



THERMAL ENGINEERING

TED Newsletter on the WEB

Thermal Engineering Division
Newsletter No.40 July 2003

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Message from the Division Director for the 81st Term



Prof. Kazuhiko KUDO

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for the 81st Term

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It is a great honor to serve as the director of the Thermal Engineering Division for the 81st term. I would like to manage this division in cooperation with the members of the steering committee, special committees, and the committee of general affairs. I would like to ask all of you for your assistance and cooperation.

The mission of the division is firstly to provide opportunities of raising the potentials of the registrants of the division and various kinds of academic services. As the results, many fruits are obtained such as progress in academic fields, introduction of new industrial fields and so on. For the purposes, our division has been giving following activities:

- (1) providing timely articles on official, academic and technical information by news letters and home page,
- (2) providing opportunities of presentation, exchanging and collecting information and meeting old and new friends by organizing conferences; thermal engineering related sessions in JSME annual meeting, thermal engineering conference and various topical symposium,
- (3) selecting division awards,
- (4) providing opportunities of raising ability of registrants and of promoting academic and industrial activities by organizing various courses and research groups,
- (5) providing opportunities of raising ability of registrants by publishing activities.

These activities have been successfully operated so far owing to the committee members in charge. And now, the operating policy and the way to do them should be reconsidered due to the change in the age. Related to this, referring the present status of ASME Heat Transfer Division may be helpful. We had a meeting with American side committee members of the 6th JSME-ASME Joint Thermal Engineering Conference held last March in Hawaii during the meeting to negotiate the basic frame of the next conference. The American side committee members proposed to merge the next conference with the Summer Heat Transfer Conference held yearly by ASME. Main reason to merge the two conferences, explained by them, is that the number of the US side attendee to the joint conference may be very little due to too many thermal engineering related conferences. The Summer Heat Transfer Conference is called as the National Heat Transfer Conference and has been jointly held annually by ASME and AIChE collecting over 1000 attendee. Recently, it is organized only by ASME and the attendee is reduced to around 300. This tremendous reduction of the attendee of heat transfer related conferences may be due to the fact that many of the researchers in the heat transfer field in the US rush to the new fields like IT, nano and bio to which US government pouring plenty of budget, and make their presentations at the conferences in the new fields rather than at heat transfer related conferences, though the number of the registered members of the Heat Transfer Division of ASME has been almost constant. Registered to the Heat Transfer Division and do not attend the heat transfer related conferences.

The fields related to our division have also been extended widely from the basic fields of heat transfer, combustion, thermophysics and energy to the new fields of life science, IT, environment/energy, nano-tech/materials. Then the above mentioned difficulties suffering the Heat Transfer Division of ASME is not just an affair of other people. So far, in Japan, those who sifted or extended their research fields to those new ones not only attend conferences in the fields but also make presentations at heat transfer related conferences, which prevents the sharp reduction of the number of the attendee to the heat transfer related conferences. This may be caused only by the difference of the attitude of the researchers between the two countries, namely, radical and rational attitudes of the US researchers and soft and ambiguous ones of Japanese researchers. And, I am afraid that the essential matter is becoming worse underneath. However, considering that the fruits of the various new fields corresponding to woof have their warp of academic bases and methodologies on basic and academic fields like thermal engineering and tight interaction between them make mutual progress and expansion, the direction we should take becomes obvious. Namely, not to take backward-looking measures like substituting the void generated by the leave of researchers, we should rather take the direction to activate the activities of our division by serving fascinating fields for the exchange of information and mutual stimulation to those engineers

and researchers who intend to enroll the new research fields. This is the main subject imposed on our division to search the way to include the new fields to our division as new fields of thermal engineering and to realize them. To accomplish them, financial back-up is indispensable. Unfortunately, until last fiscal year, our budget has been in the black, now it is balanced due to the reduction of the number of the members of JSME. Then, to gain the money to back-up new projects

we should make profit from various events. Even so, some amount of budget has been saved from the past black budget, which can be used for new events. Positive proposals are welcomed for the realization of those new events.

