

7th INTERNATIONAL SYMPOSIUM **ON MULTIPHASE FLOW, HEAT MASS** TRANSFER AND ENERGY CONVERSION

Xi'an, Shaanxi Province, China

26-30 October 2012

Editor

Lieiin Guo

State Key Laboratory of Multiphase Flow in Power Engineering Xi'an Jiaotong University, Xi'an, Shaanxi Province, China

All papers have been peer reviewed.

Sponsoring Organizations

International Center for Heat and Mass Transfer (ICHMT) National Natural Science Foundation of China Ministry of Education of China International Association for Hydrogen Energy Chinese Society of Engineering Thermophysics Xi'an Jiaotong University



Melville, New York, 2013 **AIP Proceedings**

Volume 1547

Editor

Liejin Guo State Key Laboratory of Multiphase Flow in Power Engineering Xi'an Jiaotong University Xian-ning West Street No. 28 Xi'an, Shaanxi Province China E-mail: mfoffice@mail.xjtu.edu.cn

Authorization to photocopy items for internal or personal use, beyond the free copying permitted under the 1978 U.S. Copyright Law (see statement below), is granted by the AIP Publishing LLC for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$30.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923, USA: http://www. copyright.com. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Services is: 978-0-7354-1172-2/13/\$30.00



Publishing

No claim is made to original U.S. Government works.

Permission is granted to quote from the AIP Conference Proceedings with the customary acknowledgment of the source. Republication of an article or portions thereof (e.g., extensive excerpts, figures, tables, etc.) in original form or in translation, as well as other types of reuse (e.g., in course packs) require formal permission from AIP Publishing and may be subject to fees. As a courtesy, the author of the original proceedings article should be informed of any request for republication/reuse. Permission may be obtained online using RightsLink. Locate the article online at http://proceedings.aip.org, then simply click on the RightsLink icon/"Permissions/Reprints" link found in the article abstract. You may also address requests to: AIP Publishing Office of Rights and Permissions, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502, USA; Fax: 516-576-2450; Tel.: 516-576-2268; E-mail: rights@aip.org.

ISBN 978-0-7354-1172-2"*Qtki kpcrlRtkpv+ ISSN 0094-243X Printed in the United States of America

AIP Conference Proceedings, Volume 1547 7th International Symposium on Multiphase Flow, Heat Mass Transfer and Energy Conversion

Table of Contents

| Preface: 7th International Symposium on Multiphase Flow, Heat Mass Transfer and Energy | |
|---|-----|
| Conversion Liejin Guo | 1 |
| | 1 |
| ISMF 2012 Committees | 2 |
| SESSION FG: FUNDAMENTAL OF MULTIPHASE FLOW; GENERAL TOPICS OF HEAT AND MASS TRANSFER | |
| Bubble behaviors under subcooled flow boiling instability in narrow channel Feng Gao, Puzhen Gao, and Chao Xu | 3 |
| Statistical characteristics of evaporating-freezing process of water droplet during quick | |
| depressurization Wang-Fang Du, Jian-Fu Zhao, and Kai Li | 12 |
| Research on transient flow resistance of two-phase in narrow rectangular channel under rolling motions | |
| Guangyuan Jin, Changqi Yan, and Licheng Sun | 21 |
| An experimental research on microbubble emission boiling | • • |
| Jiguo Tang, Guangyu Zhu, Licheng Sun, and Xiaxin Cao | 30 |
| Investigation of the cavitating flow in injector nozzles for diesel and biodiesel | 10 |
| Wenjun Zhong, Zhixia He, Qian Wang, Zhaochen Jiang, and Yanan Fu | 40 |
| Numerical analysis on the characteristics of carbon deposition of catalytic partial oxidation of methane in micro-chamber | |
| Li Zhang, Yunfei Yan, Zhiwei Sun, Zhongqing Yang, and Qiang Tang | 47 |
| Acquisition of void fraction of pulsatile gas-liquid two-phase flow in rectangular channel Bao Zhou, Jingxing Liu, and Jingda Tian | 56 |
| Dao Zhou, shiganig Diu, anu shigua Tian | 50 |
| Bubble departure frequency during rolling motion in a single-side heated narrow channel Chao Xu, Puzhen Gao, and Shaodan Li | 62 |

