Porous and granular materials: Applications in modern Science and Technology

Course Instructor: Prof. Arzhang Khalili, Max Planck Institute for Marine Microbiology, Germany
Course Coordinator Dr. Shanmugam Dhinakaran, The Centre for Fluid Dynamics, Department of Mech. Engg., IIT Indore, India
Course dates: December 18 - 22 and December 25 - 29, 2017 (Two weeks course) | **Venue :** IIT Indore, Indore
Website: http://people.iiti.ac.in/~sdhina/ | **Mobile : +91- 9111 74 9191**
Keywords: Porous media; Heat and mass transfer; Numerical methods; Lattice Boltzmann Method; Experimental visualization techniques; Porous media applications; Tutorials; Practical session on programming in FORTRAN

Overview

Porous materials are, compared to solid ones, characterized by a light weight, structural stability and selective filtering. These properties make porous media applicable as filters and isolating material, applied in any branch of our today's life, and provide a real alternative to all other conventional materials. Many items in our daily life appear as granules such as coffee, grains, sand or as permeable material such as sponges and filter. The collective term porous Medium refers to materials characterized by porosity and permeability, which construct a network of interconnected voids filled with gases or liquids. The specific properties of porous materials have a variety of effects on many processes in the Nature and technology.

Porous und permeable media play an important role in the exploration of oil and gases and in the biogeochemistry of our planet. For example, more than 50% of the entire continental shelf the underwater belt around the continents is made of permeable sands, and has a significant effect on the biology, biogeochemistry and ecology of the oceans and the Earth.

Another example for the biological relevance of porous media is given by marine aggregates organic matter, including plankton and diatoms which sink from the surface of the world oceans to the depth, carrying energy through the entire water column down to the seabed, and are responsible for the global Carbon budget and with this for the climate regulation.

Porous media find also manifold industrial applications. Examples contain, but are not limited to industrial foams, filters, heat or acoustic insulation, sinter ceramics, and silica gels, which we see as small spherical beads packed in small bags accompanying any electronic and electric packages. Recently, porous materials have been also used to replace classical solid building and construction materials in civil and electronic engineering.

The course is organized as follows:

- Definition and properties of porous medium
- Equations of flows through a porous medium
- Heat and mass transfer through a porous medium
- Effective numerical methods for solving porous media problems
- Experimental visualization methods in porous media
- Selected applications of porous media in modern science and technology
- Examination, answer and questions
- Study and research opportunities Max Planck Institutes and other research institutes in Germany

Course participants will learn these topics through lectures and tutorials. Practical session on programming in FORTRAN shall also be conducted.

Course Details:

<table>
<tr><td>Course Dates</td><td>This is a two weeks course.
December 18 - December 22
December 25 - December 29
Number of participants for the course will be limited to fifty.</td></tr>
<tr><td>You should attend if ..</td><td>Porous media finds applications in heat transfer in almost all areas of engineering (You should attend the course if
You are an mechanical/chemical/biomedical engineer or research scientist interested in porous media research.
you are a student interested in learning lattice Boltzmann method (LBM)..
you are a student or faculty member from academic institution interested in learning the basics of porous media</td></tr>
<tr><td>Fees</td><td>The participation fees for taking the course is as follows:<table><tr><td>Participants from abroad</td><td>USD 500</td></tr><tr><td>Industry/Research Organization</td><td>Rs. 30,000</td></tr><tr><td>Faculty members from Government Institutions</td><td>Rs. 10,000</td></tr><tr><td>Faculty members from Private Universities</td><td>Rs. 5,000</td></tr><tr><td>Faculty members from Private Colleges</td><td>Rs. 2,000</td></tr><tr><td>Students (Research Scholar, UG and PG Students) from non-Government organizations</td><td>Rs. 1,000</td></tr></table>Note: Registration fee may be waived for eligible candidates up on request. The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, free internet facility in the institute. The participants will be provided with accommodation and food on payment basis.</td></tr>
<tr><td>How to register?</td><td>Please visit http://people.iiti.ac.in/~sdhina/</td></tr>
<tr><td>Other details</td><td>Please visit http://people.iiti.ac.in/~sdhina/ to know more about the following:
Instructional materials
Visit to other labs
Computer usage in lab
Internet access
Tutorials
Assignment
Programming
Accommodation
Meals
Transport
Visit to nearby places on weekends</td></tr>
</table>