The conferences planned in this fiscal year are: thermal engineering related sessions of the Annual Meeting of JSME in Tokushima on August 6-8, the Thermal Engineering Conference in Kanazawa on November 14,15 and the pre-conference seminar on November 13 for new regions in thermal engineering, and International Symposium of Micro-engineering in Tsuchiura and Tsukuba on December 1-3. The abovementioned pre-conference seminar is planned as an introduction to the technical fields of environmental energy, bio-, micro- and nano-technologies, and keynote presentations, general presentations and information exchange related to also bio-, micro- and nano-technologies are programmed in the international symposium. You are all cordially invited to the events.

Organization of a committee for the revision of JSME Data Book: Heat Transfer (4th Edition) is also planned in this year, as 17 years has passed since the last revision of the handbook.

Since last year, we have been considering the reform of our home page and newsletter which are the only direct communication media between the division head quarters and the members. And, this year, the related committees, electronic information committee and newsletter committee, are jointly searching new forms of the home page and the newsletter to which members positively wants to access and read and which are profitable for the members accessed. Positive advices from members are welcomed for the revision of the policy and the contents.

TED Plaza

Microchannels and Minichannels – The Next Frontier of Heat Transfer Research



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1. INTRODUCTION

The interest in microchannels and minichannels has increased dramatically since the turn of the century. A recent conference sponsored by the ASME, First International Conference on Microchannels and Minichannels, held in Rochester, NY, USA during April 2003 attracted 121 technical papers emerging from 18 countries. Over 180 participants attended the conference. The topics covered heat transfer, fluid flow, microfluidics and biofluidics. With the success of this conference in mind, a follow up conference is planned next year. The **Second International Conference on Microchannels and Minichannels** is again co-sponsored by the **ASME and RIT**, and is being held in Rochester during **June 17-19, 2004**. Further details on the conference are available on the ASME website at www.asme.org/events/micromini/. We expect a record turnout for this event, and would encourage everyone to consider participating in it as an author or an attendee.

2. MICROCHANNEL CLASSIFICATION

The question of classifying the channels inevitably comes up, with many conflicting views on this topic. It should be remembered that the significance of any classification based on the channel dimension is subjective, and is invariably affected by the type of fluid (liquid or gas), operating conditions (temperature and pressure), the type of flow (single phase, boiling or condensation), and the length to diameter ratio. Nevertheless, a simple classification scheme serves as a preliminary guide to relate the channels with the physical world.

In single-phase gas flow, the rarefaction and compressibility effects become important. As the channel dimension approaches the mean free path, the Knudsen number ($Kn = \text{mean free path}/\text{channel hydraulic diameter}$) serves as a guide to the rarefaction effects. The rarefaction effects become important as Kn becomes larger. For $Kn < 0.001$, continuum assumptions are valid, the region between $0.001 < Kn \leq 0.1$ can be analyzed by slip flow models with a finite velocity at the wall. The region between $0.001 < Kn \leq 0.1$ is called transitional region in which the flow can be modeled using statistical models such as Boltzmann equations. Finally, for $0.1 < Kn$, the flow is called free molecular in which molecular forces and motion need to be considered. Based on this analysis, Kandlikar and Grande (2003) proposed the following classification scheme:

Conventional Channels:	$D_h > 3 \text{ mm}$
Minichannels:	$3 \text{ mm} \geq D_h > 200 \mu\text{m}$
Microchannels:	$200 \mu\text{m} \geq D_h > 10 \mu\text{m}$
Transitional Channels:	$10 \mu\text{m} \geq D_h > 0.1 \mu\text{m}$
Transitional Microchannels:	$10 \mu\text{m} \geq D_h > 1 \mu\text{m}$
Transitional Nanochannels:	$1 \mu\text{m} \geq D_h > 0.1 \mu\text{m}$
Molecular Nanochannels:	$D_h \leq 0.1 \mu\text{m}$

Although the above classification is based on air at atmospheric conditions, it serves as a guide for other fluids as well. In two-phase applications, as the channel size approaches $200 \mu\text{m}$, changes in heat transfer and flow characteristics are seen for water (Steinke and Kandlikar, 2003a). For liquids, the continuum assumptions are still valid; the above classification scheme merely serves as a guide to identify the physical size of the channel hydraulic diameter employed.