| Experimental study of a novel manifold structure of micro-channel heat exchanger Bo Xu, Kunhao Xu, Wei Wei, Qing Han, and Jiangping Chen | 68 |
|--|-----|
| Numerical study of the influence of particle friction on horizontal pneumatic conveying Ke Li, Shibo Kuang, Ruiping Zou, Renhu Pai, and Aibing Yu | 75 |
| Modelling the combustion of charcoal in a model blast furnace Yansong Shen, Tomo Shiozawa, Aibing Yu, and Peter Austin | 78 |
| Experimental study on the onset of nucleate boiling in narrow channel by using grey relational analysis (GRA) Dong Han, Puzhen Gao, Liming Yan, and Lulu Lv | 88 |
| Effects of structural parameters on fluid flow and mixing performance in a curved microchannel with gaps and baffles Jian Li, Guodong Xia, Yifan Li, and Xinping Tian | 96 |
| Characteristics of slug flow in narrow rectangular channels under vertical condition Yang Wang, Changqi Yan, Licheng Sun, Dianchuan Xing, Chaoxing Yan, and Daogui Tian | 102 |
| Study of optimum nozzle exit position (NXP) in a steam ejector refrigeration system Jingming Dong and H. B. Ma | 115 |
| Modelling of natural convection theory for gases neglecting effect of gravity Ravendra Kumar | 124 |
| Study on flow-induced vibration of cage type control valve Shan Tu, Chao Wang, Yulin Tang, and De Dong | 131 |
| Computational study of wax deposition in pipeline Jimiao Duan, Jing Gong, and Huishu Liu | 136 |
| Experimental study on steam condensation with non-condensable gas in horizontal microchannels Xuehu Ma, Xiaoguang Fan, Zhong Lan, Rui Jiang, and Bai Tao | 146 |
| Evaporation of sessile droplets on nano-porous alumina surfaces Sanchit K. Singh, Dheeraj Pratap, S. Anantha Ramakrishna, and Sameer Khanderkar | 156 |
| Experimental and numerical investigations on the leakage flow characteristics of labyrinth seals | |
| Jun Li, Kesong Wen, Shizhu Wang, Shengke Jiang, and Xianglin Kong | 164 |
| Interaction contributions in thermal conductivity of three-dimensional complex liquids Aamir Shahzad and Mao-Gang He | 173 |

