Normah Mohd Ghazali, Agus Sunjarianto Pamitran, Sentot Novianto and Maziah Mohamad
5:00 – 5:20 27.	A study on modeling dynamic characteristics of battery cooling system for ESS system according to the configuration of water-cooled battery cooling module	Nguyen Nhan and Park Chan Woo
5:20 – 5:40 53.	Prediction of boiling heat transfer coefficient of R1234yf inside multiport mini-channel tube by machine learning method	Nurlaily Agustiarini, Hieu Hoang Ngoc, Normah Mohd-Ghazali and Oh Jong Taek
5:40 – 6:00 54.	Application of machine learning to predict the heat transfer coefficient of R32 inside the multiport mini-channel tube	Nurlaily Agustiarini, Hieu Hoang, Vu Pham Quang, Chien Nguyen Ba and Oh Jong-Taek

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11:30 – 11:50 19.	Performance analysis of a double layer microchannel heat sink cooled with graphene nanofluid at various temperatures	Hielfarith Suffri Shamsuddin, Normah Mohd-Ghazali, Patrice Estellé, Maziah Mohamad and Ummikalsom Abidin
11:50 – 12:10 12.	Investigation on the improvement of driver's thermal comfort and energy saving by using various cooling seats	Yunchan Shin, Minjun Kim, Honghyun Cho and Donghyeon Shin
12:10 – 12:30 29.	Effect of temperature and humidity on the performance of desiccant dehumidification system under low-temperature regeneration	Hao Yu, Sang Won Seo, Kyaw Thu and Takahiko Miyazaki
12:30 – 12:50 4.	Thermofluid behavior of boron nitride nanotube nanofluid in a microchannel under optimized condition	Mohamad Nur Hidayat Mat, Normah Mohd-Ghazali and Patrice Estellé
12:50 – 1:10 23.	The effect of fin and parameters on phase change material melting and solidification in storage tank	Phuong Thanh Nguyen and Chan Woo Park

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3:45 – 4:05 59.	Equilibrium analysis of adsorption heat transformer cycle with silica gel – water vapor pairs for waste heat upgrade	Sagar Saren, Sourav Mitra, Takahiko Miyazaki, Kim Choon Ng and Kyaw Thu
4:05 – 4:25 52.	Thermal performance assessment of end-of-life vehicles transparent sandwich panels integrated in residential building in Kuala Lumpur	Norhayati Mahyuddin, Yee Choong Wong, Asrul Mahjuddin Ressang Aminuddin and Haoxiang Zhan
4:25 – 4:45 32.	Investigating the effectiveness of passive cooling strategies for low-cost dwellings in Indonesia based on numerical simulations	Solli Murtyas and Aya Hagishima
5:00 – 5:20 46.	Development of stratification analysis model for thermal energy storage tank using CFD	Hyunjun Jung, Jaehyeok Heo and Rin Yun
5:20 – 5:40 51.	Dynamic and static characteristics of absorption thermal battery system	Jaehui Jeong, Haye Min, Jinhee Jeong and Yong Tae Kang

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11:30 – 11:50 48.	Experimental investigation of two-phase flow boiling heat transfer and pressure drop of propane inside multiport minichannel	Chien Nguyen Ba, Dzung Nguyen Viet and Oh Jong-Taek
11:50 – 12:10 16.	Heat transfer performance of LiBr solution-water in a plate heat exchanger according to LiBr concentration	Yong Junhyeok, Kwon Ohkyung and Cho Honghyun
12:10 – 12:30 56.	Numerical simulation of the interference effects to outdoor air flow and ventilation around adjacent building arrays	Samuel Ayo and Normah Mohd-Ghazali
12:30 – 12:50 21.	A study on performance of heat and water vapor recovery from flue gas with transport membrane condenser material	Van Cong Le, Jun Cong Ge, Sung Joo Hong and Chan Woo Park
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3:45 – 4:05 15.	Predictive analytics application in building diagnostic for testing the health risk assessment tool of indoor air quality and sick building syndrome in educational building	Syazwan Ismail, Haslinda Mohamed Kamar, Nazri Kamsah, Mohd Ibtisham Ardani, Nazri Che Dom, Farah Ayuni Shafie, Izwyn Zulkapri and Lim Kuang Hock
4:05 – 4:25 60.	Development of a new correlation for pre-dry out evaporative heat transfer coefficient of R290 in a microchannel	Muhammad Aliff Haikal Ghazali, Normah Mohd-Ghazali, Agus Sunjarianto Pamitran and Jong-Taek Oh
4:25 – 4:45 38.	Bayesian estimation of air exchange rate based on occupant exhaled carbon dioxide	Haolia Rahman, Paulus Sukusno, Mohammad Arief Indra Permana and Hwataik Han

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5:20 – 5:40 18.	Evaluation of Calcium Chloride Sorbent-Bed Material for Portable Indoor Atmospheric Water Generation	Muhamad Hafizul Ariff Muhamad Hazli, Adzuieen Nordin and Ummikalsom Abidin

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11:30 – 11:50 22.	Physical Characteristics of Palm Kernel Shell Torrefied by Multilevel Torrefaction Reactor	Mohd Faizal Hasan, Mohd Najib Shawalluddin, Naqila Mohd Mustaat, Bemgba Bevan Nyakuma, Mohd Rosdzimin Abdul Rahman and Mohd Farid Muhamad Said
11:50 – 12:10 24.	Separation of Multicomponent Lanthanides Using Zeolite A Modified Pectin Biopolymer	Eny Kusrini, Muhammad Idrus Alhamid, Mufiid Fatkhurrahman, Dwi Aprillia Wulandari and Anwar Usman
12:10 – 12:30 55.	Effect of Cold Plasma Voltage and Treatment Duration to the Microstructure and Hydrophilicity of Mushroom Grain Spawn	Mun Oon Fong and Norhayati Binti Ahmad
12:30 – 12:50 14.	Classification technique of health risk assessment of indoor air quality and Sick Building Syndrome investigation among learners in educational building	Syazwan Aizat Ismail, Haslinda Mohamed Kamar, Nazri Kamsah, Mohd Ibtisham Ardani, Nazri Che Dom, Farah Ayuni Shafie, Izwyn Zulkapri and Lim Kuang Hock
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PLENARY: Professor Ruzhu Wang

Adsorbents for energy conversion and management, and its cross to energy-water-air nexus

R.Z. Wang

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ABSTRACT

Adsorbent is usually in the form of solid with nanoscale porous structures. Adsorption is a rate-controlled process, related to nanoscale heat and mass transfer that highly depends on the boundary conditions. Highly porous adsorbents like silica gel, molecular sieve, activated carbon (fiber), alumina, and MOF could capture gas molecules and release sorption heat through physical adsorption, which promote their widely applications in thermal processes, such as cooling, heating, energy storage, air water harvesting, humidity control, air cleaning and thermal treatment. However, the physical adsorbent is usually limited by its low adsorption capacity and weak adsorption kinetics. Thus, it is essential to tailor the structural and thermal properties of the nanoscale pore adsorbent, and even use composite adsorbents, to adapt to real applications to achieve efficient sorption in handling with water vapor, ammonia, CO_2 and etc. Reasonable thermal design in device level should be taken into consideration. Here, a strategy to synthesize efficient adsorbents and the principle to select optimal adsorbent-adsorbate working pairs for various adsorption technologies and their typical applications are introduced and discussed. This work shows that adsorbents are closely related to energy, water and air, some promising applications could be realized.

KEYNOTE: Professor Oh Jong-Taek

An up-to-date review of flow condensation heat transfer inside mini-micro scale channel

Jong-Taek Oh

Dept. of Refrigeration and Air-Conditioning Engineering,
Chonnam National University, Yeosu, 59626, South Korea

ABSTRACT

Rapid technological advancement as well as the need for the development of clean technology had called forth the nouveau method of thermal management, and mini/micro-scale condensation heat transfer, having been demonstrated to be efficient yet compact, is emerging as a potential next generation heat exchanger design. Yet given the complexities of the two-phase flow phenomena, multiple approaches, from experimental to computational/theoretical analysis, even up to the most recent application of machine learning, has been employed for the investigation of the condensation process. Therefore, extensive body of researches in the past decade had greatly expanded the field current state of art, with many of the flow phenomena has now been relatively well understood. Despite tremendous progress, there are still challenges, and open question remained to explored. This review provides an up-to-date literature review of the condensation heat transfer within mini-micro scale channel. Various methodologies (experimental, CFDs, theoretical and machine learning) are described and their unique advantages explored. The report of these investigations is summarized and reviewed so as to provide the reader with up-to-date findings of the field. Finally, new research directions are recommended for future investigation.

KEYNOTE: Professor Patrice Estellé

Graphene-Based Nanofluids for Energy and Cooling Applications

Patrice Estellé

Université de Rennes, LGCGM, F-35000 Rennes, France

ABSTRACT

Nanofluids consist of common heat transfer fluids containing nanoparticles with high intrinsic thermal properties. Since the early 1990s, nanofluids received growing attention due to their potential applications in heat transfer devices, energy and cooling systems because of their enhanced thermal properties. In this context, carbon nanomaterials such carbon nanotubes and graphene are especially promising. After a short introduction about the main challenges with carbon-based nanofluids, we report the development and the full characterization of nanofluids containing few-layer graphene (FLG). FLG was synthesized from mechanical exfoliation and characterized by TEM, High-resolution TEM and Raman spectroscopy showing their high structural quality. Then, nanofluids are produced from FLG graphene dispersion in a commercial mixture of water and propylene glycol using different nonionic surfactants and ultrasonication process. The stability of nanofluids at rest and under flow is presented as well as all their thermophysical properties in a wide range of FLG concentrations and temperature. Based on those results, and from Figure of Merits including flow regime influence and pumping consumption, the best candidate is selected, leading to promising applications.