As the channel hydraulic diameter becomes smaller, the ratio of the heat transfer surface area to the cross-sectional area available for flow increases in inverse proportion. As the flow velocities are smaller in these channels, laminar flow is generally observed in microchannels. The heat transfer coefficient in single phase then increases inversely with channel diameter as Nusselt number is constant for laminar flow.

Minichannels are being increasingly employed in compact heat exchangers for use in automotive and other applications. The channel sizes on the order of 1-mm are being applied in evaporators, condensers, and single-phase heat exchangers. Microchannels on the other hand are being used for specialized applications, such as microprocessor chip or electronics cooling, fuel cell passages, advanced heat exchange applications in space, and biological applications. One major factor that needs to be carefully considered is the cleanliness requirements with such small passages. In-line filters to remove micron-sized particles and gas bubbles are needed to avoid blockages these passages. A sample of microchannels fabricated in copper and silicon is shown in Fig. 1 (Kandlikar and Grande, 2003).

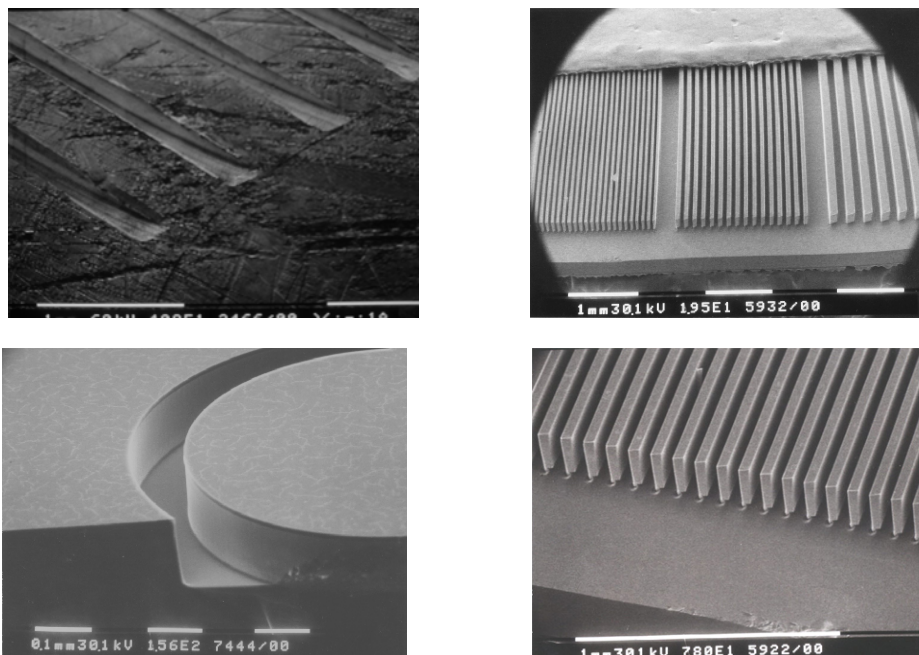


Figure 1 Samples of Microchannels fabricated in Copper (top left) and silicon (remaining three insets).

3. SCALING LAWS FOR FLOW BOILING IN MICROCHANNELS

Flow boiling in microchannels is of particular interest in dissipating high heat fluxes from electronics equipment. Cooling with flow boiling in microchannels fabricated directly on the chip provides an efficient way for heat removal.

The small passages play a direct role in the flow characteristics with bubble nucleating on the wall. Kandlikar (2003) identified three major forces during flow boiling in microchannels. These are surface tension, inertia and the force due to momentum change arising from the evaporation of liquid into vapor in the contact line region. The last force, called as the evaporation momentum force, causes the liquid-vapor interface to move into the liquid and was shown to be responsible for the CHF in pool boiling (Kandlikar, 2001). The ratio of these forces, taken two at a time, yield the following four non-dimensional numbers are:

The ratio of the evaporation momentum force to the inertia forces, denoted by \mathbf{K}_1 :

$$\mathbf{K}_1 = \left(\frac{q}{G h_{fg}} \right)^2 \frac{\rho_L}{\rho_G} \quad (1)$$

The ratio of the evaporation momentum force to the surface tension force, denoted by \mathbf{K}_2 :

$$\mathbf{K}_2 = \left(\frac{q}{h_{fg}} \right)^2 \frac{D}{\rho_G \sigma} \quad (2)$$

