

Environmental Engineering

Jaime Klapp

Leonardo Di G. Sigalotti

Abraham Medina

Abel López

Gerardo Ruiz-Chavarría *Editors*

Recent Advances in Fluid Dynamics with Environmental Applications

Jaime Klapp · Leonardo Di G. Sigalotti
Abraham Medina · Abel López
Gerardo Ruiz-Chavarría
Editors

Recent Advances in Fluid Dynamics with Environmental Applications

Editors

Jaime Klapp
Instituto Nacional de Investigaciones
Nucleares
Ocoyoacac
Mexico

Abel López
SEPI ESIME Azcapotzalco
Instituto Politécnico Nacional
Mexico City
Mexico

Leonardo Di G. Sigalotti
Departamento de Ciencias Básicas
UAM Azcapotzalco
Mexico City
Mexico

Gerardo Ruiz-Chavarría
Facultad de Ciencias
Universidad Nacional Autónoma de México
Mexico City
Mexico

Abraham Medina
SEPI ESIME Azcapotzalco
Instituto Politécnico Nacional
Mexico City
Mexico

ISSN 1863-5520

ISSN 1863-5539 (electronic)

Environmental Science and Engineering

ISSN 1431-2492

Environmental Engineering

ISBN 978-3-319-27964-0

ISBN 978-3-319-27965-7 (eBook)

DOI 10.1007/978-3-319-27965-7

Library of Congress Control Number: 2016937508

© Springer International Publishing Switzerland 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Environmental Science and Engineering

Environmental Engineering

Series editors

Ulrich Förstner, Hamburg, Germany

Wim H. Rulkens, Wageningen, The Netherlands

Wim Salomons, Haren, The Netherlands

More information about this series at <http://www.springer.com/series/3172>

Preface

Fluid dynamics has had significant advances in recent years as a result of the current vertiginous development of computational power. This expansion has nowadays enabled the implementation of numerical high-resolution simulations as never before. For instance, fluid dynamic cosmological simulations are presently being run using up to 10^{12} particles, and turbulence simulations with up to 10^{11} mesh elements. Experimental advances are also present. Just to mention, some computer methods to reconstruct the topography of a liquid's free surface have been developed in recent times bringing into play high-definition digital images. With these tools, phenomena like wave turbulence or wave breaking are at the present being investigated. The development of different computer architectures offers now the possibility to work out fluid dynamics equations with alternative methods. Recent simulations with Smoothed Particle Hydrodynamics have been done using both multicore architectures and GPUs. The advantage of this approach is that the method is meshless, so it is suitable for modeling systems with moving and irregular boundaries.

Today the Mexican fluid dynamics community is involved in the research of novel topics using the advancements mentioned above. To name but a few topics, we draw attention to the studies in microfluidics and their relation to real problems like secondary oil recovery, while—in a different vein—studies in the field of magnetohydrodynamics are now being conducted on the mutual conversion of mechanical and electromagnetic energy.

The papers included in this book are selected contributions of two meetings held in Mexico during 2014. The first one was the Spring School “Enzo Levi” on May 12–13, 2014. The second event was the Annual Meeting of the Division of Fluid Dynamics of the Mexican Physical Society on November 18–20, 2014. In both meetings, an important fraction of the Mexican community working on fluid dynamics gathered, including students, researchers, and lecturers of several institutions from all over Mexico. We are pleased to acknowledge the contributions and attendance of all colleagues of the institutes and universities that were present in

one or both meetings. Among several institutions we would like to mention: UNAM, CINVESTAV, CICESE, IPN, UAM-A, ININ, and UNACH.

The 2014 “Enzo Levi” Spring School was hosted by the recently created Aeronautical University of Querétaro (UNAQ). This university was established with the aim to provide technical assistance to the aeronautical industries located in the Mexican state of Querétaro.