SESSION 7A: REFRIGERANTS

45. Performance analysis of simultaneous cooling and heating absorption system applying alternative working fluid with ionic liquid

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ABSTRACT

In this study, simulation of refrigerant/ionic liquid was performed to replace water/lithium bromide and ammonia/water, which are the preciously commercialized working fluids of the absorption system. System modeling was carried out as a simultaneous cooling and heating absorption system in which a type 1 absorption type system and a type 2 absorption type system were combined. The NRTL model was used as a chemical model to predict the relationship between pressure, temperature, and concentration of refrigerant/ionic liquid solution. The selected refrigerants/ionic liquids are H2O/[DMIM][DMP], H2O/[EMIM][DMP], H2O/[EMIM][BF4], R32/[HMIM][Tf2N]. Cooling COP, heating COP, total COP, and circulation ratio were simulated according to generation temperature, evaporation temperature, and split ratio. As a result of the simulation, H2O/IL was suitable for use as an alternative working fluid at a performance similar to that of the H2O/LiBr, and R32/IL showed only about 50% performance of H2O/LiBr. However, it is analyzed that R32/IL can cool down to sub-zero temperature due to its low freezing point, and it is advantageous for device miniaturization due to its relatively small specific volume.

2. An optimization approach in the development of a new correlation for two-phase heat transfer coefficient of R744 in a microchannel

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ABSTRACT

To date no single method has been found to satisfactorily predict the two-phase heat transfer coefficient of R744 refrigerant in small channels. Studies are continuously being done to obtain a coefficient with acceptable mean absolute error (MAE) which measures the difference between the predicted and experimentally determined coefficient values. It is important to have available accurate heat transfer coefficient correlation for the two-phase heat transfer coefficient so that a compact heat exchanger that maximizes device performance while reducing cost and energy needs can be designed. In this study genetic algorithm (GA) is used as an optimization tool to achieve a more accurate correlation for R744 in a micro channel by minimizing the MAE. Over 536 sets of experimental data from previous studies were utilized, optimizing the six constants appearing in the force convective factor, F, and nucleate boiling suppression factor, S, of the selected superposition correlation. The results showed that the MAE between the newly optimized correlation and selected experimental data at all ranges of vapor quality has been successfully reduced from 38.39% to 34.40%. With more available data, the suggested method can be utilized to achieve a more accurate empirical prediction that matches well with the experimental data.

Keywords: *two-phase; microchannel; MAE; optimization; R744.*

50. Flow condensation heat transfer of propane refrigerant inside a horizontal micro-fin tube

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ABSTRACT

Due to the phase-out of CFCs and HCFCs refrigerants soon, natural refrigerants are considered viable alternatives. Propane is a naturally occurring substance produced as a by-product of natural gas production and oil refining. Propane has a higher latent heat and lower density than conventional refrigerants while maintaining a comparable saturation pressure and thermal conductivity. So that, propane refrigerant is already widely used in domestic fridges and freezers for many years. However, propane's operating pressures and temperatures are well suited for air conditioning equipment, including chillers. This study investigates the contributions of different heat transfer mechanisms in two-phase flow condensation heat transfer coefficients for propane inside a 6.3 mm ID micro-fin copper tube. The saturation temperature is 48^{o}C, with mass fluxes varying from 50 to 380kg/m^{2}s, and heat fluxes from 3 to 12kW/m^2. The experiments investigated vapor quality, mass flux, and heat flux on the heat transfer coefficients. The result shows that the heat transfer performances of propane are better in comparison with other refrigerants.

Keywords: *propane, condensation, heat transfer coefficient, microfin.*

10. The impact the multiport mini-channel tube cross sectional geometry on condensation pressure drop of R410A

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ABSTRACT

This paper presents an experimental study on the effect of multiport mini-channels tube cross sectional geometries on two-phase flow pressure drop. Three tubes with aspect ratios of 0.395, 0.385 and 0.446; hydraulic diameters of 1.147, 1.135, and 0.846 mm, with number of channels of 7, 11, and 18 were experimented on in this study. The testing range of heat flux was from 3 to 15 kW/m^2 and mass flux from 50 to 500 kg/m^{2}s. It was found that the pressure drop increased with mass flux while the effect of heat flux on the pressure drop was minor. Pressure drop mostly increased with vapor quality, except under low mass flux, low quality condition where the pressure drop was high. The pressure drop of the three tubes were compared and it was found that pressure drop increased significantly with the number of ports even under the same experimental condition. Finally, a pressure drop model was proposed as a means to correlate the experimental data.

Keywords: *R410A, multiport mini-channel, condensation, pressure drop*

11. Condensation heat transfer coefficient R410A inside multiport mini-channels tubes with different cross-sectional geometry

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ABSTRACT

This study experimentally investigated the impact of cross-sectional geometry on condensation heat transfer coefficient of R410A within multiport mini-channels tube. Three tubes with aspect ratios of 0.395, 0.385, and 0.446; hydraulic diameters of 1.147, 1.135, and 0.846 mm, with varying number of channels (7, 11, and 18) were tested. The heat flux ranged from 3 to 15 kW/m^2 while the mass flux from 50 to 500 kg/m^{2}s. It was observed that the heat transfer coefficient increased with heat flux, mass flux, as well as vapor quality. In low heat flux and mass flux condition, the test tube with the highest number of channels also had the highest heat transfer coefficient, although this effect is less pronounced under high mass flux, heat flux condition. In addition, the hydraulic diameter was found to decrease heat transfer coefficient. Finally, a heat transfer coefficient was proposed for the experimental data prediction.

Keywords: *R410A, multiport mini-channel, condensation, heat transfer coefficient*

26. Investigation of new refrigerant blends as R410A alternatives for air-cooled split air conditioner

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ABSTRACT

Restrictions on specific Global Warming Potential (GWP) prescribed in the Kigali Amendment and EU F-gas Regulation resulted in the phase-down of the Hydrofluorocarbon (HFC) in the EU, which prompted the industry to shift towards lower GWP solvents. The purpose of this study was to identify potential refrigerants to replace R410A for air-cooled split air conditioner applications. Refprop software was used to predict the coefficient of performance (COP) of selected refrigerants, namely, R466A and R470A under typical operating conditions of the tropical region with the evaporating and condensing temperatures of 5ºC and 47ºC, respectively. The study found that the temperature and pressure of critical points for both refrigerants are greater than R410A; however, the GWP of R466A and R470A are 65% and 56% lower than R410A, respectively, while the COP of R466A and R470A is 25% lower than R410A. It can be inferred that the selected refrigerants can be considered as potential R410A replacements regardless of their performances since both have a significant reduction of the GWP when compared to the R410A, which is a crucial criterion for solving current environmental issues.

Keywords: *R410A, R466A, R470A, air-cooled split air conditioner*

SESSION 7B: REFRIGERATION SYSTEM

7. Energy saving effect of the refrigerator truck by application of the latent heat storage

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ABSTRACT

In a refrigeration truck, it is important to maintain a constant internal temperature for product freshness. Recently, the refrigerator truck with the latent heat storage was developed and distributed to reduce the temperature variation. The purpose of this study was to compare the energy consumption of the PCM type refrigerator truck with that of the conventional engine driven refrigerator truck. Based on the 2.5-ton grade refrigerator truck, a refrigeration system with latent heat storage was designed. Experimental condition was set as a refrigerator, a freezer, and ambient with temperatures of 5°C,-18°C, and 35°C, respectively. The periodic door open test was included to consider the field situation. As a result, primary energy of the refrigeration system with PCM was reduced by 20% than that of the engine driven system.

Keywords: *refrigerator truck, phase change material (PCM) type, engine driven type, energy consumption*

25. Heat transfer performance in a plate-type condenser of absorption refrigeration system

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ABSTRACT

Traditionally, shell and tube heat exchanger are being used in THE condenser of an absorption refrigeration system. To increase the heat transfer performance, a shell and plate-type condenser was introduced. The following parameters were observed; saturation pressure (5.85 -7.10 kPa), inlet temperature (32-35 ℃,) and water mass flow rate (0.40-1.50 kg/s). The heat transfer coefficient increases with the increase of cooling water velocity and saturation pressure, whereas it decreases with the increase of inlet temperature. At the same parameters, the overall heat transfer coefficient was significantly higher than that of the shell and tube condenser. Empirical correlations are obtained based on the experimental parameters.

