fluids

MDPI

Editorial

Special Issue: Pipe Flow: Research and Applications, First Edition

Leonardo Di G. Sigalotti

Departamento de Ciencias Básicas, Universidad Autónoma Metropolitana, Unidad Azcapotzalco (UAM-A), Av. San Pablo 420, Colonia Nueva el Rosario, Alcaldía Azcapotzalco, Ciudad de México 02128, Mexico; leonardo.sigalotti@gmail.com

The transport of fluids through pipes and channels is a foundational topic in fluid mechanics, with direct applications spanning many branches of science and engineering. Whether delivering potable water across urban areas [1,2], transporting hydrocarbons through continental pipelines [3,4], or optimizing coolant flow in nuclear reactors [5,6], pipe flow remains at the heart of countless real-world systems. In recent years, new computational techniques, novel experimental diagnostics, and increasing environmental concerns have reinvigorated research in this classical field [7–10].

The first edition of this Special Issue on Pipe Flow: Research and Applications aims to highlight the breadth and depth of ongoing innovations and challenges in pipe flow research. The contributions in this Special Issue reflect the state of the art in both fundamental and applied aspects of the discipline. They include advances in various topics dealing with fluid transport in pipes. Authors from both academia and industry have provided insights that bridge theoretical developments and practical implementations, demonstrating the real-world value of research in this field. The cross-disciplinary nature of such studies underscores the versatility of pipe flow research and its adaptability to evolving technological landscapes. This Special Issue contains a collection of 13 papers, whose findings and significance are commented on as follows.

Benmbarek and Moujaes [11] performed computational fluid dynamics (CFD) simulations to investigate the heat transfer performance in a spirally corrugated tube [12,13]. They found that inserting a twisted plate into the tube significantly enhances heat transfer performance in heat exchangers and proposed a new insert geometry, which, apart from establishing a foundation for further innovation, is promoting the design of the next generation of heat exchangers.

In hydraulic engineering, the investigation of air–water interactions in pipelines is crucial for enhancing the efficiency and longevity of water supply systems [14–17]. In this line of research, Bonilla-Correa et al. [18] provided a numerical solution to the complex problem of entrapped air pockets in pipelines. The application of their model will be of great practical use to engineers working in collapse prevention and risk reduction in both the interruption and shortage of the water service.

Enhanced accuracy without significant computational costs continues to be a challenge in the art of mathematical modeling. This is especially important for real-time or large-scale simulations where three-dimensional CFD is largely impractical. Wiens [19] investigated a way to derive correction factors from CFD simulations that can be used by existing one-dimensional methods for an accurate flow description in curved pipes. This contribution is of great practical significance because by correcting for curvature, the models better reflect the real-world designs found in hydraulic systems, automotive, aerospace, and industrial machinery.

check for updates

Received: 23 May 2025
Accepted: 29 May 2025
Published: 3 June 2025

Citation: Sigalotti, L.D.G. Special Issue: Pipe Flow: Research and Applications, First Edition. *Fluids* **2025**, *10*, 149. https://doi.org/10.3390/fluids10060149

Copyright: © 2025 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Understanding how non-Newtonian fluids interact with deformable microchannels provides valuable insight for industries working with complex biological or polymeric fluids [20–22]. Rubio Martinez et al. [23] developed a mathematical model to investigate how an elastic microchannel (made of polydimethylsiloxane) deforms under the flow of a power law (non-Newtonian) fluid. This model is applicable to emerging technologies like photonic crystals, microstructure analysis, and multiplexed diagnostics, all of which rely on accurate microfluidic control.

De la Cruz-Ávila et al. [24] performed CFD simulations to underscore the importance of turbulence model selection in accurately simulating cavitation in Venturi tubes. The cavitation number trends matched well with the experimental results, supporting the model's validity in capturing cavitation onset and intensity. Their findings enhance our understanding of how turbulence affects vapor cloud dynamics, which is critical for improving hydraulic machinery performance, erosion prediction, and cavitation mitigation strategies [25].

Using experimental data obtained from the multiphase flow loop at the National University of Singapore, Guzmán et al. [26] tested existing model correlations for air–oil pressure drop predictions, providing a novel insight into two-phase flow behavior under high flow conditions. This analysis has implications in our understanding of the process of crude oil transportation through pipelines, which is a critical aspect of the midstream petroleum industry [27].

