Sandipan Kumar Das

Office 107, Mechanical Engineering Department, IIT(ISM) Dhanbad. +91 914 704 5784 (C). sandipan@iitism.ac.in

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Research Interests

My research has focused on developing computational modeling approaches for solving a wide variety of multi-scale, multi-physics, practical problems across different industry segments like energy, refining, automotive, HVAC etc. In recent years, the research emphasis has been in the energy domain. My scientific interests lie in developing different turbulence models, population balance models for multiphase flows, multicomponent diffusion transport through porous media, Boundary Integral Methods (BIM) for Stokes flows, carbon capture and green energy technologies.

Education

2001-2005 **Stanford University,** Stanford, USA
Ph.D. in *Mechanical Engineering*
Research: Lagrangian stochastic modeling of turbulence, turbulence modeling theory, pollutant dispersion.
Teaching: Course assistant in 3 graduate level courses: *Linear Algebra, Partial Differential Equations, Numerical Methods.*

1994-1996 **Indian Institute of Technology,** Mumbai, India
M.Tech. in *Mechanical Engineering*
Research: Computational fluid dynamics (CFD).

1989-1993 **Jadavpur University,** Kolkata, India
B.M.E. in *Mechanical Engineering.*

Current Position

Oct'21 – date **Professor**
Department of Mechanical Engineering
Indian Institute of Technology (ISM) Dhanbad
Dhanbad, Jharkhand, INDIA 826004.

Nov'22 - Oct'24 **Head of Center**
Naresh Vashisht Center for Hydrogen and CCUS Technologies (NVCHCCUST)
Indian Institute of Technology (ISM) Dhanbad
Dhanbad, Jharkhand, INDIA 826004.

As a Professor, I direct research mainly on the theoretical aspects of **Population Balance Models** (PBM) of bubbly flows and **Boundary Integral Methods** (BIM). The objective of the PBM research is to *develop* and *commercialize* the powerful models by implementing them in commercial Computational Fluid Dynamics (CFD) codes like **ANSYS/FLUENT** and facilitating their wide adoption by the industry. I have also drastically extended the capability of the BIM by including the exit boundary conditions in its formulation. It should open this sophisticated method to a wide variety of Stokes flow problems in the micro- and nano-fluidics community.

As the *Founding* **Head** of the Hydrogen Center, I successfully obtained initial seed external funding to kick-start its activities and directed/mentored diverse players and stakeholders towards a common goal. I brought a strong inter-disciplinary focus with active participation from the *Mechanical*, *Chemical* and *Metallurgical Engineering* and *Chemistry* departments of IIT(ISM) Dhanbad. The center principally emphasized on *commercializing* all the research that was being conducted here. Multiple patents were filed on different aspects of Hydrogen research including generation, delivery and utilization. During my watch, the center actively

pursued **Ammonia** as a Hydrogen carrier with strong support from the industry. Reputed multinational companies expressed keen interest and sought active participation in collaborative research with the center.

Industrial Experience

Feb'21-Sep'21 **Engineering Systems Inc.,** TX, USA

I was tasked with leading the initiative on building a center of excellence in Computational Fluid Dynamics within the company. I successfully introduced CFD and advanced mathematical techniques in quite a few high-profile projects. My effort eventually fructified in bringing energy transition external research and development consulting projects for the first time in the organization. My short stint in the company led to an overall exponential growth of CFD related activities across diverse internal sectors.

2012-Feb'21 **ExxonMobil Research and Engineering,** VA & TX, USA

I possessed a dual role: i) as a researcher, I identified research problems with deep business impact and then worked with partners to secure internal funding and finally develop scientific solutions towards advancing them to "technical readiness" for wide deployment in industrial sites; ii) as a technical consultant, I got called on to provide technical guidance to alleviate operational problems in industrial sites worldwide. I have been recognized with prestigious internal awards for both roles. In the process I have dealt with a breadth of physical problems like gas-liquid flows in fractionation applications, liquid-liquid flows in desalters and other separator tanks, gas-solids in regenerators/FCC, electrochemistry modeling in molten carbonate fuel cells, low Reynolds Number multiphase flows for carbon capture applications etc. The majority of the above entailed CFD simulations using ANSYS/FLUENT, with some of them requiring heavy dosage of custom model development through user defined functions. A few representative examples include:

- Developed a new nozzle injector design for wet gas scrubber applications through multiphase Large-Eddy-Simulations using FLUENT. It has been declared "technically ready" to be deployed for all refinery applications worldwide. Obtained a patent on the new design.
- Developed and integrated an electrochemistry module from scratch in the CFD code that is currently helping design the next generation molten carbonate fuel cells for carbon capture applications. Already obtained a patent from the project and a few are in the pipeline.
- Designed an innovative device for a slops tank through a series of CFD simulations that increased the separation effectiveness by more than an order of magnitude. The device has been constructed in a new tank at a refinery.