Weber number, We , representing the ratio of the inertia force to the surface tension force:

$$We = \frac{L G^2}{\rho \sigma} \quad (3)$$

and finally, Capillary number, which is the ratio of the viscous force to the surface tension force:

$$Ca = \frac{\mu V}{\sigma} \quad (4)$$

We and Ca play an important role in adiabatic two-phase flow and flow condensation in microchannels. The non-dimensional numbers \mathbf{K}_1 and \mathbf{K}_2 are important additional groups during flow boiling in microchannels. The force experienced by the rapid evaporation at liquid-vapor-solid contact line plays a critical role in the two-phase flow structure and heat transfer mechanism during flow boiling.

4. FLOW BOILING HEAT TRANSFER

A number of studies are available that have measured the single-phase and two-phase heat transfer coefficients with water and refrigerant flows. In single-phase flows, the conventional equations for heat transfer and pressure drop have been found to apply, especially for liquid flow, since there are no rarefaction or compressibility effects.

In the case of flow boiling, explosive growth of bubbles, and slug flow have been observed to be most prevalent. A schematic of the test setup used by Steinke and Kandlikar (2003a) is shown in Fig. 2. Details of the high-speed video imaging and heat transfer experiments are given in their paper.

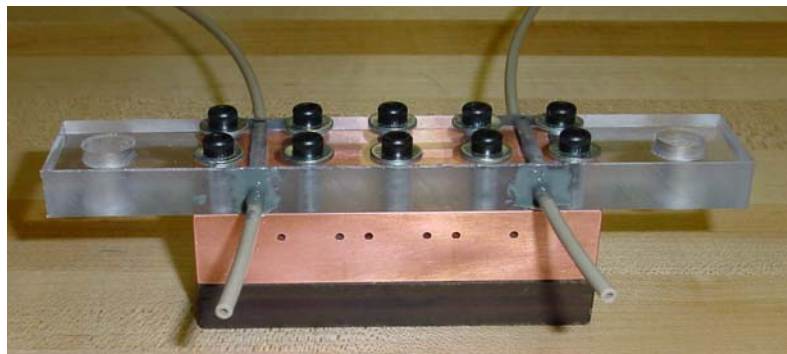


Figure 2 Flow visualization test section used by Kandlikar and Steinke (2003a) during flow boiling of water in 200 micron square microchannels.

As the flow channel dimension becomes smaller, the flow characteristics changes in two ways:

- All liquid flow Reynolds number becomes small and flow becomes laminar
- The heat transfer mechanism becomes dominated by nucleate boiling mode

As the laminar flow feature is incorporated in the predictive equation, such as Kandlikar (1990) flow boiling correlation, the flow boiling data in microchannels can be well predicted. Figure 3 shows a comparison of the modified correlations by Kandlikar and Steinke (2003b) and Kandlikar and Balasubramanian (2003) with the experimental data by Yen et al. (2002) data in the laminar region for R-134a.

A mechanistic description of the flow boiling phenomena was given by Kandlikar (2003). The absence of the nucleating cavities, subsequent liquid superheat buildup, and explosive growth of a nucleating bubble are some of the features highlighted in his model.

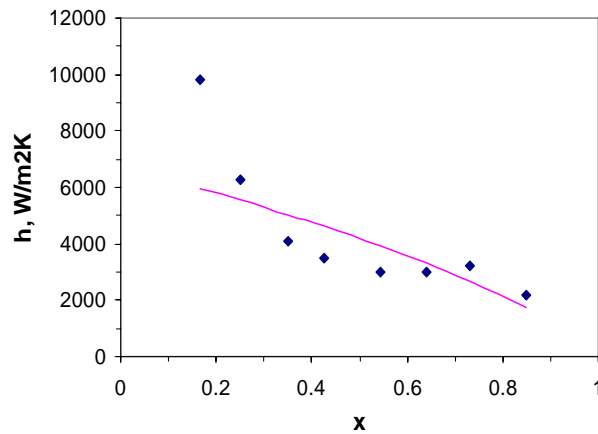


Figure 3 Comparison of the Kandlikar and Steinke (2003b) and Kandlikar and Balasubramanian (2003) correlation with Yen et al. (2002) data in the laminar region, R-134a, $D_h = 190 \mu\text{m}$, $Re_{LO} = 73$, $G=171 \text{ kg/m}^2\text{s}$, $q = 6.91 \text{ kW/m}^2$.