| Stability analysis of a square rod bundle sub-channel in supercritical water reactor Wang Hai-jun, You Ting, Zhang Lei, Gu Hong-fang, Luo Yu-shan, and Bian Ji-lian | 181 |
|---|--------|
| On-line assessment performance of high pressure natural gas filter Qiaoqi Xu, Zhongli Ji, Honghai Chen, and Zhiyi Xiong | 190 |
| Viscoelastic droplet dynamics under very low interfacial tension in a serpentine T-junction | |
| microchannel Xiao-Bin Li, Feng-Chen Li, Haruyuki Kinoshita, Masamichi Oishi, and Marie Oshima | 194 |
| The experimental study on aneurysm with PIV system Wang Yueshe, Ma Xiaoqi, and Li Di | 205 |
| Statistical analysis on the signals monitoring multiphase flow patterns in pipeline-riser system Jing Ye and Liejin Guo | 221 |
| SESSION ET: EXPERIMENTAL TECHNIQUES AND INSTRUMENTALTION IN MULTIPHASE | E FLOW |
| Effect of rolling motion on local characteristics of gas-liquid two-phase flow using an optical | |
| probe Daogui Tian, Licheng Sun, Changqi Yan, Jingyu Liu, and Bo Sun | 230 |
| Experiments on natural convection of TiO₂-water in a square enclosure Yanwei Hu, Shengnan Yan, Fenglin Tian, Xinchen Zhao, Shufu Wang, and Yurong He | 246 |
| Influence of the gas and liquid superficial velocity on slug frequency Mingsen Lin, Yinhe Liu, Yongfei Hu, and Defu Che | 253 |
| Experimental study of the Ledinegg instability in narrow rectangular channel Lulu Lv and Puzhen Gao | 264 |
| Experimental study on the local turbulence modulation in a horizontal particle laden flow | |
| with rigid fence Fusheng Yang, Daisuke Aoshima, Kenji Otakeguchi, Takahiro Tsukahara, and Yasuo Kawaguchi | 270 |
| Reconsideration of scaling measure for liquid-column break problem T. Kunugi, K. Hara, T. Nagatake, and Z. Kawara | 280 |
| Investigating particle phase velocity in a 3D spouted bed by a novel fiber high speed | |
| photography method Long Qian, Yong Lu, Wenqi Zhong, Xi Chen, Bing Ren, and Baosheng Jin | 289 |
| Bubble removal in viscoelastic solution by ultrasonic vibration Lifang Jiao, T. Kunugi, F. C. Li, and Z. Kawara | 294 |

SESSION MF: MULTIPHASE FLOW WITH PHASE CHANGE HEAT TRANSFER; DYNAMICS OF BUBBLES, AND PARTICLES; INDUSTRIAL APPLICATIONS OF MULTIPHASE FLOW

| The heat transfer characteristics of the jacket-type radial heat pipe Yonggang Jiao, Guodong Xia, and Dan Wang | 303 |
|---|-----|
| Experimental investigations on flow instabilities in a forced circulation loop at near-critical and supercritical pressures | |
| Lei Zhang, Haijun Wang, Hongfang Gu, Shouxu Qiao, Xiaobao Shi, and Yushan Luo | 312 |
| Study on two-phase flow frictional pressure drop in narrow channel based on grey relational analysis model | |
| Dong Han, Puzhen Gao, Liming Yan, and Lulu Lv | 320 |
| Experimental and CFD study on the hydrodynamic characters of dense liquid-solid fluidized bed | |
| Guodong Liu, Huilin Lu, Peng Wang, Si Tang, and Shuai Wang | 328 |
| Experimental investigations of single-phase and two-phase flow resistance in narrow rectangular duct under rolling condition | |
| Dianchuan Xing, Changqi Yan, Licheng Sun, and Yang Wang | 339 |
| The effect of geometry and operation conditions on the performance of a gas-liquid cylindrical cyclone separator with new structure | |
| Qing Han, Chi Zhang, Bo Xu, and Jiangping Chen | 350 |
| Study on heat transfer characteristic of ethanol-water mixture condensation on a vertical micro-tube | |
| Xiping Chen, Jinshi Wang, Junchao Qin, Daotong Chong, and Junjie Yan | 362 |
| Marangoni condensation of ammonia-water vapor mixtures on a horizontal tube Bin Dong, Jun Zhao, and Shixue Wang | 373 |
| Study on hydraulic characteristics of commissioning process of pipeline on hilly area Xinyu Zhang, Bo Yu, Jianyu Xie, and Guochen Kan | 380 |
| Experimental study on boiling heat transfer and two-phase frictional pressure drop characteristics of glycol-water solution in a vertical porous surface tube | |
| Shouxu Qiao, Haijun Wang, Hongfang Gu, Yushan Luo, Lei Zhang, and Wei Xiong | 390 |
| Experimental investigation of the steam condensation with air and helium Jiqiang Su, Zhongning Sun, Guangming Fan, and Ming Ding | 400 |
| Numerical investigation on distribution characteristics of dense dispersed phase in | |
| hydrocyclones Pu Cai and Bo Wang | 410 |