I have also contributed to the scientific literature by performing research on theoretical aspects of different fundamental problems and publishing the results in reputed peer reviewed journals as a single author. These include

- Developed a coalescence kernel for population balance modeling in the bubbly flow regime. It entailed developing a new mathematical framework that directly accounts for the effects of turbulence on the probability of coalescence for the first time in the literature. Also extended the approach to breakage kernels in a separate publication.
- Developed new procedures to mathematically account for the wall effects in the elliptic relaxation equations for stratified flows. This resulted in the Second Moment Closure (SMC) turbulence models correctly reproducing the Direct Numerical Simulation (DNS) data at extremely high stratification levels for stable stratification. This is a known challenge for turbulence models that has been successfully tackled in this work. In a separate publication, considerably simplified the model with little loss in accuracy for easy usage in more practical applications.
- Generalized the "Dusty Gas Model" for multicomponent diffusion in porous medium that now accounts for the pore size distribution with respect to both the porosity and the tortuosity. Explored different diffusion regimes where the new model can be much

more accurate than the standard model that assumes a constant pore size and tortuosity. Also developed analytical solutions for the one-dimensional form of the Dusty Gas Model for binary, ternary and higher order systems in a separate paper. To the best of my knowledge (and also of the reviewers) this is the first time that a correct analytical solution to this problem has appeared in the literature. This will go a long way in developing better reduced order models for concentration polarization in fuel cell applications in the future.

2010-2012 **ConocoPhillips/Phillips 66,** OK, USA
Role was similar to the job described above (ExxonMobil). Most of the projects required complex CFD simulations using ANSYS/FLUENT. Some highlights are

- Patented novel nozzle injector designs for quenching applications.
- Formulated an optimal strategy for sludge removal in crude storage tanks. Successfully patented the sludge management system.
- Developed a predictive CFD model for flow simulation through spirally wound membranes for sweetening of sour gas. Further developed a reduced order model (ODE level) for rapid use.

2005-2010 **Cascade Technologies Inc.,** CA, USA
Small CFD company that primarily relied on federal research funding and CFD consulting projects from the industry. Primary role was to oversee the proposal writing process with various academic partners, working on industrial consulting projects and writing/compiling project reports.

1996-2001 **Fluent India Pvt. Ltd.,** Pune, India
Joined the company as an individual contributor to various aspects of CFD projects like mesh generation, getting converged solutions of complex simulations, post-processing and interpreting CFD results etc. Ended the stint as the Applications group Head with diverse managerial responsibilities like bringing business, planning, monitoring, recruitment, training, mentoring etc.

1993-1994 **Development Consultants Ltd.,** Kolkata, India
Primarily worked on finite element modeling of industrial piping systems.

Publications

- ***Journal:***

  - **Das, S.K.**, 'Solution of the Poisson Equation by the Boundary Integral Method', ***International Journal of Numerical Methods for Heat and Fluid Flow***, volume 34, 2024.

  - Roy, A., Sen Gupta, S., Samanta, A., Likhith, P.V.S.S. and **Das, S.K.**, 'Prospects of energy-efficient power generation system with ammonia as Hydrogen carrier', ***International Journal of Hydrogen Energy***, volume 71, 2024.

  - Sengupta, A., **Das, S.K.**, Nandi, B.K. and Sharma, P., 'Characterizing pulverized coal combustion for high-ash content Indian coal', ***Energy Sources, Part A: Recovery, Utilization and Environmental Effects****,* volume 46, 2024.

  - **Das, S.K.**, 'Extension of the Boundary Integral Method for different boundary conditions in steady-state Stokes Flows', ***International Journal of Numerical Methods for Heat and Fluid Flow,*** volume 33, 2023.

  - **Das, S.K.**, 'A Reynolds Stress model with a new elliptic relaxation procedure for stratified flows', ***International Journal of Heat and Fluid Flow,*** volume 83, 2020.

  - **Das, S.K.**, 'Analytical expression for concentration overpotential of anode-supported Solid Oxide Fuel Cell based on the Dusty Gas Model', ***Journal of Electrochemical Energy Conversion and Storage,*** volume 17, 2020.

- **Das, S.K.**, 'General Dusty Gas Model for porous media with a specified pore size distribution', ***Chemical Engineering Science,*** volume 203, 2019.