Details of Lecture, Tutorials and Practical session

DAY 1	
Lecture 1	**Definition and properties of porous medium - Part I** *This lecture explains the ensemble averaging, interconnected voids, microscopic and macroscopic approach to a porous medium*
Lecture 2	**Definition and properties of porous medium - Part II** *In this part the properties of a porous medium, i.e., porosity, permeability, tortuosity and heat conductivity will be explained.*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 2	
Lecture 3	**Equations of flow through a porous medium - Part I** *This lecture explains the concept of the resistance to a flow when a fluid moves through a bed of solid obstacles or a granular medium: Darcy, Brinkmann and Forchheimer equations*
Lecture 4	**Equations of flow through a porous medium - Part II** *In this part equations for the transport of heat and material (chemical species) to a porous medium will be addressed.*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 3	
Lecture 5	**Heat transfer through a porous medium** *This lecture illustrates the heat transport by solving a few examples analytically*
Lecture 6	**Mass transfer through a porous medium** *This lecture illustrates the mass transfer by solving a few examples analytically*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 4	
Lecture 7	**Effective numerical methods for solving porous media problems- Part I** *This lecture explains how to develop a generalized set of equations that are valid for the fluid as well as the porous region by choosing an appropriate binary parameter without facing discontinuity*
Lecture 8	**Effective numerical methods for solving porous media problems- Part II** *This lecture explains the finite difference method by combining Adam Bashforth and Crank-Nicolson methods*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 5	
Lecture 9	**Effective numerical methods for solving porous media problems- Part III** *In this lecture the basics of lattice Boltzmann method (LBM) as one of the most powerful methods for the numerical treatment of momentum, heat and mass transfer problems are explained.*
Lecture 10	**Effective numerical methods for solving porous media problems- Part IV** *In this part effective techniques will be explained for increasing the acceleration and the efficiency of the standard LBM*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 6	
Lecture 11	**Novel experimental visualization techniques in porous media: Part I** *This lecture gives an overview of noninvasive optical and laser methods. In particular the method of Refractive Index matching (RIM) will be explained, which enables us to "look through" an opaque layer of porous medium*
Lecture 12	**Novel experimental visualization techniques in porous media: Part II** *This lecture is devoted to the method of Particle Image Velocimetry (PIV) for the visualization of the velocity field in a fluid or porous region*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 7	
Lecture 13	**Novel experimental visualization techniques in porous media: Part III** *This lecture is devoted to the method of "shadowgraphy"*
Lecture 14	**Novel experimental visualization techniques in porous media: Part IV** *This lecture is devoted to the method of Planar Laser-Induced Fluorescence (PLIF) for the visualization of material transport*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 8	
Lecture 15	**Selected applications of porous media in engineering** *This lecture brings few examples about computational and experimental results on studies pertaining flow and concentration fields around solid and porous bodies*
Lecture 16	**Selected applications of porous media in nature** *This lecture brings few examples about computational and experimental results on studies pertaining flow and concentration fields around and through marine aggregates and bio irrigating Macrobenthos larvae*
Tutorials	Tutorials session / Practical session on Programming in Fortran

DAY 9	
Lecture 17	**Examination**
Lecture 18	**Exam questions: Answers and Discussion**

DAY 10	
Lecture 19	**Research opportunities in the field of porous media**
Lecture 20	**Collaboration with Max Planck Institutes in Germany: Overview of facilities and equipments**

The Faculty

Prof. Arzhang Khalili is a Professor at the Max Planck Institute for Marine Microbiology, Germany. Through years of doing research in the field of porous and granular media, in particular for his work in the past twelve years the applicant has created a rigorous progress in experimental and numerical sector on a global scale. Already in 1997 he and his students succeeded in developing an accelerated numerical methods suitable for calculation of exchange processes in porous media, without knowing the boundary condition at the fluid-porous interfaces. In the majority of real-life porous media applications, complex chemical, physical and biological processes come into play, simultaneously. Classical, numerical solution methods, most often, fail to mimic these complex processes. Prof. Arzhang Khalili and his group have successfully developed a numerical tool based on the so-called Lattice-Boltzmann method, and demonstrated successfully its ability to resolve complex problems in different fields. Using novel, non-invasive experimental techniques such as particle image velocimetry (PIV) and planar laser-induced fluorescence (PLIF), the applicant and his staff succeeded in clarifying numerous physical mechanisms in marine environmental science and engineering for the first time. Examples to this are given by the hydrodynamic explanation of the rise of gas bubbles in saturated porous media, direct visualization of the mass transport in porous media by ascending gas bubbles and the emergence of diffusion driven particle accumulation in density gradient with relevance to climate research.

Dr. Shanmugam Dhinakaran is an Associate Professor at the Department of Mechanical Engineering, Indian Institute of Technology Indore. He received his Ph.D. from IIT Kharagpur in the area of Computational Fluid Dynamics and Heat Transfer. He has a wide postdoctoral research experience (Universite de Pays et des Pays de l'Adour, France; Universite de Valenciennes et des Hainaut-Cambresis, France; Universidade do Minho, Portugal and Faculdade de Engenharia da Universidade do Porto, Portugal) in computational and experimental fluid dynamics. His research interests are in flow, heat and mass transfer in porous media; nanofluid for heat transfer enhancement; non-Newtonian Fluid Mechanics; Bluff body flows.