| Flow regimes of adiabatic gas-liquid two-phase under rolling conditions Chaoxing Yan, Changqi Yan, Licheng Sun, Dianchuan Xing, Yang Wang, and Daogui Tian | 419 |
|--|-----|
| Visualization and flow boiling heat transfer of hydrocarbons in a horizontal tube Zhuqiang Yang, Qincheng Bi, Yong Guo, Zhaohui Liu, and Jianguo Yan | 432 |
| Experimental studies on the enhanced flow boiling heat transfer and pressure drop of organic fluid with high saturation temperature in vertical porous coated tube Dong Yang, Zhi Shen, Tingkuan Chen, and Chenn Q. Zhou | 442 |
| Optimization research on the structure of horizontally-arranged indirect air-cooling tower under strong wind condition Guoyong Chen, Hongfang Gu, Haijun Wang, and Yongbo Qin | 454 |
| The heat flow field of the intermediate heating medium inside of the cylinder type natural gas heater Yun Guo and Weiwu Cao | 463 |
| Investigation on the impact of the environment wind velocity on the indirect air-cooling tower performance Yongbo Qin, Hongfang Gu, Haijun Wang, and Guoyong Chen | 469 |
| Hydrodynamic analysis and calculation of metal temperature distribution in spiral water wall of ultra supercritical tower boiler Chengwu Shen, Dong Yang, Danhua Yao, Yufeng Zhu, and Xueyuan Xu | 477 |
| Experimental study of flow oscillations in parallel evaporators of a carbon dioxide two-phase loop Xihui Sun, Zhenhui He, and Zhencheng Huang | 485 |
| Testing research for oil-gas-water flow pattern in Daqing oilfield Xiaoyan Liu, Qianjun Mao, Lijun Liu, Ying Xu, and Wei Chen | 492 |
| Heat and mass transfer enhancement for falling film absorption with coated distribution tubes at high temperature Xuehu Ma, Zhaolong Hao, Qunchang Wang, Zhong Lan, and Yan Zhao | 496 |
| Coalescence of pendant droplets on an inclined super-hydrophobic substrate Basant Singh Sikarwar, Sameer Khanderkar, and K. Muralidhar | 505 |
| Experimental investigation on condensation heat transfer of R134a on single horizontal copper and stainless steel three-dimensional finned tubes Peng Qin, Zhengguo Zhang, Tao Xu, Xuenong Gao, and Shuangfeng Wang | 513 |
| The influence of fluid inventory on the heat transfer performance of flat loop heat pipe Wei Zhang, Shuangfeng Wang, and Zirong Lin | 522 |

| Experimental investigation on phase change spray cooling with R22 Mengjing Li, Jionghui Liu, Xiufang Liu, and Yu Hou | 531 |
|---|-----|
| Severe slugging in a flexible S-shaped riser system: Experimental studies and transient simulation | |
| Wensheng Li, Liejin Guo, and Nailiang Li | 537 |
| SESSION MN: MODELING OF MULTIPHASE FLOW AND NUMERICAL METHODS | |
| Numerical simulation of gas and particle flow in cyclone separators Noé Landry P. M'Bouana, Dan Li, Yangjia Tang, Yunchao Yang, and Huilin Lu | 545 |
| A 3D CFD simulation of liquid flow in an ironmaking blast furnace Yansong Shen, Baoyu Guo, Sheng Chew, Peter Austin, and Aibing Yu | 555 |
| Compare pilot-scale and industry-scale models of pulverized coal combustion in an | |
| ironmaking blast furnace Yansong Shen, Aibing Yu, and Paul Zulli | 564 |
| DEM simulation of heat transfer in granular materials Nan Gui, Wenkai Xu, and Liang Ge | 572 |
| Simulation of hydrodynamics using large eddy simulation-second-order moment model in circulating fluidized beds Chen Juhui, Tang Yanjia, Li Dan, Xu Pengfei, and Lu Huilin | 577 |
| Chen Junui, Tang Tanjia, El Dan, Au Tengrei, and Eu Humm | 511 |
| Numerical simulation of the gas-condensate pipeline during shutdown and restart processes by AUSM+ scheme | |
| Jing Gong, Tienan Yin, and Zhi Wang | 585 |
| Discrete particle modeling of gas fluidization with random collisional parameters Yunhua Zhao, Bing Lu, Zhichao Yang, and Yingjie Zhong | 598 |
| Numerical simulation and optimization of enhanced heat transfer for high power LED light Pu Ge, Xu Peng, Miao Houchao, and Zhang Li | 604 |
| Numerical simulation on inertia controlled steam bubble condensation using MPS Daotong Chong, Yuki Ishiwatari, Yoshiaki Oka, Junjie Yan, and Jiping Liu | 614 |
| Studies on gas-flow and flame structures surrounding a combusting droplet Ke Li and Lixing Zhou | 624 |
| Recent advances in large-eddy simulation of spray and coal combustion L. X. Zhou | 630 |
| Numerical analysis of applied forces information exerted on particles in cyclone separators Mengting Jiang and Bo Wang | 640 |