The number of participants attending the “Enzo Levi” conference was approximately 150. During this meeting, a total of 11 lectures were delivered by renowned scientists from Mexico and abroad. The topics covered by the lectures were diverse: waves produced by ships, aerogenerator designs, drag reduction in planes, turbulence at low temperatures, fluid mechanics in cosmology, and in coastal systems, among other topics. Of the lectures delivered during the meeting, some of them stand out. We would like to mention those given by Jens Sorensen, a distinguished professor of the Technical University of Denmark. His first lecture dealt with aerodynamic principles and then was centered on renewable energy, in particular on how to increase wind power. His second lecture was devoted to wind farms and the problems associated with the wakes produced by turbines. Marc Rabaud from the University Paris-Sud delivered two lectures on the wakes produced by fast boats and small obstacles, respectively. In the first case, the gravity is relevant while in the second case both gravity and capillarity are involved. With respect to aeronautics, Fausto Sánchez Cruz, from the University of Nuevo León, spoke about the development of winglets to reduce the drag on aircrafts and on the modifications of the wing end to dissipate or attenuate the wingtip vortices. In a succeeding lecture, Hugo Carmona Orvañanos spoke about the Coanda effect and its application to the reduction of the takeoff length. Enrico Fonda from New York University spoke on two aspects of turbulence, namely, experiments at low temperatures to attain high Reynolds numbers and on vorticity in superfluids. The lecture by Jorge Cervantes from Instituto Nacional de Investigaciones Nucleares (ININ) concerned fluid dynamics in the frame of cosmology in which relativistic and non-relativistic effects were reviewed. Finally, Erick Lopez Sanchez from UNAM spoke on numerical simulations of vortices in tidal induced flows in a channel flushing to the sea.

During the 2014 “Enzo Levi” Spring School, the UNAQ local organizer arranged an open house event where participants visited the aeronautical school premises including laboratories, test workshops, and toured around various airplanes donated to the institution for student training. This experience allowed visitors and local participants, researchers, and students of different institutes to establish fruitful academic links in the vibrant field of applications of fluid mechanics to aerodynamics.

The annual meeting of the Mexican Division of Fluid Dynamics was held during three days at the recently established Mesoamerican Centre for Theoretical Physics in Tuxtla Gutierrez, Chiapas, a state located south of the country. This conference was attended by approximately 250 participants. Conference activities included: oral sessions, a gallery of fluid motion and open lectures on fluid mechanics aimed at an audience of informed non-specialists in the specific topic of the talk.

Prominent scientists from Mexico and other countries delivered lectures on new trends in fluids dynamics. In relation to the contents of lectures, Tomas Bohr, from the Physics Department of the Technical University of Denmark, talked on the analogy between quantum mechanics and the behavior of a bouncing drop on the surface of a vibrating fluid. Yves Couder from the University of Paris Diderot also commented on the mentioned analogy. Tomas Bohr made a critical review of the double slit experiments. In a succeeding lecture, Joseph Niemela of the International Centre for Theoretical Physics (ICTP) gave a talk on experiments in turbulence for high Reynolds and Taylor numbers, which conveys to a better understanding of this phenomenon. For its part, Chantal Staquet from Joseph Fourier University in France talked about the statistical properties of internal waves in the ocean, their nonlinear interactions, and their importance in geophysical flows. Another lecture concerning waves was given by Francisco Ocampo Torres from CICESE, a research institute located at the Baja California Peninsula, in the north of Mexico. He spoke about the interactions between the ocean and the atmosphere, with emphasis on the surface waves and their role in the oceanic and atmospheric circulation. It is also important to mention the talk given by Nicolas Mujica from the University of Chile, related to a vibrating granular material and the occurrence of phase transitions. Finally, Vadim Kourdioumov of Centro de Investigaciones Energéticas, Madrid, gave a lecture on the propagation of flames in narrow channels. Some of these lectures have been included in this book.

