Volume Averaging Method for Upscaling in Porous Media

.....

Overview

A typical porous medium such as sand or bed of fibers consists of millions and billions of pores. Though the flow and transport can be studied in a few pores using CFD (computational fluid mechanics) software such as Fluent or StarCCM, the overall flow in any porous medium with a large number of pores is not possible using this approach. Invariably one has to resort to upscaling and deal in terms of averaged variables instead of the point-wise variables. Such a process is called creation of a porous-continuum domain where flow, heat transfer and chemical reactions are described in terms of such averaged variables. Some of the important methods for upscaling include homogenization technique and the method of mixtures. Of these, the volume averaging method remains an important method for developing governing equations in the porous-continuum domain. A special achievement of the volume averaging method, as developed by Prof. Whitaker and co-workers, is the micro-macro coupling where the averaged flow and transport equations are linked to pore-level features through a closure formulation. This allows the determination of important parameters of the macroscopic flow, such as the permeability and thermal diffusivity tensors, by solving the point-wise closure equations within the pore geometry of a unit cell. Some important applications in this discipline are oil exploration, ground-water flow, heat pipes, filtration, composites processing, wicking and bio heat & Mass Transfer.
Course participants will learn these topics through lectures and hands-on simulation experiments. Also case studies and assignments will be shared to stimulate research motivation of participants.

Modules	**Volume Averaging Method for Upscaling in Porous Media: Jan 5 - Jan 16, 2016** **Number of participants for the course will be limited to fifty.**
You Should Attend If…	▪ Executives, engineers and researchers from manufacturing, service and government organizations including R&D laboratories, especially engineering/science departments such as mechanical engg, environmental (civil) engg., chemical engg., soil science, food science, etc., but also the mathematics and physics departments of various institutes for this purpose ▪ Student at all levels (BTech/MSc/MTech/PhD) ▪ Faculty from different reputed academic and technical institutions of India
Fees	The participation fees for taking the course is as follows: **Participants from abroad : US $500** **Industry/ Research Organizations: INR 20,000** **Academic Institutions: INR 10,000(For Faculty), INR 2,000 (For Student)** The above fee includes all instructional materials, computer use for tutorials and assignments, computer laboratory usage charges, The participants will be provided with accommodation and food on payment basis.

The Faculty

Dr. Krishna M. Pillai is a tenured Associate Professor in the Mechanical Engineering Department at University of Wisconsin-Milwaukee (UWM), USA. He is also the director of Laboratory for Flow and Transport Studies in Porous Media at UWM. Dr. Pillai received his B.Tech. and M.Tech. degrees from the prestigious I.I.T. Kanpur of India. He did his Ph.D. from University of Delaware (USA) at its famous Center for Composite Materials under Prof. Suresh Advani and later completed a post-doctoral research fellowship under Prof. Chuck Tucker III of University of Illinois, Urbana-Champaign, USA and Dr. Fred Phelan of NIST (National Institute of Standards and Technology), USA.

Dr. Pillai's research interests span several fields of porous media including processing of composites, wicking of liquids, evaporation of multicomponent liquid mixtures, and oil exploration. He has published more than sixty papers in reputed international journals and presented his work in numerous international conferences and workshops. He is a co-editor of the book 'Wicking in Porous Materials'. He is in the editorial boards of two prestigious international journals including *Composites Part A*, and is also a member of the scientific committee for the FPCM (Flow Processes in Composites Materials) conferences. He is currently co-editing a special issue of *Transport in Porous Media* on thin porous media. He was a laureate of the 2014 Rosette award by Interpore, the international society for porous media research, and organized its 2014 annual conference. Several multinational companies, state agencies, as well as the National Science Foundation (NSF) of USA have funded Dr. Pillai's research. He is the recepeient of the 2004 prestegious CAREER research grant awarded to outstanding young faculty by NSF.

