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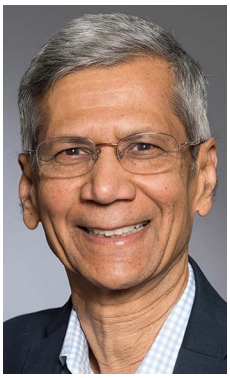
Guest Editorial

Professor Satish G. Kandlikar on His 70th Birthday



Satish G. Kandlikar

Professor Satish G. Kandlikar is one of the well-known names in the field of flow boiling. He was born in June 1950 in India. He received his B.S. in Mechanical Engineering from Marathawada University, India. He received his M.S. and Ph.D. degrees from the Department of Mechanical Engineering at the Indian Institute of Technology (IIT) in Mumbai, India. His supervisor was Prof. S. P. Sukhatme. After finishing his Ph.D. in 1975, Prof. Kandlikar became a faculty member in the Department of Mechanical Engineering at IIT before coming to Rochester Institute of Technology (RIT), in Rochester, New York, in 1980. Currently, he is the Gleason Professor of Mechanical Engineering in the Department of Mechanical Engineering, Rochester Institute of Technology. He was the founder of the RIT Thermal Analysis and Microfluidics Laboratory in 1990, which examines essential phenomena related to microscale fluid dynamics and mechanics.

During his career at RIT, Prof. Kandlikar became involved in several activities. For instance, he founded the ASME Heat Transfer chapter in Rochester. He also founded and served as the first Chairman of the E-cubed fair—science and engineering fair for middle school students in celebration of Engineers Week. Furthermore, at the 12th International Heat Transfer Conference (IHTC12) in Grenoble, France, in 2002, Prof. Kandlikar suggested the organization of an international conference on microchannels and minichannels. In 2003 and 2004, he organized the first and second International Conference on Microchannels, and Minichannels (ICMM2003 and ICMM2004), respectively, which were sponsored by the ASME Heat Transfer Division at RIT, Rochester, New York. As a guest editor, Prof. Kandlikar published two special issues of selected papers from the first and second International Conference on Microchannels and Minichannels [1,2] in the Heat Transfer Engineering. This conference later expanded its scope and went global with the conference title as International Conference on Nanochannels, Microchannels & Minichannels (ICNMM).

During his academic tenure at IIT and RIT, Prof. Kandlikar published many articles, reports, and books on flow boiling correlation and roughness effect, heat transfer, and fluid flow in microchannels, water management in PEM fuel cells, evaporation momentum force, pool boiling surface enhancements, flow boiling with a tapered manifold, electronics cooling, and more recently on breast cancer thermal imaging [3–6]. His paper in the ASME *Journal of Heat Transfer* titled "A General Correlation for Saturated Two-Phase Flow Boiling Heat Transfer Inside Horizontal and Vertical Tubes" [7] is his most cited paper.[1] His work on flow and pool boiling has produced among the highest heat fluxes along with very high heat transfer coefficients reported at that time.

In honor of Professor Kandlikar, three dimensionless numbers are named after his name. They are Kandlikar first number (K_1), Kandlikar second number (K_2), and Kandlikar third number (K_3) [8–10]. The Kandlikar third number (K_3) was introduced in Prof. Kandlikar's reply [11] to the discussion by Awad [12]. These three dimensionless numbers represent the ratio of two forces among a total of four forces: evaporation momentum force, inertia force, surface tension force, and viscous force. For the definitions of K_1, K_2, and K_3, the numerator represents the evaporation momentum force while the denominator is the inertia force in the case of K_1, surface tension force in K_2, and viscous force in K_3. These Kandlikar numbers can be related to each other using other dimensionless numbers. For example, the ratio (K_2/K_1) is the Weber number (We). the ratio (K_3/K_1) is the Reynolds number (Re), and the ratio (K_2/K_3) is the Capillary number (Ca). Using the Kandlikar numbers instead of the boiling number (Bo) in critical heat flux (CHF) correlations has the advantage of taking the effect of density ratio of liquid and gas or vapor (ρ_l/ρ_g) into account [13,14]. These Kandlikar numbers such as K_3 can be used to derive a map for flow boiling in microchannels and microgravity [15].