- **Das, S.K.**, 'Elliptic relaxation model for stably stratified turbulence', ***International Journal of Heat and Fluid Flow,*** volume 74, 2018.

- **Das, S.K.**, 'Towards enhancement of carbon capture by Molten Carbonate Fuel Cell through controlled thermodiffusion', ***International Journal of Heat and Mass Transfer,*** volume 127, part A, 2018.

- **Das, S.K.**, 'Direct solver for pentadiagonal matrix containing tridiagonal submatrices', ***Numerical Heat Transfer, Part B: Fundamentals,*** volume 72, issue 1, 2017.

- **Das, S.K.**, 'A new turbulence induced theoretical breakage kernel in the context of the population balance equation', ***Chemical Engineering Science,*** volume 152, 2016.

- **Das, S.K.**, 'Development of a coalescence model due to turbulence for the population balance equation', ***Chemical Engineering Science,*** volume 137, 2015.

- **Das, S.K.** and Durbin, P.A., 'Prediction of atmospheric dispersion of pollutants in an airport environment', ***Atmospheric Environment,*** volume 41, issue 6, 2007.

- **Das, S.K.** and Durbin, P.A., 'A Lagrangian stochastic model for dispersion in stratified turbulence', ***Physics of Fluids,*** volume 17, issue 2, 2005.

- ***Book:***

  - **Das, S.K.,** 'Pollutant dispersion prediction in airports: A Lagrangian stochastic modeling approach', ***VDM*** *publishers,* ISBN # 9783639124798, 2009. (My Ph.D. thesis has been published as a book by the publisher) https://www.amazon.com/Pollutant-Dispersion-Prediction-Airports-Lagrangian/dp/3639124790

- ***Conference/Talk/Media:***

  - **Das, S.K.**, 'General Dusty Gas Model for Porous Media with a Specified Pore Size Distribution', featured in *Advances in Engineering*, (https://advanceseng.com/general-dusty-gas-model-porous-media-specified-pore-size-distribution/).

  - **Das, S.K.** (Lead Author), Hanson, H. (Topic Editor),'Modeling Atmospheric Dispersion of Pollutants', *Encyclopedia of Earth* (http://www.eoearth.org), *Ed: Cutler J. Cleveland,* 2007.

  - **Das, S.K.**, 'Backward Lagrangian Stochastic Modeling for Pollutant Dispersion in Airports', *LAX Air Quality and Source Apportionment Study, Technical Work Group Meeting No. 4,* March 22, 2007.

  - **Das, S.K.** and Durbin, P.A., 'Airport Pollutant Dispersion Modeling', *Thermal and Fluid Sciences Affiliates & Sponsors Conference,* Stanford University, 2004.

  - **Das, S.K.**, Kalitzin, G. and Durbin, P.A., 'A Model for Prediction of Bypass Transition', *Thermal and Fluid Sciences Affiliates & Sponsors Conference,* Stanford University, 2003.

Patents granted

- 'An integrated fluidized bed reactor system for Ammonia combustion to obtain Hydrogen and power and method to do the same'. ***Patent Number:*** 541857 (India). ***Grant Date:*** June 14, 2024. ***Date filed:*** March 15, 2023. ***Inventors:*** ***Sandipan Kumar Das***, Arunkumar Samanta, Siddhartha Sengupta, Soumyajit Sen Gupta.

- 'Method and system for optimum usage of Ammonia by generating power using coupled heat exchanger-combustor'. ***Patent Number:*** 513499 (India). ***Grant Date:*** February 21, 2024. ***Date Filed:*** December 1, 2022. ***Inventors:*** ***Sandipan Kumar Das***, Aditi Sengupta, Laltu Chandra.

- 'Desalter Inlet distributor designs and methods'. ***Patent Number:*** 1173415 (USA). ***Type:*** Grant. ***Date of Patent:*** November 16, 2021. ***Date Filed:*** August 13, 2019. ***Inventors:*** ***Sandipan K. Das***, Andrew P. Sullivan, Magaly C. Barroeta.

- 'Housing for multiple fuel cell stacks'. ***Patent Number:*** 10622660. ***Type:*** Grant (USA). ***Date of Patent:*** April 14, 2020. ***Inventors:*** Frank Hershkowitz, Timothy A. Barckholtz, Paul J. Berlowitz, ***Sandipan K. Das***, Thomas A. Badgwell.

- 'Nozzle for wet gas scrubber'. ***Patent Number:*** 10478835. ***Type:*** Grant (USA). ***Date of Patent:*** November 19, 2019. ***Inventors:*** Glenn M. Beatty, Christopher J. Fowler, Venkatesh Subramania, ***Sandipan K. Das***, John B. Barnes, Laura Johnsen.