| Control of impurities transport in an industrial directional solidification furnace for silicon ingots basing on computer modeling | |
|---|-----|
| Qinghua Yu, Lijun Liu, Genxiang Zhong, and Xinming Huang | 652 |
| Simulation of air-droplet mixed phase flow in icing wind-tunnel Leng Mengyao, Chang Shinan, Wu Menglong, and Li Yunhang | 659 |
| Numerical simulation of the erosion in the 90° elbow Yunzhong Deng, Yinhe Liu, Jianying Chen, and Yongjian Zhang | 671 |
| Development and verification of the modified dynamic two-fluid model GOPS Chengyi Song, Yuxing Li, Lan Meng, and Haiyan Wang | 684 |
| Numerical simulation on single Taylor bubble rising in LBE using moving particle method Xin Li, Wen X. Tian, Rong H. Chen, Guang H. Su, and Sui Z. Qiu | 700 |
| Numerical study of natural supercavitation influenced by turbulent drag-reducing additives Chen-Xing Jiang and Feng-Chen Li | 711 |
| DEM simulation of non-spherical granular segregation in hopper He Tao, Wenqi Zhong, Baosheng Jin, and Bing Ren | 720 |
| CFD investigation of effects of wind tunnel walls on flow properties over S809 airfoil Mohammad Moshfeghi and Yonghui Xie | 727 |
| Numerical simulation of bubble departure in subcooled pool boiling based on non-empirical boiling and condensation model Y. Ose and T. Kunugi | 733 |
| The numerical simulation of oil-water two phase flow in horizontal pipeline based on the VOF model | |
| Xiaoyan Liu, Wei Chen, Lijun Liu, and Dianwei Liu | 741 |
| Numerical research of dynamic characteristics in tower solar cavity receiver based on step- change radiation flux Zhengwei Chen, Yueshe Wang, Yun Hao, and Qizhi Wang | 746 |
| Modeling the evolution of aeolian sand transport in a wind tunnel Fengjun Xiao, Liejin Guo, Debiao Li, and Yueshe Wang | 758 |
| Gas-liquid two-phase severe slugging in a pipeline-riser system with S-shaped flexible riser: Experiments and modeling Nailiang Li, Liejin Guo, and Wensheng Li | 766 |
| Numerical study of the effect of pore geometry on non-wetting phase trapping in porous media | |
| N. Zhou, J. Yang, K. Takehana, T. Suekane, and Q. W. Wang | 780 |

| Numerical investigation of sinter cooling process in sinter cooler Y. Liu, J. Wang, X. Yuan, J. Yang, and Q. W. Wang | 788 |
|--|-----|
| Robust multi-objective optimization of state feedback controllers for heat exchanger system with probabilistic uncertainty | |
| Babak Lotfi and Qiuwang Wang | 796 |
| Conference Photographs | 810 |
| Author Index | 813 |