5. FUTURE RESEARCH NEEDS

Microchannels have been shown to provide high heat transfer coefficients that are necessary in meeting the challenges in high heat flux cooling applications. Although basic feasibility has been demonstrated by a number of experimental studies worldwide, the next challenge is to develop a system that is mechanically sound. In addition, operating concerns such as pressure oscillations and instabilities, flow maldistribution, critical heat flux limits in flow boiling, and cost-effective manufacturing need to be considered. Finally, the importance of obtaining local heat transfer and CHF data is emphasized to facilitate in the development in accurate predictive and design methodologies.

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The Report of the 6th ASME-JSME Thermal Engineering Joint Conference (AJTEC-2003)



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The 6th ASME-JSME Thermal Engineering Joint Conference (AJTEC-2003) was held on March 16 to 20, 2003, in Hawaii Island, Hawaii. The American Society of Mechanical Engineers (ASME) and the Japan Society of Mechanical Engineers (JSME) have co-developed a successful series of joint conferences on thermal engineering at four-yearly intervals. The previous conferences in this series were held in: Honolulu, Hawaii (1983 and 1987); Reno, Nevada (1991); Maui, Hawaii (1995); and San Diego, California (1999). The conference chairs of AJTEC-2003 were Professor Adrienne Lavine at UCLA and I.

The 21st century may be symbolized by the phrase “integration and collaboration.” In the new century, thermal engineers should make continued efforts to attain a better understanding of fundamental phenomena in thermal and energy systems. At the same time, we must increase our efforts to integrate thermal engineering in more complex systems involving other disciplines, and broaden our perspective to include an ever-widening range of time scales (from ultra rapid to long term phenomena) and length scales (from nanoscale to global). Such efforts require our will to challenge new technologies and collaborate with people working in other disciplines. The 21st century is welcoming such directions because the new century is facing some issues which can only be overcome by collaboration.

To provide a forum for the interchange of such new ideas and the presentation of the latest work in the field, the conference covered the following fundamental and applied topics in thermal engineering.

- Thermal Engineering in Topical Areas; Heat Transfer and Transport Phenomena in Micro/Nanoscale Systems, Heat and Mass Transfer Issues in Biotechnology, Thermal Engineering in Electronic Equipment and Information Technology, Thermal Engineering in New Energy Systems, Thermal Aspects of Environmental Engineering and Technology, Thermal Engineering in Manufacturing, Material Processing and Recycling
- Thermal Engineering in Mechanical and Energy Systems; Energy Systems and Equipment, Combustion Systems, Thermal Engineering in Cryogenic Systems, Thermal Engineering in Space Systems, Heat Transfer Equipment and Thermal Devices
- Fundamentals in Thermal Engineering; Thermodynamics and Thermal Properties, Heat Conduction, Thermal Radiation, Convective Heat and Mass Transfer, Turbulent Phenomena, Heat Transfer and Transport Phenomena in Multiphase Systems, Fire and Combustion Phenomena, Measurement and Diagnostics/Advances in Experimental Techniques, Computational Heat Transfer/Inverse Analysis and Design in Thermal Systems

Throughout the conference, the following eight keynote papers and 376 general papers (118 from US, 189 from Japan, and 69 from other countries) were presented:

- J.R. Howell (The Use of Inverse Methods for the Design and Control of Radiant Sources)
- P. Ayyaswamy (Three-dimensional Bone-like Tissue Generation in Rotating-wall Bioreactors)
- F. Issacci (Thermal Management and Transport Phenomena in Fuel Cell Systems – Practical Issues)
- A. Majumdar (Nanoscale Heat and Mass Transfer Issues in Energy Conversion and Biotechnology)
- S. Hirasawa (Knowledge Database of Thermal Control in Manufacturing (Including Micro-Manufacturing))
- M. Katsuki (Recent Advances in Combustion Technology for Heating Processes)
- M. Akai (Towards a Deep Reduction of GHG Emissions beyond Kyoto Target)
- H. Honda (Advances in Enhanced Boiling Heat Transfer from Electronic Components by Use)

JSME was the lead society of the conferences in this series for the first time and the success of this conference was supported by voluntary efforts by the members of the organizing committee. The total of attendees was 385 (112 from US, 229 from Japan, 44 from other countries). We trust that the technical content of this conference brought about the new era with “integration and collaboration” to thermal engineering and we look forward to the continued success of the ASME-JSME Thermal Engineering Joint Conference.