Keywords: p*late-type condenser, absorption system, heat exchanger*

49. Experimental evaluation of refrigeration effect of cellulose evaporative cooling pads

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ABSTRACT

In this paper, we investigate the experimental analysis of the cellulose cooling pads using as evaporative coolers. The experimental data were conducted under the variation of air velocity from 0.5 m/s to 4 m/s, the water temperature was ranged from 8 – 10^{o}C, the temperature and humidity of ambient were ranged from 28 - 30^{o}C and 65 - 75%, respectively. The results show that the effectiveness of the cooling pad strongly depends on the chilled water temperature, temperature and humidity of the inlet air and the ratio of water-air flow rate. Also, a correlation was developed to predict the cooling capacity of the cooling pad, which shows good agreement with the experimental data

Keywords: c*ooling pad; evaporative cooling; porous foam; green building*

58. An experimental test of a reciprocating magnetic heat pump system at room temperature using irregular-shaped gadolinium particles

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ABSTRACT

An experimental study was conducted to evaluate the performance of a reciprocating magnetic heat pump system at the Seoul National University. A magnetic field source was constructed, having magnetic flux density measured as 0.823 ~ 0.921 T for magnetization and 0.013 T for demagnetization in the magnetic field area. A hydraulic system had a maximum volume flow rate of 0.25 LPM for heat transfer fluid (HTF) in the magnetic heat pump system. Four active magnetic regenerators (AMRs) were manufactured including irregular particles of Gadolinium, which approximate diameter was in the range of 1.40 mm ~ 2.36 mm. The total mass of the magnetocaloric material (MCM) was 56.9 g in the AMRs. Performance tests were conducted under the conditions of 0.04 ~ 0.82 of utilizations and 0.20 Hz, 0.25 Hz and 0.30 Hz of operating frequencies. The temperature was measured as 23.2 ℃ on average for the HTF at the outlet of a hot side heat exchanger. No-load test results showed the maximum temperature span of 3.3 ℃ under a steady-state condition. The maximum cooling capacity was calculated as 1.0 W at around 0.45 of a utilization, providing 2.0 ℃ of a temperature span.

Keywords: s*olid-state caloric cooling, magnetic refrigeration system, magnetocaloric effect, active magnetic regenerator (AMR)*

35. Sources of leakage in refrigeration and air conditioning systems and technical solutions to prevent the leaks

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ABSTRACT

Refrigerant leakage is one of the most common faults in compressor-based appliances, which are primarily used in refrigeration and air conditioning (RAC) systems. Leakage of synthetic high global warming potential refrigerants from RAC systems has significant climate impacts. Moreover, it represents a high cost in terms of energy use due to loss of refrigerant charge and consequential decrease in system's efficiency. There are a number of potential leak sources in RAC systems that are responsible for significant amounts of energy loss as well as emissions of potent greenhouse gases (GHGs). This research aimed to investigate the common leak sources appeared over operational period of RAC equipment. For doing so, a survey was conducted in 35 RAC service and maintenance companies in Malaysia to investigate the most common leak sources during service and maintenance of RAC systems. The result of the study shows that flare joint and brazing joint are the most observed leak source in Malaysian RAC industry. A number of technical solutions for prevention of such leaks were extracted from the literature to reduce leakage rate, prevent refrigerant emissions, and to enhance the energy efficiency of RAC systems.

Keywords: *refrigeration systems, leakage, flared joints, brazed joints, energy efficiency*.

28. Efficiency of precision air conditioning on temperature and cooling load change

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ABSTRACT

In the data center industry, server equipment requires cooling facilities to maintain the temperature, performance, and life time of the server device. The data center must be able to operate for 24 hours without stopping. Cold air that enters the server device must be maintained and controlled at a certain temperature so that it does not damage the performance of the server device. This study aimed to study changes in air temperature parameters on the temperature distribution of air flow in precision AC with the result of maintaining the precision of air temperature. The method used was to compare the temperature distribution of the air flow in the room using the 6SigmaRoom software with parameters based on return air temperature 26 ℃ and 24 ℃. The results of the study explain that air flow with different parameters on cooling based on data center space which has a cooling capacity of 71.48 kW can still serve the data center well. Besides that, it is also explained that the increase in temperature return water has an effect on decreasing the air flow rate and decreasing the power usage.

Keywords: *precision AC, 6SigmaRoom, cooling load, efficiency*

37. Experimental study of flow condensation heat transfer of ammonia inside a multiport mini-channel tube

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ABSTRACT

Ammonia (NH3) refrigerant was used from 1876 in a vapor compression machine by Carl Von Linde. It is the most environmentally friendly refrigerant, and it has both GWP and ODP equal to zero. Compared with other CFCs and HCFCs industrial refrigerants, the ammonia systems cost 10-20% less to build than one that uses CFCs, 3-10% more efficient refrigerants than CFCs, saving energy and operating cost. In this work, the experimental data of ammonia condensation inside a multiport tube are investigated. Experimental data were obtained for mass fluxes from 50 to 500 kg/m^{2}s and heat fluxes from 3 to 12 kW/m^2 at a fixed saturation temperature of 48 °C. The effects of vapor quality, mass flux, and heat flux on the heat transfer coefficient have been clarified and analyzed. The comparison of heat transfer coefficients among R22, R410A, R32, R290, R-1234yf, and R717 is analyzed.

Keywords: *ammonia, condensation, heat transfer coefficient, multiport, mini channel.*

SESSION 8A: AC/AC SYSTEMS

30. Study of frost and defrost characteristics of thermally conductive carbon fiber composite based heat exchanger

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ABSTRACT

When heat pumps are utilized in severely cold weather, frost accumulates on the external evaporator fins, reducing the thermal efficiency significantly. Carbon fiber reinforced polymer composite can be used as evaporator fins because of their efficient material features and heat resistivity nature. Using resistive heating characteristics, the thermal efficiency of a heat exchanger unit based on CFRP fins was examined.

Keywords: c*arbon fiber reinforced polymer, frosting, defrosting, resistive heating*

43. Desiccant air conditioning (DAC) systems and their prospects for energy savings in tropical climates: the Philippines scenario

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ABSTRACT

Space cooling consumes a huge fraction of electricity end use in tropical countries. Thermally-driven desiccant and evaporative cooling-based technologies are promising greener and cheaper alternatives to compressor-based systems due to its separate handling of latent and sensible loads. Desiccant Air Conditioning (DAC) systems, which consist a desiccant dehumidifier, cooling unit, heat source for regeneration, and a heat recovery unit, can be arranged in several configurations with varying overall system and economic performance. In this study, the performance of thermally-driven desiccant dehumidifier and dew point evaporative cooling systems were investigated for various configurations (standard cycles in ventilation and recirculation modes with and without internal cooling, and multistage systems) using a psychrometric approach. System parameters such as regeneration temperature, desiccant load, cooler load, heating load, heat recovery load, thermal COP, fan power requirements, and system size were analyzed. A selection guide for tropical climates was also discussed for the selection of a suitable, sustainable, and cheaper space cooling technology.

Keywords: *Space cooling, desiccant air conditioning, dew point evaporative cooling, tropical climate*

57. A feasibility study on the ED-assisted liquid desiccant regeneration method

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ABSTRACT

Liquid desiccant (LD) dehumidification has attracted attention for its high energy efficiency. However, it has limitations in that it requires a large amount of heat for the desiccant regeneration and the LD is highly corrosive. To solve these problems, in this study, theoretical models of electrodialysis (ED) and packed bed dehumidifier/thermal regenerator were integrated into an ED-thermal hybrid dehumidification system model. The working fluid of the hybrid system was selected as KCOOH known for its non-corrosiveness. Under various operating air conditions, the electrical energy consumption for the regeneration of the hybrid system was simulated, and it was compared with that of the conventional LD dehumidification system. Under all the operating conditions, the simulation result showed that the hybrid system required around 20% less electric energy for heating and cooling the LD than the conventional system. However, the total electric energy consumption of the hybrid system was more than double that of the conventional system due to the large energy consumption by the ED stack. Therefore, for the practical application of the proposed system to be feasible, membrane properties such as the transport number and the electric conductivity should be improved.

Keywords: *Electrodialysis, liquid desiccant, dehumidification, regeneration, potassium formate*

3. Energy consumption estimation for a hydrothermal energy used in building by ECO2

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ABSTRACT

Buildings consume much energy and emit extremely large amount of greenhouse gases. Many governments in the world have conducted building energy performance certification programs to reduce the building energy consumption. In this study, a reference building and its HVAC system were simulated, and the energy load and consumption were estimated by the ECO2 software. The software is a simple building simulation program based on a monthly calculation method. The simulation results showed that 4.7% of total annual energy consumption could be reduced through the application of heat recovery ventilation system installed in the building air-conditioned space by electrically driven heat pumps. Furthermore, the simulation that was performed for the heat pump used river water as the hydrothermal energy source and the results presented showed that the heat pump could generate an annual renewable energy per unit area of 13.7 kWh/m^2 for heating, cooling, and hot water supply. For the reference building, the calculated Energy Independence Rate (EIR) was 10.5% by using hydrothermal energy.

Keywords: *building energy, energy consumption, heat pump, heating and cooling load, hydrothermal energy*

62. Fault diagnosis of an air conditioner using physical-based simulation model

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ABSTRACT

To operate the air conditioner efficiently and to save energy, it is necessary to estimate the amount of refrigerant charge. However, it takes a lot of time and cost to acquire steady-state data, and since actual operation varies according to changes in outdoor temperature and cooling load, steady-state data extraction for predicting the amount of refrigerant charge may reduce the accuracy of prediction. In this study, operation experiments of the air conditioner with different refrigerant charge amounts were performed, and the operation of air conditioner at transient-state was simulated using the physical-based model and could verify the accuracy of model.

