SAJJAD FOROUGHI

Ph.D., Research Associate, Imperial College London

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PROFILE

- With more than 5 years of dedicated research experience, my expertise lies in modeling and simulating multiphase flow in porous media at both pore and continuum scales. My primary focus involves understanding the challenges associated with multiphase flow in porous media, which is critical for applications such as CO_2 and hydrogen storage, comprehending underground reservoirs, and utilizing geothermal energy. I emphasize the significance of studying pore-scale phenomena in driving advancements for large-scale energy transition projects.
- Skilled in computer programming, data science, applied optimization, uncertainty quantification, machine learning, and analytical modeling. Eager to apply these technical skills to tackle problems in the energy transition mission.
- Providing mentorship and co-supervision to over 20 junior researchers, including postgraduate and undergraduate students. Moreover, establishing global collaborations with a successful track record.
- Experienced in project management, teamwork, and bridging the gap between numerical models and experimental laboratories for the seamless practical application of theoretical advancements (e.g., designing poreXtractor software). Demonstrated leadership in modeling activities, along with the management of the porescale GitHub and overseeing the pore-scale modeling and imaging webpage.

ACADEMIC EXPERIENCES

Imperial College London, Research Associate **Feb 2019 – Present**

◇ **Imperial–Shell Digital Rocks II (Jan 2021 – Present):** Heterogeneous rocks exhibit a diverse range of pore sizes, spanning from less than 0.1 microns to over 50 microns. The challenge arises in capturing the entirety of the pore space using micro-CT imaging techniques. The inclusion of sub-resolution pore space is crucial for characterizing porous media and predicting multiphase flow within it.

I have developed a multi-scale pore network model that facilitates the incorporation of sub-resolution pore space in modeling. The workflow has been successfully validated against various rocks, encompassing a wide spectrum of pore size distributions, including Estaillades, Silurian dolomite, Ketton, and complex sandstone reservoirs with bimodal pore size distributions.

Throughout the development of this workflow, I proposed a closed-form capillary pressure equation applicable to all types of wettability. The resulting capillary pressure model has been published and later integrated into an industrial software.

Currently, the multi-scale pore network workflow is under review, and two additional works are in preparation for submission.

◇ **Imperial–Shell Digital Rocks (Feb 2019 – Dec 2020):** My research focused on enhancing our comprehension of the dominant physical factors governing two-phase flow (relative permeability) in rocks, with an emphasis on translating this insight into effective numerical models. I devised an optimization workflow dedicated to determining wettability in diverse porous systems. This involved formulating an inverse problem using micro-CT experimental fluid configurations and pore network modeling results. The approach enabled the identification of optimal wettability parameters that minimize discrepancies between the model and experimental outcomes. Notably, the findings underscored the crucial role of spatial correlation of wettability in accurately modeling mixed-wet systems.

The efficacy of the workflow was demonstrated through testing on steady-state micro-CT and synchrotron experiments, culminating in the publication of two papers, with another manuscript currently in preparation. The excellence of this work secured my continued involvement in the subsequent phase of the project.

◇ **Correcting Relative Permeability Measurements for Inhomogeneous Saturation Profiles in One-Dimensional Flow – (TotalEnergies)**: This optimization workflow takes into account the saturation profile in modeling. Traditionally, relative permeability is obtained by assuming a uniform saturation profile. However, due to the inhomogeneous nature of saturation profiles in heterogeneous porous media, our new workflow appears to be essential. We are able to consider the saturation profile along the flow to determine relative permeability more accurately. the workflow has been published on GitHub.

◇ **Multi-scale Generalized Pore Network Modelling – (TotalEnergies)** : I provided guidance in applying the multiscale pore network workflow that I developed to the generalized pore network modeling. The difference between this method and classical pore network models lies in the complexity of geometries in network elements in this method, leading to a distinct workflow and methodology.