On the 5th International Boiling Heat Transfer Conference



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This international conference has been held every three years in order to discuss only the contents of research relevant to boiling phenomena and gives a chance to exchange and share mutual information and have intensive and fruitful discussion relating to this field. It is the 5th time for this conference: On the 1st occasion, the site was Santa Barbara (America), and subsequently, Banff Canada, Irsee (Germany), and Alaska (America) and this year Montego Bay (Jamaica). Personally, I have joined this conference four times, continuously from the second one.

In the conference, the main theme is settled each time, such as for the second, “Flow convective boiling”, the 3rd, “Pool boiling” and the 4th, Phenomena & Emerging application. This time, however, a central theme was not defined.

In this meeting, the number of participants is limited to less than 100 persons and all participants live under the same roof by night, often falling asleep from early in the morning, which makes it also possible to continue an argument. In the morning or after the day’s presentation, some participants do things just for the sport of it or alternatively there is enough drinking time available for other ones to enjoy some discussion and enjoy table talk (see the photograph taken after the Banquet).

Prof. Y. Fujita (Kyushu University), Prof. M. Shoji (University of Tokyo), Prof. Y. Takada (Kyushu University), Mr. Tange (Graduate student in University of Tokyo), and I, five persons participated in this meeting, which was the fewest participants from Japan in the past five occasions for this conference.

The feature of this meeting is that it is at home and all the members are there, and it is possible to join every presentation. This requires that the schedule is set up for a long time with net four days to cover for example 57 papers including 12 keynote papers to debate together.

The number of participants was 76 persons and the details are listed in Table 1. Other than from the United States, the largest group of participants was from Germany.

Although the main theme was not set at this meeting, many papers were related to basic research focusing on the effect of surface conditions such as configurations of surface roughness on boiling heat transfer and transition boiling. The next most common theme was boiling heat transfer in Micro Channels. The research on boiling heat transfer in a forced convection situation, critical heat flux and on applications were extremely few compared with the previous meetings.

Fundamental research concerned with the effect of surface conditions and transition boiling occupied about one third of the total papers, most of which were presented by German researchers. The reason why German researchers intensively presented many papers is that the research done for five years with the help of DFG (Deutsche Forschungsgemeinschaft) was completed last year and a series of publications based on it are requested to open the obtained result, which looks like a series of presentations promoted by GRANT-IN-AID FOR SCIENTIFIC RESEARCH in Japan. Some of the results presented by Professor Auracher, Professor Gorenflo, Professor Stephan and their colleagues were the contents already put out in other international conferences, and this did not have so much freshness. The systematic research project and systematic result, however, are impressive nonetheless. Recently, financial support for basic research has decreased worldwide and an eye not only in the United States but also in Japan tends to turn towards applied research. As against USA and Japan, one cannot help

Table 1 Number of participant and presented papers.

Country	Participant	Keynote	Paper
America	36	4	18
Germany	13	3	8
United Kingdom	5	1	4
Japan	5	2*	2
Sweden	3	0	2
South Korea	2	1	1
Switzerland	2	1	1
Poland	2	0	2
Italy	1	0	1
Canada	1	0	1
Spain	1	0	0
Czech Republic	1	0	1
Nigeria	1	0	0
Brazil	1	0	1
India	1	0	1
Netherlands	1	0	2
Total	76	12	45

* Two keynote lectures from Japan were presented by Professor Shoji and Prof. Monde.

feeling that German government has a positive attitude to science.

Many research works related to boiling heat transfer in Micro Channels were presented, although it is not completely clear whether the popularity for this topic is like the proverb "plants also flutter in the wind" or a sure interest in micro phenomenon. During listening to those presentations I could not help thinking how a micro result is applied even to evaporation apparatus (macroscopic thing). The number of the papers concerned with enhancement of heat transfer was as usual. The research efforts on critical heat flux (CHF) and boiling heat transfer in mixtures were quite few compared with those in the previous conferences.