Keywords: *Air conditioner, Fault diagnosis, Simulation model*

36. Condensation heat transfer characteristics of R1234yf inside the multiport mini-channel tube

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ABSTRACT

R1234yf is an HFO that is used as a good candidate for replacing R134a in automotive air conditioning, and it has a low global warming potential of 4 and zero ODP. R1234yf has a cooling performance that is 5% less than R134A but is significantly better for the environment. This research report measured and analyzed the heat transfer performances of R1234yf in the condensation process inside two different multiport mini-channel tubes. Experimental data were obtained for mass fluxes from 50 to 500 kg/m^{2}s, and heat fluxes from 3 to 12 kW/m^2 at a fixed saturation temperature of 48°C. The flow distribution of the R1234yf effect on the heat transfer coefficient was analyzed. Finally, a new heat transfer coefficient correlation was developed from the experimental data.

Keywords: *R1234yf, condensation, heat transfer coefficient, multiport, mini channel.*

SESSION 8B: MODELLING - AC/REFRIGERATION/COOLING

6. Through use of an artificial neural network to optimize time allocation strategy a three-bed adsorption chiller

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ABSTRACT

The advantage of 3-bed adsorption cooling systems is that the chilled water temperature at the evaporator output remains constant. Due to the huge number of operational parameters involved in a 3-bed system, experiments are not a practical technique for conducting comprehensive case studies. In several recent applications, it has been suggested that instead of trials, a simpler multi-regression model be used. Artificial neural networks (ANN) are a type of artificial intelligence (AI) method. Using ANN with five variables, such as adsorption/desorption time ratio (f_{ad}), high/low evaporator time ratio (f_p), cycle time (τ), and the time lag between each adsorption bed ($\underline{\delta}_2$, $\underline{\delta}_3$), the optimal time allocation for a 3-bed, 2-evaporation adsorption cooling system were systematically calculated. Each case was carefully simulated using a method devised and verified, which took an average case of 7 days to compute. When the ANN-estimated COP and SCP target data were compared to the actual results, the errors were within ±4%.

Keywords: *adsorption chiller, optimization, artificial neural network*

8. Numerical study for the temperature uniformity evaluation of gasket plate heat exchanger

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ABSTRACT

In this study, CFD analysis was performed to investigate the cause of the thermal stratification in the channel and the temperature non-uniformity of the plate heat exchanger. The temperature non-uniformity in the channel was shown in the order of Section 1 > Section 3 > Section 2. As the cold-side mass flow rate increased from 0.03 kg/s to 0.12 kg/s, the non-uniformity of temperature at Sections 1 and 2 decreased from 0.0061 to 0.0028 and from 0.0041 to 0.0034, whereas it increased from 0.0054 to 0.006 in Section 3.

Keywords: *plate heat exchanger, flow distribution, non-uniform temperature*

40. TRNSYS simulation of thermal environment according to outdoor conditions in desiccant cooling space driven by gas engine cogeneration

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ABSTRACT

In this study, TRNSYS was used to predict the performance and indoor thermal environment according to outdoor air conditions in desiccant cooling linked to gas engine cogeneration. Simulations were performed under four outdoor conditions: hot and dry (HD), cool and dry (CD), hot and humid (HH), and cool and humid (CH). When sufficient dehumidification is achieved, thermal comfort is well secured. The heat of regeneration increased in the order of HD, CD, HH, and CD. The cooling capacity was 6.8, 5.3, 4.9, and 3.5 kW for HH, CH, HD, and CD outdoor air, respectively. The coefficient of performance was found from 2.6 to 0.7 in the same order as the outdoor air condition where regeneration heat is favorable because the effect of regeneration heat was more dominant than the cooling capacity. As a result of applying the converted value of heat and electricity, the value of regenerated heat decreased, showing good performance in the order of HD, HH, CD, and CH.

Keywords: *hybrid desiccant cooling system (HDCS), regeneration heat, cooling capacity, coefficient of performance (COP)*

20. Two-phase heat transfer microchannel system identification with particle swarm optimization (PSO) approach

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ABSTRACT

The complex behavior of two-phase flow particularly in microchannels can be unpredictable. Experimental measurements are near impossible because of the unavailable compatible assessment equipment. This paper reports a system identification (SI) analysis of the collected experimental data of two-phase flow of propane (refrigerant R290) in a microchannel test rig. An ARX model was chosen as the dynamic model and the modelling of the input-output data was done using a new methodology based on Particle Swarm Optimization (PSO) technique. Measured temperature difference across the microchannel test section and the mass flow rate were the input and output, respectively. The performance of the Particle Swarm Optimization with Discoverer (PSOd) was investigated and compared to the original PSO technique. The model was then validated by mean-squared error (MSE). Results demonstrate the advantages of discoverer in PSOd over its standard counterpart with a smaller MSE of $6.2629x10^{-11}$ and a faster convergence. The SI allows a better prediction of the mass flow rate before any further experiments to obtain the heat transfer coefficient are actually done. The model provides better management of design of experiments that involve the complex two-phase flow in a microchannel.

Keywords: *particle swarm optimization, particle swarm optimization with discoverer, system identification, two-phase heat transfer, microchannel*

27. A study on modeling dynamic characteristics of battery cooling system for ESS system according to the configuration of water-cooled battery cooling module

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ABSTRACT

Lithium batteries are playing an important role in emissions reduction and fuel solutions. However, Lithium battery thermal management is a challenging issue for the energy storage industry, especially for the electric vehicle industry. Therefore, many studies are released to analyze battery cooling performance. In this study, the simulation is implemented using the Simscape toolbox of MATLAB/Simulink is to firstly simulate a battery cooling system using water coolant at different C rates. Results demonstrated that battery characteristic in experiment and simulation is matched.

Key words: ***e****lectric vehicle,* ***b****attery cooling system, MATLAB/SIMULINK simulation*

53. Prediction of boiling heat transfer coefficient of R1234yf inside the multiport mini-channel tube by machine learning method

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ABSTRACT

An application of machine learning to predict the boiling heat transfer coefficient of R1234yf inside a multiport mini-channel tube is proposed. The ANN (Artificial Neural Network) model on machine learning is applied to train and test the data of R1234yf with hydraulic diameter of 0.969 mm, saturation temperature of 6^{o}C, mass flux of 50-500 kg/m^{2}s, and heat flux of 3-12 kW/m^{2}. The experimental data of R1234yf on flow boiling is divided into 80% and 20% for train data and test data, respectively. The input parameter consisted of 16 dimensionless numbers, mass flux, heat flux, and vapor quality. The result of the ANN model prediction with hidden layers (512,256,128,64,32,16) is compared to the superposition model prediction. It showed that the prediction by ANN model was better than the superposition model with a mean deviation of 10.25%. The ANN model could be a new convenient method to predict the boiling heat transfer coefficient.

Keywords:
machine learning, artificial neural network, R1234yf boiling, heat transfer coefficient, multiport mini-channel

54. Application of machine learning to predict the heat transfer coefficient of R32 inside the multiport mini-channel tube

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ABSTRACT

Recently, the development of correlations to predict the boiling heat transfer coefficient has been a topic of discussion to design a new refrigeration and air-conditioning equipment and many others. Generally, to develop a new boiling heat transfer coefficient correlation, a large amount of data and research analysis are needed. There are several methods of analysis to predict the boiling heat transfer coefficient, one of which is machine learning. An application of machine learning to predict the heat transfer coefficient inside a multiport mini-channel tube is proposed. The ANN model with hidden layers (256,128,64,32,16) was used to train and test the data of R32 divided into 80:20 for train data and test data. The experimental study of R32 on flow boiling was conducted on hydraulic diameter of 0.969 mm, saturation temperature of 6^{o}C, mass flux of 50-500 kg/m^{2}s, heat flux of 3-6 kW/m^2, and vapor quality of 0-1. There are 10 dimensionless numbers used as input parameters including the mass flux, heat flux, and vapor quality. The prediction of the ANN model is then compared to the superposition model. The result showed that prediction by an ANN model was better than the asymptotic model with a mean deviation of 11.11%.

Keywords:
machine learning, ANN, flow boiling R32, heat transfer coefficient, multiport mini-channel

SESSION 9A: COOLING EFFECTS

5. Sinusoidal surface roughness effect on solidification of water considering degree of supercooling

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ABSTRACT

A numerical case study was conducted to examine the effect of surface roughness of the enclosed type sinusoidal cylindrical PCM, on the solidification process. The effect of the degree of supercooling on solidification was investigated in addition to the surface effect. Previous research was used to validate the numerical methods used in this work, and the results showed a good agreement. The findings reveal that the amplitude of the surface roughness and the degree of supercooling have a significant impact on solidification. As a result, the rate of solidification was the lowest when the amplitude was the smallest and the degree of supercooling was the highest.

Keywords: *PCM, roughness, super-cooling*

19. Performance analysis of a double layer microchannel heat sink cooled with graphene nanofluid at various temperatures

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ABSTRACT

Many studies have been completed to explore the capabilities of nanofluids as a coolant in a microchannel heat sink (MCHS) to manage the high heat fluxes generated from integrated circuits. Although complex geometries and various conditions have been investigated, most of the studies involved a single layer of parallel channels (SL-MCHS) with few utilizing experimental data of the thermophysical properties. This paper reports the investigation of the performance of a graphene (FLG) nanofluid-cooled SL-MCHS as well as that of double layer MCHS (DL-MCHS) using experimental data for thermophysical properties with different concentrations. The DL-MCHS has 2 levels of parallel microchannels with the same MCHS unit dimension as that of the SL-MCHS, a total height of 500 μm with its length and width 1 cm by 1 cm. A multi-objective particle swarm optimization (PSO) was utilized to simultaneously minimize the thermal resistance and pressure drop of the MCHS unit, the channel aspect ratio and width ratio being the design variables. Results showed that at 10 ℃ and 0.05 concentration of FLG, the DL-MCHS reduced the thermal resistance and the pressure drop by 3.6% and 14%, respectively. For higher temperatures, up to 50 ℃, further reduction was achievable which is attractive since a MCHS unit normally operates at the higher temperature range with many units of the MCHS in operation.