◇ **Network Modeling of Resistivity Index in Laminated Sandstones – (Wintershall Dea)** : The inclusion of sub-resolution porosity in network modeling for these rock types is crucial for accurately determining resistivity. Leveraging our developed multi-scale pore network modeling, we successfully simulated the resistivity index for the complex systems laminated reservoir sandstone. Building upon this research and another study, I am currently preparing a journal paper for submission, focusing on modeling the electrical properties of porous media.

◇ **Integration of Pore-Scale Imaging and Modeling – (BP)** : In this project, we efficiently compared lattice Boltzmann with pore network modeling, examining the strengths and weaknesses of these models by aligning their results with experimentally acquired images for two-phase flow through reservoir rocks. Demonstrating both accuracy and computational efficiency, we highlight the effectiveness of pore network modeling in simulating multiphase flow in porous media. I am currently preparing this work for submission as a journal paper.

◇ **Software Development for Experimental Researchers and PhD Students:**

I have developed the pore occupancy analysis software, poreXtractor, designed for quantifying micro-CT images of porous media. This software facilitates the quantification of phase distribution within porous media, providing valuable insights into the underlying phenomena. We successfully applied this software to analyze microCT images from hydrogen and CO_2 storage experiments and two-phase flow studies involving reservoir rocks such as Kettons, Estaillades, Bentheimers, and other porous media. Rigorous testing was conducted for both steady-state micro-CT experiments and synchrotron experiments.

The efficacy of this software is evident in its application to experiments, significantly enhancing the precision and accuracy of process understanding. I have actively collaborated on more than 15 research projects, engaging with over 10 experimentalist researchers. Publications resulting from these collaborations are either published, under review, or in preparation. Worth noting, the software is available on GitHub and has been successfully used for analysis of micro-CT images by other institutes.

◇ **Co-Supervision Role and Mentorship for Modelling Works Within the Group:**

- Development of a thermodynamically-based pore-scale network model to simulate fluid intermittency during two-phase flow.
- Exploration of fluid-fluid displacement in mixed-wet porous media through numerical study.
- Investigation of the coupled influence of rock structure and flow properties on reaction rates in chemically heterogeneous rock using X-ray microtomography.

The journal papers related to these projects are currently in preparation for submission soon.

◇ **UK and International Collaborations**

- ***Uppsala University***: Collaborated with a PhD student in investigating the impact of the remobilization of residually trapped CO_2 using pore network modeling. This is crucial for understanding the long-term stability of CO_2 storage. Results have been published as a journal paper.
- ***Glasgow University***: Collaboration on modeling carbon geosequestration in limestone: pore-scale dissolution and geomechanical weakening. This work is ongoing.

- ***Dalian University of Technology***: Supervised a PhD student in a study on Image-Based Pore-Scale Modeling of the Effect of Wettability on Breakthrough Capillary Pressure in Gas Diffusion Layers. Results have been published as a journal paper.
- ***Zhejiang University***: I actively co-supervised a PhD student in the development of a dual-scale pore network model to study heat transfer. Also, we are working on the statistical analysis of CO_2 trapping at the pore scale using constructed porous media generated by Generative AI deep learning and pore network modeling. Two papers have been published, one is under review, and two others are in the preparation stage.
- ***Pennsylvania State University***: Co-supervised a PhD student in quantifying Fluid–Fluid Interfacial Area and investigating its impact on relative permeability using Pore Network Modeling. One journal paper has been published based on this collaboration.
- ***China University of Petroleum***: Co-supervised a PhD student in the numerical study of two-phase flow through porous media and pore-scale study of mobilization of a trapped NAPL ganglion. This collaboration has resulted in one published paper, and another one is currently under review.

◇ **Administrative Responsibilities:** I am in charge of the maintenance of the pore-scale modeling and imaging webpage to ensure it is up-to-date. Additionally, I manage the porescale GitHub. I am responsible for keeping repositories up to date and addressing inquiries from researchers around the globe regarding these repositories. The open-source codes on our GitHub page have been used thousands of times by researchers worldwide for a variety of applications, helping to understand pore-scale phenomena.