Incidentally, one may say that about critical heat flux, a generalized correlation was proposed for various flow configurations and conditions, predicting it with a satisfactory level in the sense of a macroscopic point of view. In addition, a macroscopic effect of concerned parameters on CHF was clearly grasped, resulting in successful improvement of CHF. Nevertheless, the satisfactory situation about clearing the mechanism for CHF and its understanding has not been reached due to the complicated phenomenon, yet.

As for transition boiling, there is no hysteresis in the boiling curve, provided that the process is steadily carried out. The heat flux depends on a fraction between wetted area and dry area on a heated surface. These results were experimentally verified by a series of research papers by Professor Auracher. Does not any hysteresis occur, if the process between nucleate boiling and film boiling regions are unsteadily done? It surely occurs as is always observed in an ordinary experiment, since there is a coupling problem among solid, liquid and vapor. How the unsteady process influences the hysteresis is not cleared, yet. Although most of the previous research has focused on boiling in the steady state, recently the challenge for us may be to tackle more about transient phenomena. Transient phenomena are encountered in various fields where a body being at a temperature higher than the Leidenfrost temperature is quenched by a liquid, such as in rewetting and hot rolling or hardening. The complete understanding for these problems is still left behind due to the complexity of the phenomenon and the difficulty of measurement. As future research relevant to boiling phenomenon, it is probably needed to challenge both an unsteady problem and a coupling problem.

It is currently felt to be the time to set up a new paradigm for basic research, although research related to applications will progress naturally or probably follow the advanced progress of technology.



Photo1 Enjoy and discussion after the Banquet.

Meeting Calendar

[2003], [2004], [2005], [2006]

- 2003 -

[21st IIR International Congress of Refrigeration](#)

17 - 22 August 2003, Washington, USA

[International Symposium on Transient Convective Heat and Mass Transfer in Single and Two-Phase Flows](#)

17 - 22 August 2003, Cesme, TURKEY

[7th Triennial International Symposium on Fluid Control, Measurement and Visualization](#)

24 - 28 August 2003, Sorrento, ITALY

[Microgravity Transport Process in Fluid, Thermal, Biological and Material Sciences Conference III](#)

14 - 19 September 2003, Davos, SWITZERLAND

[International Conference on Global Environment and Advanced Nuclear Power Plants](#)

15 - 19 September 2003, Kyoto, JAPAN

[International Conference on Supercomputing in Nuclear Applications](#)

22 - 24 September 2003, Paris, FRANCE

[4th International Conference on Compact Heat Exchangers and Enhancement Technology for the Process Industries](#)

29 September - 3 October 2003,
Fodele Beach Hotel, Crete Island, GREECE

[NURETH-10, 10th International Topical Meeting on Nuclear Reactor Thermal Hydraulics](#)

5 - 9 October 2003, Seoul, S. KOREA

[4th International Symposium on Turbulence, Heat and Mass Transfer](#)

12 - 17 October 2003, Antalya, TURKEY

[International Gas Turbine Congress 2003](#)

2 - 7 November 2003, Tokyo, JAPAN

[2nd International Conference on Computational Methods in Multiphase Flow](#)

3 - 5 November 2003, Santa Fe, New Mexico, USA

[3rd International Symposium on Heat Transfer Enhancement and Energy Conservation](#)

8 - 11 November 2003, Guangzhou, CHINA

International Conference on Power Engineering - 03 (ICOPE-03)

9 - 13 November 2003, Kobe, JAPAN

2003 ASME International Mechanical Engineering Congress and Exposition - IMECE

16 - 21 November 2003, Washington, USA

AICHE 2003 Annual Meeting

16 - 21 November 2003, San Francisco, USA

International Symposium on Micro-Mechanical Engineering - Heat Transfer, Fluid Dynamics, Reliability and Mechatronics -

1-2 December 2003, Mechanical Engineering Research Laboratory, Hitachi, Ltd., Tsuchiura, JAPAN