The formation and localization of pipe structures in sedimentary basins, especially in fluid migration and expulsion processes, are of great geophysical relevance. Gay et al. [28] presented laboratory experiments for the simulation of fluid injection into water-saturated sands using a Hele-Shaw cell setup, focusing on bilayered sediments. Their study reveals that maximum surface deformation occurs only when the fine layer is fluidized, providing a mechanistic basis for predicting subsurface fluid behavior in geophysical settings.

The internal flow dynamics in submerged entry nozzles (SENs) under varying sliding-gate valve (SGV) conditions has direct implications for steel quality in continuous casting processes. In this line of work, Gonzalez-Trejo et al. [29] performed an experimental study of how the SGV modifies the structure and dynamic behavior of the outlet jets for flat-bottom and well-bottom bifurcated SENs used in continuous casting machines. An important practical implication of this study is that steel producers can use these findings to adjust SGV operation and SEN design to achieve the desired mold flow characteristics, enhancing slab uniformity and quality.

Kinra and Pal [30] investigated how suspensions of cellulose nanocrystals (CNCs) behave during pipeline flow, specifically examining how changes in concentration and pipe diameter affect the flow characteristics. CNC suspensions are industrially relevant because their flow behavior is critical for pumping, mixing, and processing design [31,32]. A key finding of this study is that at concentrations lower than 1 wt%, CNC suspensions behave as a Newtonian fluid, while at higher concentrations, the suspensions exhibit a non-Newtonian, power law behavior. The transition from Newtonian to non-Newtonian behavior with an increasing concentration has broader implications in the rheology and fluid mechanics of nanomaterials [33–35].

Krishnappa et al. [36] compares single-channel serpentine flow field (SCSFF) and cross-split serpentine flow field (CSSFF) geometries in an all-iron redox flow battery (AIRFB). This study contributes valuable data and modeling validation for improving the fluid dynamics and operational efficiency of redox flow batteries, which are key components in scalable, renewable energy storage solutions.

Valuable insights for improving the efficiency and safety of sluice gate operations in hydraulic engineering were provided by the study performed by Abbaszadeh et al. [37], who

investigated the effects of gate openings and different sill widths on the sluice gate's energy dissipation and discharge coefficient. Most importantly, they provided non-linear polynomial relationships based on dimensionless parameters to predict the energy dissipation and outflow coefficient.

Rodríguez-Rivera et al. [38] performed CFD simulations to investigate the hydrodynamic performance of a novel pipe network using a Rhombic Tessellation Pattern (RTP) with allometric scaling, compared to a traditional Parallel Pipe Pattern. Their study reveals that the RTP provides a highly promising geometry for advanced fluid transport systems, especially where energy efficiency and flow control are critical [39,40].

This Special Issue closes with a comprehensive review of fluid flow in helical pipes [41]. In general, helically coiled pipes are relevant in industrial applications involving heat exchangers, steam generators, and chemical reactors [42–44]. This review addresses important fluid dynamics characteristics that are unique to helical pipes, such as the emergence of secondary flows, the delay of the laminar-to-turbulent transition compared to straight pipes, and turbulence stabilization effects. This review compiles and compares experimental and theoretical studies from the open literature, highlights areas that require further exploration, acts as a knowledge base for researchers and practitioners, and facilitates practical design and optimization in industry.

As the Guest Editor of this Special Issue, I am encouraged by the quality and diversity of the submissions. The articles selected for publication within this Special Issue not only reflect current advancements but also chart future directions for pipe flow research. I hope that this Special Issue will serve as a valuable resource for researchers, engineers, and policy-makers alike and fosters continued innovation and collaboration in the field.

In spite of recent effort, several challenges and future needs persist as systems become ever more complex and performance demands increase continuously [45–47]. Current challenges in pipe flow research include the following: the accurate prediction of turbulent flows under varied geometries and transient conditions, the development of better predictive tools for multiphase and multicomponent pipe flows, the derivation of better constitutive models for non-Newtonian and complex fluids, the development of in situ flow diagnostics for aging systems due to pipe corrosion, scaling and biofilm growth, and, last but not lease, the accurate prediction of the coupled fluid–structure interaction that can cause pipe damage and efficiency losses. Therefore, future research needs and directions must focus on the development of high-fidelity simulation tools and data-driven modeling for creating real-time digital representations of fluid networks, the use of advanced experimental techniques, such as high-speed imaging to capture detailed flow dynamics, optical fiber sensors, and ultrasound for real-time flow measurements inside pipes. Other needs require improving the energy efficiency and optimization of flow control strategies under variable demands and promoting research in emerging areas, such as micro- and nanoscale pipe flow, which are becoming increasingly more important for biomedical devices and microfluidics. In the near future, the rise of smart infrastructure will demand the integration of CFD modeling, experimental data, and machine learning to advance the field.