Keywords: *nanofluid, double layer microchannel heat sink, thermal resistance, pressure drop*

12. Investigation on the improvement of driver's thermal comfort and energy saving by using various seats

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ABSTRACT

In this study, the thermal comfort analysis of the driver according to the use of a basic seat, a ventilation seat, and a cold water seat with the air conditioner in the car cabin under summer condition was performed. As a result, the subjective questionnaires (TSV, CSV, CLV) of the driver were the most comfortable when using the cold water seat. Compared with the previous research results, it was confirmed that the temperature of the air-conditioning system should be lowered in order to satisfy the same thermal comfort when using the basic seat and the ventilation seat compared to the use of the cold water seat. The use of basic and ventilation seats requires a lower evaporation temperature than the cold water seat, which consumes more power consumption in the automobile air conditioning system. Accordingly, when the evaporation temperature of the air conditioner increases from 7.2°C (basic seat) to 13.2°C (cold water seat), the annual consumption power of the compressor in an air-conditioning system using R134a, R1234yf, R1234ze(E), R152a can be reduced by 80.3, 79.6, 77.4, and 79.6 kWh/year, respectively.

Keywords: *air-conditioning system, annual consumption power, cold water seat, thermal comfort*

29. Effect of temperature and humidity on the performance of desiccant dehumidification system under low-temperature regeneration

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ABSTRACT

The desiccant dehumidification system can separate the latent heat and sensible heat in the air conditioning system and achieve energy saving by removing latent heat. Industrial waste heat and renewable energy could be utilized in desiccant dehumidification systems, which results in the desorption process at a temperature below 70°C. This study will focus on the effect of various temperature and humidity ratios of regeneration air in the low regeneration temperature range on the desorption process. The experiment is divided into two groups and the humidity ratios of each group in regeneration process are fixed at 0.005 kg/kg and 0.010 kg/kg, respectively. Various regeneration temperatures have been applied in the temperature range 40°C - 70°C. The evaluation of this study employs moisture removal capacity and COP as key performance indexes. The results indicate that the higher desorption temperature leads to higher average desorption capacity. Besides, with the increased desorption temperature, the average moisture removal capacity increases but COP decreases. In contrast, the high humidity ratio of regeneration air leads to a weak dehumidification ability. When the regeneration temperature is lower than 54°C, both COP and average water removal capacity are significantly higher at the humidity ratio 0.005 kg/kg.

Keywords: *adsorption, dehumidification, desiccant, performance analysis*

4. Thermofluid behaviour of boron nitride nanotube nanofluid in a microchannel under optimized conditions

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ABSTRACT

While numerical modeling of different types of nanofluids in various microchannel heat sink geometry under different flow conditions are many, few involved utilizations of experimental data. Reports so far have indicated the potential cooling capability of nanofluids in general, yet none have looked into the effects of the surfactant alone on the fluid flow, in particular the thermofluid flow pattern. This paper reports the results of a numerical simulation with CFD on the fluid flow of Triton TX-100 surfactant with Boron Nitrate nanotubes (BNNT) in distilled water (base fluid) at 30℃ and 50℃. The nanofluid (BNNT) operated at high temperature provided a lower thermal resistance. A higher pumping power was found for BNNTs and TX-100 at 30℃ compared to distilled water at both temperatures. The outcomes of the present study provide a better understanding of flow characteristics and flow visualization along a microchannel heat sink so that better design decision can be made for improvement of this application for different needs.

Keywords: *numerical simulation, boron nitride nanotubes, surfactant, microchannel*

23. A study on the thermal performance characteristics of high-efficiency PCM heat storage tank for solar heat storage using graphite fin

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ABSTRACT

Graphite is a promising material in application of thermal storage system, due to its high thermal conductivity and extreme lightweight. In the current study, research on a rectangular graphite finned latent heat storage was experimented and numerically simulated. The effect of fin material, fin thickness, inlet heat transfer fluid temperature, and water flow rate has been considered related to the thermal performance of charging and discharging process of PCM. To evaluate the system, heat transfer rate, total thermal resistance, and liquid fraction are the main parameters for analysis.

Keywords: *PCM, latent heat storage, graphite fin, thermal storage system, fin material*.

SESSION 9B: ENERGY CONSERVATION & UTILIZATION

13. Investigation of thermal comfort during driving with seat heating mode in winter using driver's PPG

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ABSTRACT

The indoor environment of the vehicles in winter is very cold. A driver's thermal comfort and driving concentration need to be enhanced by using the heating system. Generally, the evaluation of thermal comfort is mainly subjective and requires objective indicators. Therefore, a study on thermal comfort using the driver's heart rate variability using photoplethysmography (PPG) while using seat heating mode was carried out during actual driving conditions in winter. As a result, at the beginning of the experiment, the Low frequency/High frequency (LF/HF) of PPG was temporarily reduced and then increased again; after that, it remained almost constant. Stress index and Root mean square of standard deviation (RMSSD) was relatively high in the early stage of the experiment but decreased significantly after 5 min and 7.5 min of the experiment, which means that the subjects felt stable. Therefore, the use of seat heating mode during driving in winter can quickly improve the thermal comfort of the driver.

Keywords: *thermal comfort, biosignal, heart rate variability, photoplethysmography*

59. Equilibrium analysis of adsorption heat transformer cycle with silica gel – water vapor pairs for waste heat upgrade

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ABSTRACT

In the present study, an equilibrium model of adsorption heat transformer (AHT) cycle has been developed and performance analysis has been carried out for possible application in the waste heat upgrade and thermal desalination. The cycle involves heat sink at low temperature (T_L), heat source at medium temperature (T_M), and heat supply at high temperature (T_H). Multiple silica gel – water vapor pairs have been used as adsorbent-adsorbate pair. Numerical optimization technique has been utilized for determination of intermediate pressure and uptake after preheating and precooling phase of the AHT cycle. The performance parameters in terms of useful heat ratio and condensation heat ratio have been determined and compared between the different pairs at 30 °C (T_L) – 60 °C (T_M) – 80 °C (T_H) temperatures. Parametric analysis of the AHT cycle by varying heat sink, heat source, and heat supply temperatures has been carried out. It has been found out that an increase in the heat source temperature T_M and decrease in the heat supply temperature T_H (reducing source-supply temperature difference) have a positive impact on the useful heat ratio and a negative influence on the condensation heat ratio of the AHT cycle.

Keywords: *adsorption heat transformer, waste heat upgrade, desalination, equilibrium analysis*

52. Thermal performance assessment of end-of-life vehicles transparent sandwich panels integrated in residential building in Kuala Lumpur

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ABSTRACT

The construction industry is increasingly becoming a high-energy consumer, accounting for 40% of total energy consumption with 35% of carbon dioxide is released into the atmosphere. To find ways to reduce energy consumption, energy efficiency has been highly recognized and developed through government policies. If the number of houses in the urban area increases excessively, the energy use of buildings will pose a huge threat to the city's energy supply chain. The applications of newly configured sandwich panels seem to meet building performance and energy efficiency requirements, especially in optimizing building envelopes or modernizing existing buildings. In this study, a simulation method was used to study the application of ELV-based panels in residential buildings in Kuala Lumpur, Malaysia. For a complete evaluation, the verification simultaneously addresses the effects of CO^2 emissions and permeability on thermal performance. The study determined and verified the effectiveness and advantages of ELV-based sandwich panels in terms of energy saving and thermal comfort. In addition, this study used a simulation method designed to shape the profile for application to thermal performance. The results of such studies are intended to make a certain contribution to the energy efficiency of buildings when considering residential buildings in tropical cities.

Keywords: *transparent sandwich panel, energy efficiency, building envelope, ELV-based glazing, building thermal performance*

32. Investigating the effectiveness of passive cooling strategies for low-cost dwellings in Indonesia based on numerical simulations

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ABSTRACT

In this study, we aimed to identify affordable passive cooling measures using building energy simulations, to improve indoor thermal environments. Three baseline building models made of contrasting construction materials were assumed, namely House 1 with plywood walls, House 2 with brick walls, and House 3 with plaster-brick walls, based on past field measurements conducted in the urban district of Kampung. Furthermore, two passive cooling methods, that is, natural ventilation (modelled with increased air infiltration rate), and roof shading were adopted to assess their effectiveness at reducing indoor air temperature, in comparison with the baseline models. Sensitivity analysis revealed that natural ventilation was the most beneficial for House 3, in which the time fraction of indoor air temperature over 30 ℃ was reduced. Moreover, roof shading effectively reduced the indoor air temperatures during the peak hours of daytime, for all the modelled dwellings House 1 showed significant reduction in the probability of having temperatures over 32 ℃. The results of this study could be used in designing affordable measures to improve the living environment of low-cost dwellings in Kampung.