EDUCATION

PhD Petroleum Engineering **Sept 2012–Sept 2018**
Chemical & Petroleum Engineering Department, Sharif University of Technology,
Thesis: "Simulation of Two-phase Flow Through Micro-fractured Rocks Using Multi-block Lattice Boltzmann Method"
GPA (Cumulative): 18.55/20

MSc Chemical Engineering **Sept 2009–Sept 2011**
Chemical & Petroleum Engineering Department, Sharif University of Technology,
Thesis: "Lattice Boltzmann Simulation of Fluid Flow through Porous Media Using Local Grid Refinement"
GPA (Cumulative): 17.63/20

BSc Petroleum Reservoir Engineering **Sept 2005–July 2009**
Petroleum University of Technology
Thesis: "Foamy Oil Flow through Porous Media"
GPA (Cumulative): 17.51/20

INDUSTRIAL EXPERIENCES

Sept 2011–Feb 2019: MAPSA Technology Center (MTC), Technical Programmer

An Iranian software development industrial company engaged in the development of petroleum engineering related software applications.

- Technical Programmer, Mud Logging Software, Sept 2011–June 2013. My role involved developing computational modules, including optimization and drilling hydraulic analysis.
- Technical Programmer, PVT Pro Software, June 2012–Feb 2019. My role involved developing computational modules, such as optimization, global Sensitivity analysis, hydrocarbon characterization, slim tube simulation, and predicting asphaltene precipitation using PC-Saft EOS.

July 2012–July 2014: Developing a general smart framework; Integrated reservoir engineering optimization aimed to optimise the technical-economical decisions for Iranian South Pars Gas Field.

TEACHING EXPERIENCES

Supporting Learning and Teaching Pathway (SLTP), Imperial College London July 2023

- I successfully completed the SLTP, one of Imperial College's Foundations in Teaching pathways, accredited within the Imperial STAR Framework. This achievement allows me to apply for the status of Associate Fellow at Advance HE. The work completed during the SLTP contributes to the application for Associate Fellow, and my application is currently in progress.

Mentorship and Co-supervision, Imperial College London Jan 2019 - Present

- Provide mentorship and co-supervise more than 10 MSc and MSci research projects at Imperial College London. These collaborative efforts have significantly contributed to the successful completion of projects. Our focus includes modeling and studying single-phase and two-phase flow through porous media, as well as the meticulous analysis of acquired micro-CT 3D images of porous media. Through tailored guidance and support, students have achieved meaningful insights and breakthroughs, ensuring the overall success of their research endeavors.

Teaching Assistant, Sharif University of Technology (Iran) Spring 2015 and 2016

- Computational Fluid Dynamics (CFD)
- Advanced Fluid Flow through Porous Media

Lecture Instructor, Sharif University of Technology (Iran) 4 semesters (2012 - 2014

- Drilling Engineering Lab

HONORS & AWARDS

- Ranked 4th among more than 5,000 participants in the PhD Iranian Nationwide Entrance Examination in Petroleum Engineering in 2012, securing a scholarship for the Ph.D. program.
- Attained the 2nd rank out of over 1,000 participants in the MSc Iranian Nationwide Entrance Examination in Petroleum Engineering in 2009, earning a scholarship for the M.Sc. program.
- Achieved the 1066th position (top 0.3%, Regional rank 45) out of more than 367,000 participants in the Iranian University Entrance Exam (Konkour) in 2005.
- Recognized as the Best PhD Research Student at the Chemical and Petroleum Engineering Department of Sharif University of Technology in September 2017.
- Granted Honorary Membership in the "Iranian National Foundation of Elites" in 2015.
- Awarded a Scholarship (Fellowship) for B.Sc. in Petroleum Engineering from Petroleum University of Technology, 2005-2009.
- Admitted to the M.Sc. Program in Petroleum Engineering at Petroleum University of Technology in 2009.

ACADEMIC SERVICES

Journal Reviewer: Water Resources Research, Transport in Porous Media, SPE J, Geoenergy Science and Engineering, Advances in Water Resources, Journal of Energy Engineering.

TECHNICAL SKILLS

Programming: Professional programmer with more than 14 years of experience in developing codes by **C++, Python, MATLAB, C#, FORTRAN.**