I express my sincere gratitude to all the authors, reviewers, and editorial staff whose efforts made this Special Issue possible. A very special thanks goes to Assistant Editor Ms. Cori Jia for all her help and assistance. I also look forward to the second edition of this Special Issue that will continue to capture the dynamism and relevance of pipe flow research in an ever-changing world.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Dawidowicz, J. Evaluation of a Pressure Head and Pressure Zones in Water Distribution Systems by Artificial Neural Networks. *Neural Comput. Appl.* **2018**, *30*, 2531–2538. [CrossRef] [PubMed]
2. Taiwo, R.; Yussif, A.-M.; Zayed, T. Making Waves: Generative Artificial Intelligence in Water Distribution Networks: Opportunities and Challenges. *Water Res. X* **2025**, *28*, 100316. [CrossRef]
3. Han, F.; Lan, Q.; Liu, Y.; Yin, G.; Ong, M.C.; Li, W.; Wang, Z. Unveiling Turbulent Flow Dynamics in Blind-Tee Pipelines Enhancing Fluid Mixing in Subsea Pipeline Systems. *J. Mar. Sci. Eng.* **2024**, *12*, 1199. [CrossRef]
4. Manzano-Ruiz, J.J.; Garballo, J.G. *Multiphase Transport of Hydrocarbons in Pipes*; John Wiley & Sons: Hoboken, NJ, USA, 2024.
5. Wang, H.; Zhu, Z.; Zhang, M.; Han, J. Numerical Investigation of the Large Over-Reading of Venturi Flow Rate in ARE of Nuclear Power Plant. *Nucl. Eng. Technol.* **2021**, *53*, 69–78. [CrossRef]
6. Xiao, H.; Yang, T.; Xie, A. CFD Study of Two-Phase Cross Flow and Heat Transfer in Subchannels of Pressurized Water Reactor Fuel Assemblies. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1171*, 012012. [CrossRef]
7. Kalpakli Vester, A.; Örlü, R.; Alfredsson, P.H. Turbulent Flows in Curved Pipes: Recent Advances in Experiments and Simulations. *Appl. Mech.* **2016**, *68*, 050802. [CrossRef]
8. Kassim, M.S.; Sarow, S.A. Flows of Viscous Fluids in Food Processing Industries: A Review. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *870*, 012032. [CrossRef]
9. Kavokine, N.; Netz, R.R.; Bocquet, L. Fluids at the Nanoscale: From Continuum to Subcontinuum Transport. *Annu. Rev. Fluid Mech.* **2021**, *53*, 377–410. [CrossRef]
10. Zhang, J.; Zou, Z.; Fu, C. A Review of the Complex Flow and Heat Transfer Characteristics in Microchannels. *Micromachines* **2023**, *14*, 1451. [CrossRef]
11. Benmbarek, M.M.; Moujaes, S.F. CFD Analysis of Heat Transfer Enhancement for Twisted Tape Inserted in Spirally Corrugated Tubes and Proposal of a New Vane-Inserted Geometry. *Fluids* **2025**, *10*, 73. [CrossRef]
12. Li, X.; Liu, S.; Mo, X.; Sun, Z.; Tian, G.; Xin, Y.; Zhu, D. Investigation on Convection Heat Transfer Augment in Spirally Corrugated Pipe. *Energies* **2023**, *16*, 1063. [CrossRef]
13. Yu, C.; Shao, M.; Zhang, W.; Huang, M.; Wang, G. Enhancing Heat Transfer Efficiency in Corrugated Tube Heat Exchangers: A Comprehensive Approach Through Structural Optimization and Field Synergy Analysis. *Heliyon* **2024**, *10*, e30113. [CrossRef] [PubMed]