Dr. Pradyumna Ghosh is an Associate Professor at Department of Mechanical Engineering in Indian Institute Of Technology (Banaras Hindu University), India. He has 10 years of teaching experience and 5 years of industry/research experience. He has been working in various aspects of heat

Course Co-ordinator

Dr. Pradyumna Ghosh
Phone: 91-9415256256
E-mail: pghosh.mec@iitbhu.ac.in

.....
.....

transfer, CFD, flow through porous media, nanofluids, microgravity fluid physics. He has several publications in various national and international journals. He has authored a book “Thermal Convection in Microgravity”, moreover he serves as reviewer of various international journals like Journal of Porous media, ASME Heat Transfer, Energy, International Journal of Heat & Mass Transfer.

Objectives :

The main purpose of this course will be to teach this mathematically rigorous technique for upscaling to scientists and researchers. The basic mathematics associated with this technique including the tensor manipulations, averaging theorems and variable decomposition, will be covered in this course. The students/attendees will learn how to convert the microscopic pore-scale equations into the macroscopic domain-scale equations. This will allows the attendees to confidently apply this valuable technique to derive the macroscopic governing equations for various porous media phenomena that are of industrial and scientific interest.

Course details:

The whole course will consist of some eight lectures and one simulation lab of around 3 hours each that are covered over a period of ten working days. During the course of their lectures, the instructors will refer to various sectors of industry, including ground-water flow management and oil exploration, and cite their problems in order to provide context for the concepts presented in the class. Home assignments can be given if the attendees desire.

Lecture 1:
Basics of porous media flows: basic quantities including porosity and filteration/average velocities, single- and two-phase flows, measurement of important parameters including porosity, permeability, relative permeability and capillary pressure

Lecture 2:
Basics of porous media flows (cont’d): Principal components of a permeability tensor, measurements of this tensor using 1-D and radial flow methods

Lecture 3:
Basics of tensor manipulations and tensor algebra

Lecture 4:
Definition of various averages, Averaging theorems and their derivations

Lecture 5:
Volume averaging applied to single-phase flows: Derivation of Darcy’s law using the averaging theorems, Development of closure formulation

Lecture 6:
Multiplicity of flow regimes found in two-phase flows, Volume averaging applied to two-phase flows: Derivation of the two permeability tensors along with the two viscous-drag tensors, Development of appropriate closure formulations.

Lab1(3 Hours):
Determination of 3D permeability using COMSOL Multiphysics

Lecture 7:
Volume averaging applied to two-phase flows: Development of a workable closure formulation using transformations

Lecture 8:
Volume averaging applied to non-Darcy flows, Volume averaging applied to multiscale porous media

Further Details:

The course will be organized at I.I.T. BHU at Varanasi, UP, India. The course will start on January 5, 2015 (Tuesday) and will be held over two weeks till January 16, 2015 (Satday). This will be conducted at the Mechanical Engineering Dept. http://www.iitbhu.ac.in/mec/ of the institute. The course participants will be accommodated at the visitor’s hostel during this period. Note that the weather is quite pleasant and sunny during this time of the year with temperatures hovering around

8 -20 degree Celsius. BHU, which is the full form of Banaras Hindu University, is one of the oldest centers of learning in modern India, has a beautiful campus with all modern amenities and transportation facilities http://www.bhu.ac.in.

About the City

The holy city of Varanasi is known as the city of temples and learning. It is a place of great historical and cultural importance. This religious capital of India is situated on the bank of the holy river Ganges and is famous for temples of Lord Shiva, Buddha (at Sarnath) and Sankat Mochan etc. Varanasi is the premiere most place of oriental learning also. Simultaneously it is keeping pace with modern advanced knowledge. The city is reputed for silk fabrics, perfumes, artistic brass and copper wares and a variety of handicrafts. This vibrant city with multiple dimensions of knowledge and liberation has a magnetic attraction for people all over the world.

Route to Varanasi

The city of Varanasi is well connected by road, rail and air with all the important places of India. Regular flights are there from Varanasi to Delhi, Mumbai, Chennai, Bangalore, Kolkata, Khajuraho and Lucknow. The Banaras Hindu University campus is only 10 Km from Varanasi Cant and 20Km from Mughalsarai railway station and 35 Km from the airport.