Professor Kandlikar is an Executive Editor (Heat in History Editor) of Heat Transfer Engineering. He is also an Associate Editor of the *International Journal of Heat and Technology* (IJHT) published by the International Information and Engineering Technology Association (IIETA). In addition, he is currently serving on the Editorial Advisory Board of Microfluidics and Nanofluidics. Furthermore, he is one of the corresponding members of the Japanese Society for Multiphase Flow (JSMF) in the USA. Moreover, he has served on the scientific and organizing committees of many international conferences, including the ASME ICNMM since its start in 2003.

He is a Fellow of the American Society of Mechanical Engineers (ASME) and has received numerous international awards including the Eisenhart Award for Outstanding Teaching and Trustees Scholarship Award—both from RIT, Engineer of the Year Award from the Rochester Engineering Society, and the 2012 ASME Heat Transfer Memorial Award.[2] In May 2020, RIT honored Professor Satish G. Kandlikar as one of three recipients of the Distinguished Faculty Award.[3] In July 2020, there was a Symposium Honoring Professor Kandlikar at the ICNMM 2020 (virtual).[4] For instance, Jon Kriegel, the Founder of RIT's ASME Student Chapter, wrote an article summarizing Prof. Kandlikar's efforts in promoting science, technology, engineering, and math (STEM) outside of academia [16]. Also, one of his former graduate students, Pruthvik Raghupathi, presented a review paper on the research work of Prof. Kandlikar over the past 30 years [17]. This paper was co-authored by 16 former and current graduate students of Prof. Kandlikar's Thermal Analysis, Microfluidics, and Fuel Cell Lab at RIT. In addition, Prof. Masahiro Kawaji talked about his research on microchannel

[1] https://scholar.google.com/citations?hl=en&user=mdAlRMAAAAAJ&view_op=list_works

[2] https://www.asme.org/about-asme/honors-awards/achievement-awards/heat-transfer-memorial-award

[3] https://www.rit.edu/news/rit-honors-distinguished-faculty-awardees-2020

[4] https://event.asme.org/ICNMM/Program/Call-for-Papers

flow and a summary of 20 years of interactions with Prof. Kandlikar [18]. At ICNMM 2020, Prof. Kandlikar[5] gave a plenary lecture entitled "Can Infrared Imaging Improve Breast Cancer Detection?—An RIT-RGH initiative using a novel, computer-driven, patient-specific approach."

On the occasion of Prof. Kandlikar's 70th birthday, on behalf of his colleagues, friends, and students all over the world, we wish him a continuous active life in happiness, good health, and a very happy birthday!

References

[1] Kandlikar, S. G., 2004, "Selected Papers From the First International Conference on Microchannels and Minichannels," Heat Transfer Eng., **25**(3), pp. 1–2.

[2] Kandlikar, S. G., 2005, "Editorial, Selected Papers From the Second International Conference on Microchannels and Minichannels," Heat Transfer Eng., **26**(3), pp. 1–2.

[3] Kandlikar, S. G., Shoji, M., and Dhir, V. K., 1999, *Handbook of Phase Change: Boiling and Condensation*, Taylor & Francis, PA.

[4] Kandlikar, S. G., Garimella, S., Li, D., Colin, S., and King, M. R., 2006, *Heat Transfer and Fluid Flow in Minichannels and Microchannels*, 1st ed., Elsevier, New York.

[5] Jensen, M. K., Peles, Y., Borca-Tasciuc, T., and Kandlikar, S. G., 2006, "Multiphase Flow, Evaporation and Condensation," *Micro Process Engineering: Fundamentals, Devices, Fabrication, and Applications*, N. Kockmann, ed., WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, Chapter 4.