14. Valero, D.; Felder, S.; Kramer, M.; Wang, H.; Carrillo, J.M.; Pfister, M. Air-Water Flows. *J. Hydraul. Res.* **2024**, *62*, 319–339. [CrossRef]
15. Zuo, J.; Qian, Y.; Zhu, D.Z.; Zhang, Z. Air-Water Interaction in a Partially Filled Circular Pipe. *Phys. Fluids* **2025**, *37*, 013315. [CrossRef]
16. Chen, Y.; Li, P.; Fei, Z.; Wang, R.; Zhang, H.; Zhu, D.Z.; Qian, S. Air-Water Interactions During Rapid Filling of a Closed Horizontal Pipe. *Phys. Fluids* **2025**, *37*, 043326. [CrossRef]
17. Paternina-Verona, D.A.; Coronado-Hernández, O.E.; Fuertes-Miquel, V.S.; Arrieta-Pastrana, A.; Ramos, H.M. Two-Dimensional Analysis of Air-Water Interaction in Actual Water Pipe-Filling Processes. *Water* **2025**, *17*, 146. [CrossRef]
18. Bonilla-Correa, D.M.; Coronado-Hernández, O.E.; Arrieta-Pastrana, A.; Pérez-Sánchez, M.; Ramos, H.M. Proposed Approach for Modelling the Thermodynamic Behaviour of Entrapped Air Pockets in Water Pipeline Start-Up. *Fluids* **2024**, *9*, 185. [CrossRef]
19. Wiens, T. Correction Factors for the Use of 1D Solution Methods for Dynamic Laminar Liquid Flow through Curved Tubes. *Fluids* **2024**, *9*, 138. [CrossRef]
20. Raj, M.K.; Chakraborty, J.; DasGupta, S.; Chakraborty, S. Flow-Induced Deformation in a Microchannel with a Non-Newtonian Fluid. *Biomicrofluidics* **2018**, *12*, 034116. [CrossRef]
21. Anand, V.; David, J., Jr.; Christov, I.C. Non-Newtonian Fluid-Structure Interactions: Static Response of a Microchannel Due to Internal Flow of a Power-Law Fluid. *J. Non-Newton. Fluid Mech.* **2019**, *264*, 62–72. [CrossRef]
22. Tanveer, A.; Salahuddin, T.; Khan, M.; Malik, M.Y.; Alqarni, M.S. Theoretical Analysis of Non-Newtonian Blood Flow in a Microchannel. *Comput. Methods Programs Biomed.* **2020**, *191*, 105280. [CrossRef] [PubMed]
23. Rubio Martinez, A.; Chávez Castellanos, A.E.; Noguez Méndez, N.A.; Aragón Rivera, F.; Pliego Díaz, M.; Sigalotti, L.D.G.; Vargas, C.A. Flow Modeling of a Non-Newtonian Viscous Fluid in Elastic-Wall Microchannels. *Fluids* **2024**, *9*, 77. [CrossRef]
24. De la Cruz-Ávila, M.; De León-Ruiz, J.E.; Carvajal-Mariscal, I.; Klapp, J. CFD Turbulence Models Assessment for the Cavitation Phenomenon in a Rectangular Profile Venturi Tube. *Fluids* **2024**, *9*, 71. [CrossRef]
25. Li, J.; Li, D.; Li, T. Progress in the Understanding and Modeling of Cavitation and Related Applications. *Fluid Dyn. Mater. Process.* **2025**, *21*, 445–470. [CrossRef]
26. Guzmán, E.; Hernández Pérez, V.; Aragón Rivera, F.; Klapp, J.; Sigalotti, L.D.G. Comparative Study of Air–Water and Air–Oil Frictional Pressure Drops in Horizontal Pipe Flow. *Fluids* **2024**, *9*, 67. [CrossRef]
27. Hamied, R.S.; Ali, A.N.M.; Sukkar, K.A. Enhancing Heavy Crude Oil Flow in Pipelines through Heating-Induced Viscosity Reduction in the Petroleum Industry. *Fluid Dyn. Mater. Process.* **2023**, *19*, 2027–2039. [CrossRef]