3 December 2003, National Institute of Advanced Industrial Science and Technology, Tsukuba, JAPAN

International Conference on Energy and Environment

11 - 13 December 2003, Shanghai, CHINA

- 2004 -

The First International Symposium on Micro & Nano Technology (ISMNT-1)

14 - 17 March 2004, Honolulu, Hawaii, USA

Submission of Abstract : 31 July 2003

4th European Thermal Science Conference EURO THERM & Heat Exchange Engineering Exhibition

29 - 31 March 2004, Birmingham, UK

International Symposium on Advances in Computational Heat Transfer

19 - 24 April 2004, Kikenes and Bergen, NORWAY

Submission of Abstract : 1 October 2003

The 11th International Conference on Fluidization: Present and Future for Fluidization Engineering

9 - 13 May 2004, Ischia (Bay of Naples), ITALY

15th International Symposium on Transport Phenomena

9 - 15 May 2004, Bangkok, THAILAND

ICMF-2004, International Conference on Multiphase Flow

31 May - 3 June 2004, Yokohama, JAPAN

Submission of Abstract : 1 September 2003

ITherm 2004: Ninth Intersociety Conference on Thermal and Thermo Mechanical Phenomena in Electronic Systems

1 - 4 June 2004, Las Vegas, Nevada, USA

Submission of Abstract : 15 August 2003

International Conference on Thermal Engineering Theory and Applications

31 May - 4 June 2004, Beirut, LEBANON

Submission of Abstract : 1 September 2003

2004 ASME Summer Annual Meeting

13 - 17 June 2004, TBD, USA

Second International Conference on Fuel Cell Science, Engineering and Technology

14 - 16 June 2004, Rochester, NY, USA

Submission of Abstract : 24 November 2003

Second International Conference on Microchannels and Minichannels

17 - 19 June 2004, Rochester, NY, USA

Submission of Abstract : 1 December 2003

RAD04, Fourth International Symposium on Radiative Transfer

20 - 25 June 2004, Istanbul, TURKEY

Submission of Abstract : 15 December 2003

Second International Symposium on Micro/Nano- scale Energy Conversion and Transport

11 - 17 July 2004, Seoul, S. KOREA

Submission of Abstract : October 2003

Submission of Abstract : 15 December 2003

12 - 15 July 2004, Lisbon, PORTUGAL

Submission of Abstract : 15 December 2003

30th International Symposium on Combustion

25 - 30 July 2004, Chicago, USA

Submission of Abstract : 1 December 2003

The 7th Asian Thermophysical Properties Conference (ATPC2004)

23 - 28 August 2004, Hefei & Huangshan, Anhui, CHINA

Submission of Abstract : 30 November 2003

World Renewable Energy Congress VIII & Expo

28 August - 3 September 2004, Denver, Colorado, USA

Submission of Abstract : 30 November 2003

6th Gustav Lorentzen Natural Working Fluids Conference - Current Applications and Opportunities

29 August - 1 September 2004, Glasgow, UK

Submission of Abstract : 1 February 2003

3rd International Symposium on Two-Phase Flow Modeling and Experimentation

22 - 24 September 2004, Pisa, ITALY

Submission of Abstract : 24 October 2003

6th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operations and Safety

4 - 8 October 2004, Nara, JAPAN

Submission of Abstract : 1 September 2003

Transport Phenomena in Micro and Nanodevices

17 - 21 October 2004, Kona, Hawaii, USA

AICHE 2004 Annual Meeting

7 - 12 November 2004, Austin, Texas, USA

2004 ASME International Mechanical Engineering Congress and Exposition - IMECE

14 - 19 November 2004, Anaheim, CA, USA

- 2005 -

ExHFT-6, 6th World Conference on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics

17 - 21 April 2005, Matsushima, JAPAN

Heat and Mass Transfer in Spray Systems

5 - 10 June 2005, TURKEY (organized by ICMHT)

Wavelet Transform and Its Applications in Transport Phenomena

October 2005, TURKEY (organized by ICMHT)

- 2006 -

Heat and Mass Transfer in Biotechnology

June 2006, TURKEY (organized by ICMHT)

13th International Heat Transfer Conference

13 - 18 August 2006, Sydney, AUSTRALIA

World Renewable Energy Congress (WREC-2006)

26 August - 1 September 2006, Yokohama, JAPAN

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