[6] Hayner, C. N., Steinke, M. E., and Kandlikar, S. G., 2014, *Contemporary Perspectives on Liquid Cold Plate Design: Design and Manufacturing Liquid Cooled Heat Sinks for Electronics Cooling*, Begell House, Danbury, CT.

[7] Kandlikar, S. G., 1990, "A General Correlation for Saturated Two-Phase Flow Boiling Heat Transfer Inside Horizontal and Vertical Tubes," ASME J. Heat Transfer, **112**(1), pp. 219–228. https://asmedigitalcollection.asme.org/heattransfer/article-abstract/112/1/219/454100/A-General-Correlation-for-Saturated-Two-Phase-Flow?redirectedFrom=fulltext

[8] Awad, M. M., 2012, "Two-Phase Flow," *An Overview of Heat Transfer Phenomena*, S. N. Kazi, ed., InTech, Rijeka, Croatia, pp. 251–340, Chapter 11. Available at: http://www.intechopen.com/articles/show/title/two-phase-flow

[9] Kandlikar, S. G., 2001, "A Theoretical Model to Predict Pool Boiling CHF Incorporating Effects of Contact Angle and Orientation," ASME J. Heat Transfer, **123**(12), pp. 1071–1079.

[10] Kandlikar, S. G., 2004, "Heat Transfer Mechanisms During Flow Boiling in Microchannels," ASME J. Heat Transfer, **126**(2), pp. 8–16.

[11] Kandlikar, S. G., 2012, "Closure to Discussion of `Heat Transfer Mechanisms During Flow Boiling in Microchannels (2012, ASME J. Heat Transfer, 134, p. 015501)," ASME J. Heat Transfer, **134**(1), p. 015502.

[12] Awad, M. M., 2012, "Discussion: Heat Transfer Mechanisms During Flow Boiling in Microchannels (Kandlikar, S. G., 2004, ASME Journal of Heat Transfer, 126 (2), p. 8–16)," ASME J. Heat Transfer, **134**(1), p. 015501. .

[13] Awad, M. M., 2013, "Comments on "Boiling Heat Transfer in Rectangular Microchannels with Reentrant Cavities"," Int. J. Heat Mass Transfer, **62**(23–24), pp. 541–542.

[14] Awad, M. M., 2013, "Comments on "Experimental Study of Flow Boiling of FC-72 in Parallel Minichannels Under Sub-Atmospheric Pressure"," Appl. Therm. Eng., **56**(1–2), pp. 110–111.

[15] Awad, M. M., 2015, "Kandlikar Third Number (K3) Map for Flow Boiling in Microchannels and Microgravity," Therm. Sci., **19**(3), pp. 1131–1134.

[16] Kriegel, J., 2020, "Recognizing the Community Service and ASME Contributions of Dr. Satish Kandlikar" Paper No. ICNMM2020-1015," Symposium Honoring Satish Kandlikar, The ASME 2020 18th International Conference on Nanochannels, Microchannels, and Minichannels (ICNMM2020), FL, July 13–15.

[17] Raghupathi, P., Owens, A., Steinke, M., Lin, T. Y., Kalani, A., Moreira, D., Gonzalez-Hernandez, J.-L., Lu, Z., Banerjee, R., Daino, M., Jaikumar, A., Chauhan, A., Rishi, A., Perez-Raya, I., Emery, T., and Aguilar, F. G., 2020, "Insight to Innovation: An Overview of Research Journey of Dr. Satish Kandlikar," The ASME 2020 18th International Conference on Nanochannels, Microchannels, and Minichannels (ICNMM2020), Paper No. ICNMM2020-1071, Symposium Honoring Satish Kandlikar, FL, July 13–15.

[18] Kawaji, M., 2020, "My Microchannel Flow Research and 20 Years of Interactions with Prof. Satish Kandlikar," The ASME 2020 18th International Conference on Nanochannels, Microchannels, and Minichannels (ICNMM2020), Paper No. ICNMM2020-1073, Symposium Honoring Satish Kandlikar, July 13–15, FL (Online).

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