28. Gay, A.; Tangevelou, G.; Vidal, V. Pipe Formation by Fluid Focalization in Bilayered Sediments. *Fluids* **2024**, *9*, 66. [CrossRef]
29. Gonzalez-Trejo, J.; Miranda-Tello, R.; Gabbasov, R.; Real-Ramirez, C.A.; Cervantes-de- la-Torre, F. Experimental Analysis of the Influence of the Sliding-Gate Valve on Submerged Entry Nozzle Outlet Jets. *Fluids* **2024**, *9*, 30. [CrossRef]
30. Kinra, S.; Pal, R. Pipe Flow of Suspensions of Cellulose Nanocrystals. *Fluids* **2023**, *8*, 275. [CrossRef]
31. Shojaeiarani, J.; Bajwa, D.S.; Chanda, S. Cellulose Nanocrystal Based Composites: A Review. *Compos. Part C Open Access* **2021**, *5*, 100164. [CrossRef]
32. Xu, J.; Wang, P.; Yuan, B.; Zhang, H. Rheology of Cellulose Nanocrystal and Nanofibril Suspensions. *Carbohydr. Polym.* **2024**, *324*, 121527. [CrossRef] [PubMed]
33. Zhuang, Y.; Liu, Z.; Xu, W. Experimental Investigation on the Non-Newtonian to Newtonian Rheology Transition of Nanoparticles Enhanced Phase Change Material During Melting. *Colloids Surf. A Physicochem. Eng. Asp.* **2021**, *629*, 127432. [CrossRef]
34. Yan, Z.; Li, Z.; Cheng, S.; Wang, X.; Zhang, L.; Zheng, L.; Zhang, J. From Newtonian to Non-Newtonian Fluid: Insight into the Impact of Rheological Characteristics on Mineral Deposition in Urine Collection and Transportation. *Sci. Total Environ.* **2022**, *823*, 153532. [CrossRef] [PubMed]
35. Kaveh, K.; Malcherek, A. Enhancing Non-Newtonian Fluid Modeling. A Novel Extension of the Cross Flow Curve Model. *J. Hydro-Environ. Res.* **2024**, *56*, 17–27. [CrossRef]
36. Krishnappa, R.B.; Subramanya, S.G.; Deshpande, A.; Chakravarthi, B. Effect of Serpentine Flow Field Channel Dimensions and Electrode Intrusion on Flow Hydrodynamics in an All-Iron Redox Flow Battery. *Fluids* **2023**, *8*, 237. [CrossRef]
37. Abbaszadeh, H.; Norouzi, R.; Sume, V.; Kuriqi, A.; Daneshfaraz, R.; Abraham, J. Sill Role Effect on the Flow Characteristics (Experimental and Regression Model Analytical). *Fluids* **2023**, *8*, 235. [CrossRef]
38. Rodríguez-Rivera, R.; Carvajal-Mariscal, I.; Torres-Peña, H.; De la Cruz-Ávila, M.; De León-Ruiz, J.E. Numerical Evaluation of the Flow within a Rhomboid Tessellated Pipe Network with a 3×3 Allometric Branch Pattern for the Inlet and Outlet. *Fluids* **2023**, *8*, 221. [CrossRef]
39. Yu, H.; Li, T.; Zeng, X.; He, T.; Mao, N. A Critical Review on Geometric Improvements for Heat Transfer Augmentation of Microchannels. *Energies* **2022**, *15*, 9474. [CrossRef]
40. Agoua, W.; Favier, B.; Morales, J.; Bos, W.J.T. A critical Transition of Two-Dimensional Flow in Toroidal Geometry. *J. Fluid Mech.* **2024**, *988*, A33. [CrossRef]
41. Sigalotti, L.D.G.; Alvarado-Rodríguez, C.E.; Rendón, O. Fluid Flow in Helically Coiled Pipes. *Fluids* **2023**, *8*, 308. [CrossRef]
42. Hardik, B.K.; Prabhu, S.V. Heat Transfer Distribution in Helical Coil Flow Boiling System. *Int. J. Heat Mass Transf.* **2018**, *117*, 710–728. [CrossRef]
43. Çolak, A.B.; Akgul, D.; Mercan, H.; Dalkılıç, A.S.; Wongwises, S. Estimation of Heat Transfer Parameters of Shell and Helically Coiled Tube Heat Exchangers by Machine Learning. *Case Stud. Therm. Eng.* **2023**, *42*, 102713. [CrossRef]
44. Sahin, H.E.; Ozturk, H.K. A Novel Model for U-Tube Steam Generators for Pressurized Water Reactors. *Energies* **2025**, *1886*, 1506. [CrossRef]
45. Eckert, M. Pipe Flow: A Gateway to Turbulence. *Arch. Hist. Exact Sci.* **2021**, *75*, 249–282. [CrossRef]
46. Avila, M.; Barkley, D.; Hof, B. Transition to Turbulence in Pipe Flow. *Annu. Rev. Fluid Mech.* **2023**, *55*, 575–602. [CrossRef]
47. Mendes Quintino, A.; da Fonseca Junior, R.; Hernandez Rodriguez, O.M. Experimental Study of Liquid/Dense-Gas Pipe Flow. *Geoenergy Sci. Eng.* **2023**, *230*, 212179. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.