Keywords: *low-cost dwellings, passive cooling strategies, numerical simulation, natural ventilation, roof shading*

46. Development of stratification analysis model for thermal energy storage tank using CFD

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ABSTRACT

Recently, Thermal energy storage technology has been achieved with a variety of technologies to develop eco-friendly and renewable energy sources. The optimal design and technology development of the thermal storage tank is important because such thermal energy can be stored in the TES tank to balance the heat supply and heat demand. In this study, the size of the TES model was designed to be 7 m in diameter and 7 m in height. The pipe inserted into the TES tank for charging and discharging working fluid located in the upper and lower parts of the TES tank was designed with a gap distance of 0.5 m from the wall considering the change of water level. The inside diameter of the TES tank inner pipe was 80 mm, the external diameter was 90 mm, and the diameter of the diffuser plate was 800 mm. When the hot water of 333 K temperature was charged in tank filled with low temperature water of 300 K temperature depending on the existence of the diffuser. The TES tank with the diffuser has a difference of at least 5 ℃ depending on the radial height direction of the TES tank compared to that without the diffuser.

Keywords: *thermal energy storage tank, Ansys Fluent, thermal stratification, CFD 3D transient state simulation*

51. Dynamic and static characteristics of absorption thermal battery system

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ABSTRACT

Low heat loss and high energy storage density has emerged as a promising solution for thermal energy storage application. Combined with an absorption cycle, the single-effect thermal battery system is the simplest form of the absorption thermal energy storage. However, the complex behavior of the system due to intricate thermophysical property of the binary mixture leads to difficulty of clear interpretation of the system. Existing studies have mainly used COP (Coefficient of Performance) or ESD (Energy Storage Density) as the key performance index. However, the time constant of the system is important in actual operation as well. The purpose of this study was to analyze the design factors affecting the time constant. Consequently, it is confirmed that the NTU affects the time constant dominantly only in the region where the NTU values of both heat exchangers was below 2. Considering an environment where the thermal battery is operated, the supply time of the energy required for charging will be limited. Therefore, when designing the thermal battery system, the time constant will be an important design factor because it represents the required energy supply time for charging.

Keywords: *absorption thermal energy storage, time constant, NTU, design factors*

SESSION 10A: ENERGY CONSERVATION & ENVIRONMENT

41. Development of chilled water turbine inlet air cooling model for enhancement of turbine performance

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ABSTRACT

The research presents a study on turbine inlet air cooling (TIAC) technology for enhancement of turbine performance for Universiti Teknologi PETRONAS (UTP) Gas District Cooling (GDC) plant. Using the analytical model, the performance of the Gas Turbine (GT) was analyzed and the size of the heat exchanger also were determined. Results of the analysis indicate that by implementing the TIAC technology to the plant, there is an increasing pattern of 19% to the power generated, with the size of the heat exchanger that can cope to decrease the inlet temperature of the inlet of GT to 15 ℃ is 3208 m^2. The size of the thermal energy storage (TES) was calculated as 1156.3m^3 to meet the cooling requirement.

Keywords: *turbine inlet air cooling, heat exchanger, chilled water*

48. Experimental investigation of two-phase flow boiling heat transfer and pressure drop of propane inside multiport minichannel

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ABSTRACT

In this work, the two-phase flow heat transfer coefficient and pressure drop of propane (R290) inside minichannel multiport tubes was investigated. The experimental data was conducted under the heat fluxes of 3 kW m^{-2} and 6 kW m^{-2}, the mass flux ranges from 50 to 500 kg $m^{-2}s^{-1}$, the saturation temperature of 6 ºC, and the vapor quality from 0.1 to 1.0. The test tube has 18 parallel rectangular channels with a hydraulic diameter of 0.83 mm. The heat transfer coefficient of R290 was found to be affected by the heat flux, mass flux, and vapor quality, while the frictional pressure drop gradient was dependent on the variation of heat flux. The present data were also compared with various heat transfer coefficient correlations and pressure drop models.

Keywords: *R290; heat transfer coefficient; pressure drop, multiport tube*

16. Heat transfer performance of LiBr solution-water in a plate heat exchanger according to LiBr concentration

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ABSTRACT

In this study, the heat transfer characteristics of LiBr/water solution at different concentrations in a brazed plate heat exchanger were experimentally analyzed. The working fluid at the low-temperature side was water, and the temperature and mass flow rate of water was fixed at 40°C and 300 kg/h, respectively. Also, the working fluid at the high temperature side was LiBr solution, and its temperature was 80°C. In addition, the mass flow rate of LiBr solution was varied from 200 to 700 kg/h. To analyze the heat transfer performance according to the concentration of LiBr solution, the experiment was conducted by changing the LiBr concentration with 56, 58, 60, and 62 wt % solution respectively. As a result, the heat transfer rate of all concentrations increased with the increase in mass flow rate. Also, at a mass flow rate of 700 kg/h, when the LiBr solution concentration increased from 56wt% to 62wt%, the heat transfer capacity decreased from 9.49 to 8.88 kW, which was 21.7%-26.8% lower than that of water.

Keywords: *heat transfer, LiBr/H_2O solution, plate heat exchanger, concentration*

56. Numerical simulation of the interference effects to outdoor air flow and ventilation around adjacent building arrays

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ABSTRACT

This study explores the pedestrian-level wind environment around a building array within the vicinity of a taller one located upwind. The objective is to determine the mechanism of flow and impact of the separation distance between the two building arrays for various height ratios of the arrays on the air flow and ventilation. The study utilizes Computational Fluid Dynamics numerical simulation technique to predict the mean wind field around the building arrays. The full-scale sizes of the buildings and actual wind data were utilized. Results show that thermal comfort parameters defined as air velocity ratio and air flow rate are generally dependent on the separation distance, which determines the proportion of corner-stream inflow into the streets. The stream flow was found to significantly enhance the level of ventilation in the streets, providing up to about 50% of the total inflow for some of the cases. The findings demonstrate the importance of corner-streams in invigorating wind flows and enhancing outdoor air ventilation around a building array shielded from wind by an imposing one located upwind.

Keywords: *building arrays, separation distance, air flow, numerical simulation, ventilation*

21. A study on performance of heat and water vapor recovery from flue gas with transport membrane condenser material

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ABSTRACT

Flue gas in power plant units takes a large amount of heat loss and wastewater. Recovery of heat and water vapor is highly expected to enhance power plant efficiency and reduce the water consumption. A transport membrane condenser has been demonstrated to be an effective method based on the condensation and transport of vapor from flue gas to the collected flow. A flat microporous alumina membrane is applied in this study. The steam generator is used to produce the artificial flue gas with 100% relative humidity at controlled temperature and flow rate. A chiller incorporated with a plate heat exchanger is utilized to control the mass flow rate and temperature of the cooling water. The effects of different operating conditions in both flue gas side and coolant water side are investigated by the heat and mass change of water. The efficiencies are estimated through the rate of heat/water recovered to heat/water supplied. In the future, membrane thermal and chemical properties will be enhanced by several methods to optimize the efficiencies and to be applied in different scales and geometries.

Key words: t*ransport membrane condenser, TMC, alumina membrane, heat recovery, water recovery.*

9. Numerical assessment of ceiling-mounted air curtain on the particle distribution in surgical zone

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ABSTRACT

The airflow distribution in an operating room plays an important role in preventing surgical site infection. It could dilute and remove the particles released by medical staff, subsequently reducing particle settlement on a patient. The objective of this study was to examine the efficiency of a ceiling-mounted air curtain in reducing the particle distribution in a surgical zone. A computational fluid dynamic (CFD) software was used to simulate the airflow and the particle movements in the operating room. A Re-Normalisation Group (RNG) k-ε model was used to simulate the airflow, while a Lagrangian model was used to simulate the particle movements. The baseline case and case 1 was equipped with air supply diffusers, while case 2 to case 5 utilized a combination of air supply diffusers and air curtains. The results showed that the use of an air curtain does not reduce the number of particles settled on a patient. The use of air curtain in cases 2, 3, 4 and 5 increased the particle settlement 3.3-fold, 4.3-fold, 3-fold, and 6.7-fold, respectively. However, the increment in the area of the air supply diffuser from 4.32 m^2 to 7.74 m^2 managed to reduce the number of particles by 33.3 %.

Keywords: a*ir curtain, CFD simulation, particle settlement, operating room, air diffuser*

SESSION 10B: COOLING & ENVIRONMENTAL ANALYSIS

33. The prospective of particle image velocimetry (PIV) measurement in measuring velocity profile in thermoacoustic system

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ABSTRACT

Precise measurement of fluid velocities is an important aspect in several applications including thermoacoustic refrigeration systems. A thermoacoustic refrigeration system uses a high-amplitude acoustic standing wave to generate a cooling effect. The understanding of the fluid flow characteristic between the refrigerant and a stack is important to improve the heat transfer process and to minimize thermal and viscous losses. This paper reviews the various methods employed by previous researchers in analysing the velocity profiles in the thermoacoustic refrigeration system and the prospective implementation of Particle Image Velocimetry (PIV). PIV is a non-invasive technique that provides velocity estimates in several points of the measuring region. This review looked at the method employed to analyze the velocity profile, error analysis, and the effectiveness of another measurement method compared to the PIV measurement. The discussions include related parameters that have been considered by past researchers.