- 'Sludge management system for crude oil storage tanks'. ***Patent Number:*** 10384242. ***Type:*** Grant (USA). ***Date of Patent:*** August 20, 2019. ***Inventors:*** ***Sandipan Kumar Das***, Sally Ann Thomas.

- 'Injector nozzle quenching process for piping systems'. ***Patent Number:*** 9650691. ***Type:*** Grant (USA). ***Date of Patent:*** May 16, 2017. ***Inventors:*** ***Sandipan Kumar Das***, Steven Allen Trese.

- 'Injector nozzle quenching for piping systems'. ***Patent Number:*** 9487842. ***Type:*** Grant (USA). ***Date of Patent:*** November 8, 2016. ***Inventors:*** ***Sandipan Kumar Das***, Steven Allen Trese.

Patents published

- 'A fabric based structured bed gas-solid contractor system for capturing CO_2 and process for capturing CO_2 therein'. ***Publication Number:*** 202431032179. ***Publication Date:*** May 3, 2024. ***Date filed:*** April 23, 2024. ***Inventors:*** Arunkumar Samanta, Babuni Prasad, ***Sandipan Kumar Das***, Soumyajit Sen Gupta. (Indian Patent)

- 'A process for the production of Hydrogen from Aluminum waste'. ***Publication Number:*** 202431005303. ***Publication Date:*** February 23, 2024. ***Date filed:*** January 25, 2024. ***Inventors:*** Arunkumar Samanta, Chitrang Jayantibhai, Babuni Prasad, Tapas Kumar Mandal, ***Sandipan Kumar Das***, Soumyajit Sen Gupta. (Indian Patent)

- 'A system for Ammonia combustion with two stage coupled combustor'. ***Publication Number:*** 202331078073. ***Publication Date:*** December 1, 2023. ***Date filed:*** November 16, 2023. ***Inventors:*** ***Sandipan Kumar Das***, Arunkumar Samanta, Soumyajit Sen Gupta. (Indian Patent)

- 'Dual fluidized bed chemical looping gasification system for Hydrogen production and process of Hydrogen production therein'. ***Publication Number:*** 202331073657. ***Publication Date:*** November 24, 2023. ***Date filed:*** October 30, 2023. ***Inventors:*** Arunkumar Samanta, ***Sandipan Kumar Das***, Soumyajit Sen Gupta. (Indian Patent)

- 'Cathode collector structures for Molten Carbonate Fuel Cell'. ***Publication Number:*** 20200176783. ***Type:*** Application (USA). ***Publication Date:*** June 4, 2020. ***Date Filed:*** November 26, 2019. ***Inventors:*** Jonathan Rosen, Timothy A. Barckholtz, Heather A. Elsen, Gabor Kiss, Lu Han, Thomas M. Smith, ***Sandipan K. Das***, Chao-Yi Yuh, Carl A. Willman, Timothy C. Geary, Keith E. Davis, Abdelkader Hilmi, Lawrence J. Novacco.

- 'Flow field baffle for Molten Carbonate Fuel Cell Cathode'. ***Publication Number:*** 20200176787. ***Type:*** Application (USA). ***Publication Date:*** June 4, 2020. ***Date Filed:*** November 26, 2019. ***Inventors:*** Timothy C. Geary, Timothy A. Barckholtz, Jonathan Rosen, ***Sandipan K. Das***, Carl A. Willman, Abdelkader Hilmi, Chao-Yi Yuh.

- 'Integrated operation for Molten Carbonate Fuel Cells'. ***Publication Number:*** 20170271701. ***Type:*** Application (USA). ***Publication Date:*** September 21, 2017. ***Date Filed:*** March 3, 2017. ***Inventors:*** Paul J. Berlowitz, Timothy A. Barckholtz, ***Sandipan K. Das***.

Honors and Awards

2019 **PTD 2019 Innovator of the year** Highest award in the Process Technology Department (PTD) of ExxonMobil R&D.

2013 **Leadership Award** from Process Technologies division for exceptional accomplishments aligned with ExxonMobil Research & Engineering (EMRE) business drivers.

2010 Listed in **Marquis' Who's Who** in America (2010).

1995 **Forbes Marshall Scholarship** in Masters program.

1992 Certificate from Alumni Association N.C.E. Bengal & Jadavpur University for merit and academic activities.

1989 **National Scholarship** in high school.

Academic Activities

- **Associate Editor** of the *Journal of Electrochemical Energy Conversion and Storage* (Impact Factor: 2.7)
- Member of the *American Society of Mechanical Engineers* (ASME)