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ON CONSERVATION OF SCATTERED RADIATION ENERGY AND ANGLE IN MODELING OF RADIATIVE TRANSFER

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ABSTRACT:

In engineering problems where radiation is the dominant mode of heat transfer, such as high-temperature combustion and material processing, fire and atmospheric radiation, renewable solar energy, space exploration, microwave and laser applications, accurate and complete solutions of the governing equation of radiative transfer (ERT) are desired. The integro-differential nature of the ERT makes analytical solution difficult, and thus numerical methods, such as the finite volume method (FVM) and discrete-ordinates method (DOM), are preferred. Numerical methods have garnered increasing attention in the field of radiation heat transfer, as they provide cost-effective alternatives to costly experimentation and their efficiency and accuracy has been improved with the advance of computational technology. Ray effect and false scattering are two well-known numerical errors associated with DOM. They also exist in all discretization-based numerical methods including the FVM. The false scattering error was originally categorized as the numerical diffusion errors due to spatial discretization in the dimension domain. It could be better renamed as numerical smearing, because directional discretization in the solid-angle domain generates the real-meaning false scattering effect. Thus, there are three types of numerical errors, namely, ray effect, numerical smearing, and angular false scattering. During numerical computations of radiative heat transfer, it is well known that the scattered energy after angular discretization must be conserved; but less known is the preservation of scattering directions. Only recently it was discovered that angular discretization would result in change in the physical property of asymmetry factor, which is the average cosine of scattering angle. To correct this issue, one approach is phase-function normalization, which was commonly adopted for conserving scattered energy. Normalization of scattering phase functions must now satisfy two constrains –preservation of scattered asymmetry factor and conservation of scattered energy. In this talk, we will introduce and compare five normalization techniques to gauge the importance of appropriate phase-function normalization and the possible issues associated with each approach. The applicability of phase-function normalization techniques will be examined using the DOM and FVM. The results will be compared with Monte Carlo predictions. Both Henyey-Greenstein and Legendre polynomial phase functions will be taken into account. Diffuse as well as collimated radiation will be considered.

BIOGRAPHY:

Dr. Zhixiong Guo is a tenured full Professor of Mechanical and Aerospace Engineering at Rutgers University-New Brunswick, USA. He received his B.S., M.S., and Doctorate, all in Engineering Physics, from Tsinghua University, China, in 1989, 1991, and 1995, respectively. Then he worked as a Research Fellow in KAIST, South Korea, and a Research Associate in Tohoku University, Japan. From 1999 to 2001, he worked as a Research Staff Member in Polytechnic School of Engineering, NYU, New York, where he completed his Ph.D. in Mechanical Engineering in the same time period. He joined the faculty at Rutgers in 2001. His research interests include heat transfer and applied optics, with notable expertise in radiation-matter interactions, laser applications in biomedicine and material processing, molecular and nanoscale optical sensing, and thermal radiation. He is an Associate Editor of ASME Journal of Heat Transfer and of the international journal Heat Transfer Research. He also serves in the editorial board of several other journals, and in the organization or scientific committee of several international conferences, including Co-Chair of three international workshops. Dr. Guo is an elected Fellow of ASME, for his pioneering research and development in ultrafast laser-matter interactions and their associated fundamental heat transfer problems. He is K-18 technical committee Chair of Heat Transfer Division in ASME.