Keywords: *thermoacoustic, velocity profile, particle image velocimetry*

15. Predictive analytics application in building diagnostic for testing the health risk assessment tool of indoor air quality and sick building syndrome in educational building

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ABSTRACT

The purpose of this study is to create, train, test, and validate the predictive analytics model from epidemiology and exposure assessment data collected for sick building syndrome diagnosis among learners. A set of MM040NA sick building syndrome questionnaires used in the evaluation process and score was given to the respondents. Health complaints (doctor diagnose based) were also recorded and scored. Indoor air quality airborne measurement was made using occupational hygiene method at the individual location of the respondents. Predictive analytics algorithm models namely Neural Network, Logistic Regression, Classification Tree, Random Forest, and Support Vector-machine were used in the training and testing of the dataset for predicting the health risk based on exposure of indoor environment. Results reveal that there was significant higher classification accuracy of the predictive model for neural network (82.5%) as compared to other predictive algorithms. Validation result suggests there were significant predictors of the level of indoor air quality parameters able to predict the status of the health complaint based on the status of the indoor air quality served by mechanical ventilation. Predictive analytics using neural networks can be used in diagnosing the occurrence of sick building syndrome and health complaints from the indoor air quality status by utilizing minimum air quality parameters for preliminary evaluation.

Keywords: *epidemiology, pattern recognition, environmetrics, chemometrics, iaq, ieq*

60. Development of a new correlation for pre-dryout evaporative heat transfer coefficient of R290 in a microchannel

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ABSTRACT

R290 is reported to be more energy efficient than R22. Although many correlations are being developed for two-phase heat transfer coefficient correlation in microchannels, none has the desired accuracy yet. This paper presents prospective improvements in the convective heat transfer coefficient correlation accuracy for the dry-out conditions; when the heat transfer coefficient drops at a certain vapor quality. An accurate heat transfer coefficient forecast is needed to minimize over or under design, conserve energy and material, and maximize the performance. A new correlation relevant for R290 across 831 sets of experimental data points in a microchannel was generated by optimizing six variables in the nucleate boiling suppression factor, S, and force convective factor, F, of a selected superposition type correlation. The new correlation was optimized for saturation temperature ranging between 5 and 25 °C, diameter ranging between 1.0 and 6.0 mm, heat flux ranging between 2.5 and 60 kW/m^2, and mass flux ranging between 50 and 500 kg/m^{2}s. The MAE was reduced from 21.84 to 17.02 % for pre-dry out data. The new correlation may be utilized to estimate the heat transfer coefficient of R290 in heat transfer analysis in a microchannel under the investigated operating conditions.

Keywords: *R290, microchannel, two-phase flow, pre-dry out, superposition*

38. Bayesian estimation of air exchange rate based on occupant exhaled carbon dioxide

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ABSTRACT

A complicated procedure of air exchange rate test (e.g. perfluorocarbon tracers) may not meet the economic consideration for all zone types and their applications. A practical way of measuring air exchange rate based on occupant exhaled carbon dioxide is presented in this paper. The model is based on the mass balance model of CO_2 concentration. With the help of the Bayesian MCMC algorithm, it is expected to overcome the uncertainty of the measurement that inherently exists in the model. The aim of the study was to investigate the accuracy of the estimation method for measuring air exchange rate and its effect under constant and varied ventilation schemes. A small office room equipped with a ventilation system and control was used. The result shows that the accuracy of air exchange test is significantly dependent on how well the environmental conditions can be maintained while the effect of ventilation scheme does not influence strongly.

Keywords: *air exchange rate, carbon dioxide, Bayesian MCMC*

SESSION 10C: OTHERS

39. Thermal Simulation for A First-Degree Skin Burn Injury Assessment

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ABSTRACT

In electric vehicles, a radiant heater is a potential heating technology for reducing energy usage and therefore increasing driving range. The radiant heater heats the human body locally and directly without overheating the entire cabin space while providing equivalent thermal comfort to the driver and passengers. Skin burn injury from an unintentional touch with the hot surface of the heater is a concern when using radiant heaters. A first-degree burn is known as a superficial burn that affects the first layer of the human skin that is called the epidermis. Arrhenius models of irreversible thermal alterations in tissues are widely used for skin burn injury assessment that is dependent on the rise of the skin temperature and duration. The current study conducted a thermal simulation to assess the transient temperature change in a multi-layer fingertip skin in contact with a radiant heater. The first-degree burn assessment was conducted by importing the simulated temperature profile of the skin layers into the Arrhenius model. The impacts of several factors including the cabin ambient temperature, the heater surface temperature, and the area of contact between the heater and the fingertip have been studied with the created simulation tool.

Keywords: *heat transfer, radiant heater, thermal injury simulation, skin burn injury, arrhenius model*

18. Evaluation of calcium chloride sorbent-bed material for portable indoor atmospheric water generation

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ABSTRACT

Fresh water is getting scarce and researchers all over the world are finding a new opportunity in producing water from atmospheric air. Malaysia is country with a hot and humid climate and has a potential in atmospheric water generation (AWG). AWG applies the dehumidification and condensation concept to extract water from the humid air. Sorbent bed-based solid adsorbent is an attractive method in AWG utilizing very low energy and low in cost. In this study, calcium chloride as one of most potent moisture absorbing compounds is used as a portable sorbent bed-based solid adsorbent for water production under humid indoor atmospheric condition. From the experiments conducted, water volume generated increases with weight of calcium chloride adsorbent used. The maximum amount of water produced was 200 ml for 400 g of calcium chloride and 100 ml for 200 g of calcium chloride. The highest desorption rate of 0.333 ml/min was also achieved with 400 g calcium chloride used. This research gives an insight on capability of calcium chloride as sorbent bed material for AWG application in high humidity environment.

Keywords: *atmospheric water generation (AWG), dehumidification, condensation, sorbent bed-based, solid adsorbent*

SESSION 11A: OTHERS

44. Porous Media Characterization for Self-powered Micropump

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ABSTRACT

Self-powered micropump is a powerless microfluidic device for transporting fluid in microchannel. Recently, porous media from filter paper has been used for a self-powered micropump actuation. However, there are insufficient studies on self-powered micropump fabrication technique effect on fluid flow through the porous media. In this work, characterization of porous media from different specifications of Whatman ashless grade W40 and W41 filter papers has been conducted with xurography and thermal lamination fabrication. Scanning Electron Microscope (SEM) and ImageJ analysis verified Whatman filter paper W41 porosity of 70.82 % and W40 porosity of 70.24 %. Experiments of water wicking through the porous media was conducted to further study the fluid flow parameters in free and confined environment. Filter paper W41 obtained higher value of flow rate and permeability than W40 due to its thickness and porosity. The pressure difference calculated for filter paper grade W40 in free and confined environment are 9.32 Pa and 3.84 Pa. On the other hand, filter paper W41 has lower pressure different of 1.92 Pa and 1.12 Pa in free and confined environment respectively. This study provides important findings on the filter papers' characterization which will be beneficial in self-powered micropump design.

Keywords: *self-powered micropump, microfluidics, porous media, wicking*

22. Physical Characteristics of Palm Kernel Shell Torrefied by Multilevel Torrefaction Reactor

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ABSTRACT

The transformation from strong dependence on fossil fuels to diversification of energy sources is necessary to cope with the increasing energy demand scenario, as well as to secure environmental and human protection. Torrefaction is one of the pre-treatments that has potential to convert agricultural residues into solid biofuels for electricity production. However, the use of inert gas such as nitrogen during single level torrefaction is not worthwhile and causes a burden in terms of operational cost. Therefore, in the present study, a novel multilevel reactor is introduced to increase the biofuel production rate for the same amount of flowing nitrogen. The multilevel torrefaction was performed for palm kernel shell under various temperatures of 250 to 300°C, fixed residence time of 40 minutes and nitrogen flow rate of 1 litre/min. It was found that PKS was successfully torrefied at all levels of the reactor. Based on the results, it can be said that the physical appearance and mass yield of the torrefied PKS are more affected by operating temperature rather than level number.

Keywords: *torrefaction, multilevel, palm kernel shell, biomass*

24. Separation of multicomponent lanthanides using zeolite A modified pectin biopolymer

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ABSTRACT

Zeolite A was modified with pectin to produce zeolite A/pectin composite (ZAP) and used as an adsorbent for separation of multicomponents lanthanide ions from aqueous solution. ZA was synthesized from natural kaolin by hydrothermal method. Pectin was introduced into a zeolite A to increase its adsorption performance of zeolite-A for simultaneous separation of lighter and heavier lanthanides. ZAP composite was characterized by FTIR (Fourier transform infrared) and SEM-EDX (Scanning electron microscopic-energy dispersive). Concentration of lanthanide was determined using XRF (X-ray fluorescence). SEM images showed ZAP composite produces a morphological shape like a nest, in which zeolite-A contained in the pectin skeleton system. The lanthanide used are lighter lanthanides (La, Ce, Nd, Sm) and heavier lanthanide (Dy) with contact time ranged from 30 to 60 minutes and pH ranged from 4 to 10. The highest adsorption efficiencies of dysprosium (Dy) with concentration of 0.061 mmol/L, was observed at contact times of 60 minutes at pH 4. On the other hand, the highest adsorption for neodymium (Nd) of 0.062 mmol/L wa osbserved at pH 7 for 60 minutes. Overall, the results showed that ZAP composite is potential used as adsorbent for separation of multicomponent lanthanides from aqueous solution.

Keywords: *lanthanides, pectin biopolymer, pH, simultaneous separation, Zeolite A*

55. Effect of Cold Plasma Voltage and Treatment Duration to the Microstructure and Hydrophilicity of Mushroom Grain Spawn

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ABSTRACT

Cold plasma surface treatment is known to be clean, non-toxic, and highly efficient. However, not much is known about the applications in the mushroom industry, given that the demand for mushrooms is projected to increase over the years as a great source of proteins, vitamins, and minerals. Thus, the purpose of this research is to determine the effects of cold plasma on Pleurotus sajor-caju (P. sajor-caju) grain spawns in terms of surface morphology, chemical changes, hydrophilicity, and mycelium growth under applied voltages (2, 2.5, 3, 3.5, 4kV) and treatment durations (5, 15, 30, 45, 60s). The grain spawns were being treated by a cold plasma treatment system. The proposed characterisation tests included scanning electron microscopy (SEM), Fourier-transform infrared spectrometry (FTIR), and apparent contact angle (ACA) sessile drop technique. It was found that reactive plasma species were responsible for the depressed surface and cracks on the mycelium structures, where etching and oxidation were theorised to be taking place. OH species were proposed to play an important role in improving the hydrophilicity properties of the mycelium surface by accumulating on the surface during the treatment. It is expected that at 2.5 kV applied voltage and 15s could promote the fastest mycelium growth.

Keywords: *cold plasma treatment, reactive plasma species, mushroom mycelium, applied voltage, treatment duration*

14. Classification technique of health risk assessment of indoor air quality and Sick Building Syndrome investigation among learners in educational building

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ABSTRACT

The purpose of this study was to classify, characterize, and analyze the indoor air pollutants according to the different health complaints in educational buildings. A set of MM040NA sick building syndrome questionnaires used in the evaluation process and score was given to the respondents. Classification method using cluster analysis and Discriminant Analysis was used to identify the classified region of overall spatial condition of indoor air measurement. Principal Component Analysis (PCA) was used to identify the possible source of pollutants in the pattern recognition technique. Cluster analyses indicate that the indoor air pollutants regressed and clustered according to 3 clusters which were then further validated. Classification accuracy reported is more than 95% based on 6 parameters. The PCA revealed that the main pollutants which are high risk issues are related to ventilation, smaller and larger particulate, and chemical dispersion from aldehyde compounds. Moderate risk showed issues on ventilation and chemical filtrations followed by particulate issues. Low risk showed issues related to the low ventilation and aldehyde dispersion within indoor environment. Techniques of classification of indoor air quality show promising reliable results and should be used as important tools in preliminary assessment of indoor air quality.

Keywords: *heat map, spatial epidemiology, indoor environment quality, IEQ, university, building related illness*

61. Transient Size Analysis of Carbon Nanotube Synthesis in Methane Diffusion Flame

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ABSTRACT

The mechanism of carbon nanotubes (CNT) growth is crucial to be studied for optimizing synthesis in producing high-quality products at a faster rate. Unlike chemical vapor deposition (CVD), flame synthesis undergoes complex process to provide suitable growth condition for carbon nanotubes. The nature of the flame, where heat and carbon source are interrelated at a high degree, creates a narrow gap of ideal condition for CNT growth. The growth of CNT diameter is extensively studied to better understand the growth mechanism, especially in the transient stage. In the present study, nickel catalyst coated on a substrate is exposed in methane diffusion flame at various exposure times, and the diameter of the grown CNTs is measured through Scanning Electron Microscopy (SEM) images. At all durations, the purity of the grown CNT exhibits a similar quality. The average diameter of the grown CNTs increases until 30 s, where the diameter shows a steady distribution. This growth possibly occurs due to the simultaneous catalyst nanoparticle formation and CNT growth in the flame that happens almost instantaneously. The aggregation-agglomeration of nanoparticle formation reshaping the size, which determines the diameter of grown CNT. The vapor-liquid-solid and solvation-diffusion-precipitation mechanism partly explained the growth mechanism. The diameter distribution of CNT correlates closely to the distribution of particle size.

Keywords: *Growth mechanism, diameter, carbon nanotubes, flame synthesis, nickel catalyst*

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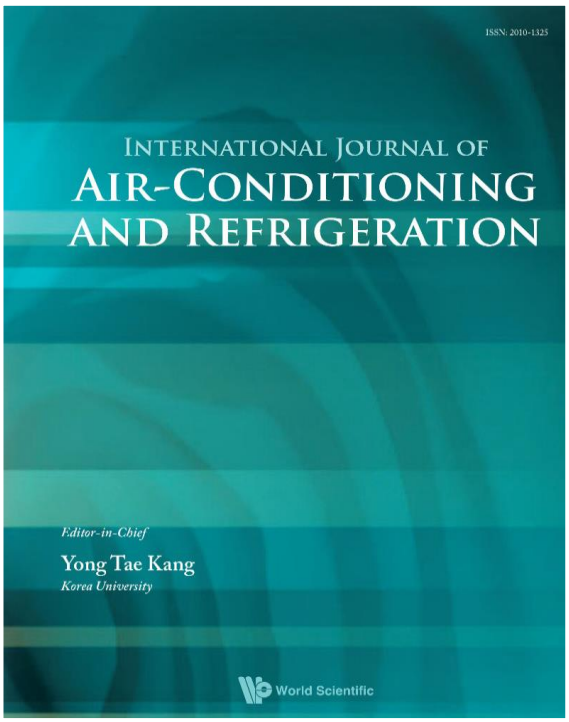
ISSN: 2010-1325
INTERNATIONAL JOURNAL OF
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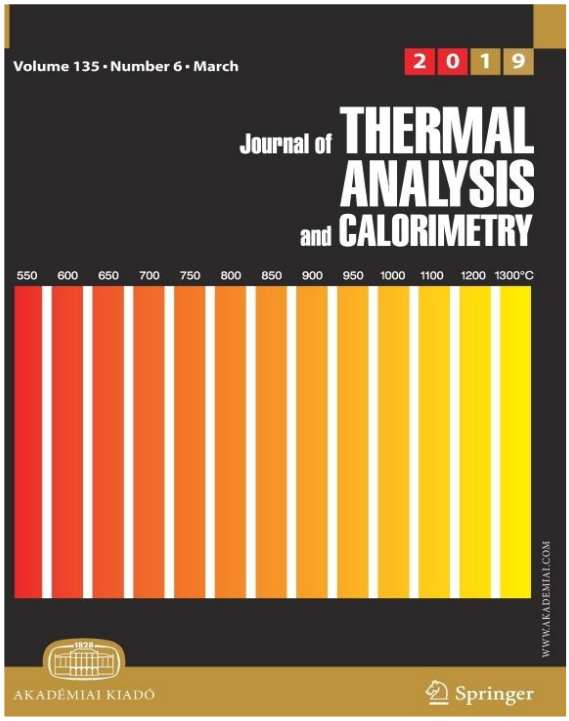
Volume 135 • Number 6 • March
2019
Journal of THERMAL
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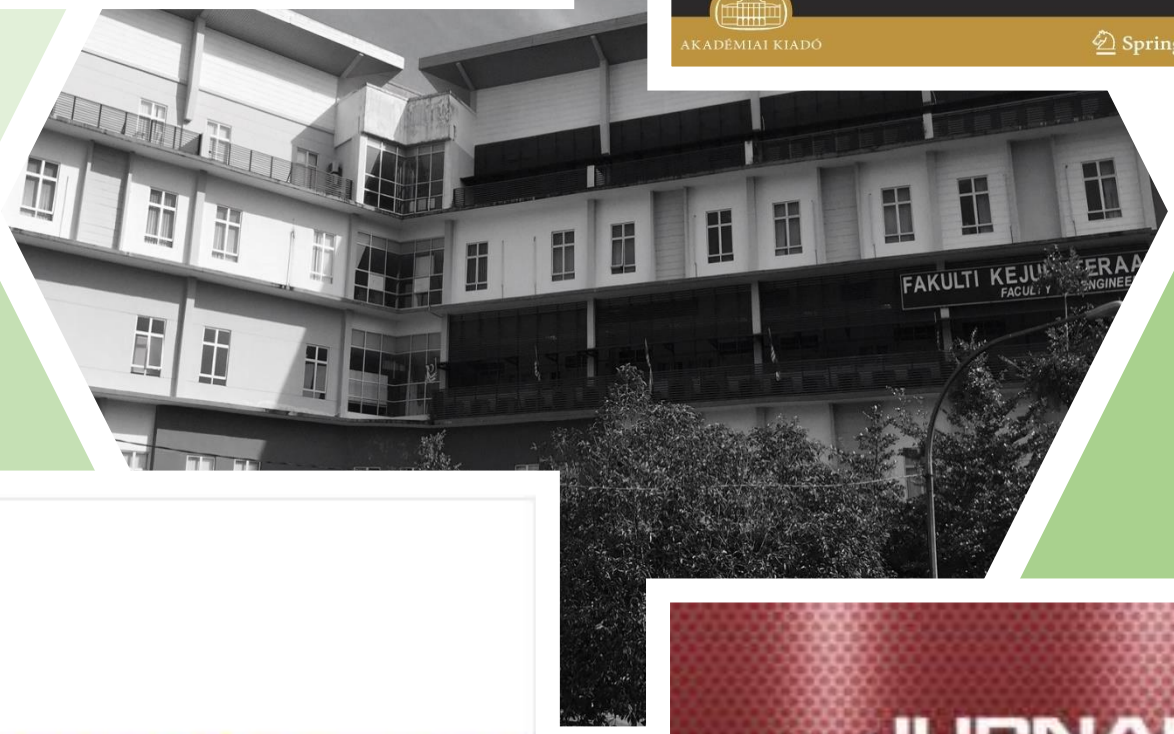
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Volume.01
March 2014
Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy
ISSN: 2189-0420 (Print)
ISSN: 2432-5953 (Online)


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