The book contains review and research papers, covering a wide spectrum of topics in fluid dynamics. It is divided into four parts, each one having papers based on invited lectures and a selection of works presented in the annual 2014 meeting. The first part is devoted to vortices and circulation phenomena. It contains contributions like vortices produced by deformable objects (a flexible plate and a flexible cylinder). Three papers treating some applications to aerodynamics, for example, structures generated behind flapping foils or the study of the Coanda effect to increase the lift of airplanes. The part includes also a paper about the vortices created in tidal induced flows and two papers on the technique known as Background Oriented Schlieren. Finally, a paper of the crossflow in a non-isothermal open cavity is included. The second part is entitled "Environmental Applications". This part includes experimental and numerical investigations of the modeling of hydrodynamic processes in lagoons, offshore, and in atmospheric systems in Latin American countries such as Colombia and Mexico. In addition, the part includes a paper on fractals and rainfalls and other one on the evaluation of a cooling system. The third part is devoted to the fluid-structure interaction. In this part there are papers on magnetohydrodynamics, microfluidics, applications to the automotive industry, and an introduction to novel techniques like the fractional Navier-Stokes equation. There are in addition papers on the formation of Rayleigh jets, the trajectories of water and sand jets, the flow of viscoelastic fluids, and so on. In this part of the book there are contributions that reflect some of the new trends of the research developed by the Mexican community of fluid dynamics. The last part is entitled "General Fluid Dynamics and Applications". In this part a relevant paper of Tomas Bohr is included which deals with the analogy between

a bouncing drop and quantum mechanics. There are also two papers on astronomical applications of fluid dynamics, namely the dynamics of novae and the X-ray outflow in active galactic nuclei. This part contains a paper written by Nicola Mujica and Rodrigo Soto on the dynamics of non-cohesive granular media. Other papers deal with fundamental problems such as heat propagation or the use of new computing capabilities. Such is the case of a paper in which the method of Smoothed Particle Hydrodynamics is programmed to run in parallel using GPUs and multicore architectures.

The book is aimed at senior and graduate students, and scientists in the field of physics, engineering, and chemistry that have an interest in fluid dynamics from the experimental and theoretical points of view. The material includes recent advances in experimental and theoretical fluid dynamics and is adequate for both teaching and research. The invited lectures are introductory and avoid the use of complicated mathematics.

The editors are grateful to the institutions that made possible the International Enzo Levi Spring School 2014, and the XX National Congress of the Fluid Dynamics Division of the Mexican Physical Society, particularly the Consejo Nacional de Ciencia y Tecnología (CONACYT), the Sociedad Mexicana de Física (SMF), the Aeronautical University of Queretaro (UNAQ), the Mesoamerican Centre for Theoretical Physics in Tuxtla Gutierrez, Chiapas, the Universidad Nacional Autónoma de México (UNAM), the ESIME of the Instituto Politécnico Nacional (IPN), Cinvestav-Abacus, the Universidad Autónoma Metropolitana-Azcapotzalco (UAM-A), and the Instituto Nacional de Investigaciones Nucleares (ININ).

Mexico City
January 2016

Jaime Klapp
Leonardo Di G. Sigalotti
Abraham Medina
Abel López
Gerardo Ruiz-Chavarría

Contributors

A. Aguayo Ortiz Facultad de Ciencias, UNAM, Delegación Coyoacán, D.F., Mexico

A. Aguilar-Corona Faculty of Mechanical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Ciudad Universitaria, Morelia, Michoacán, Mexico

A. Aguirre-Guzman Laboratorio de Física de la Atmósfera Y El Espacio Ultraterrestre, Universidad de Carabobo, Valencia, Venezuela

Anders Andersen Department of Physics, Technical University of Denmark, Kgs. Lyngby, Denmark

J. Arellano Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico

A. Barreiro EPhysLab Environmental Physics Laboratory, Universidad de Vigo, Ourense, Spain

H. Barrios-Piña Tecnológico de Monterrey, Guadalajara, Jalisco, Mexico

Tomas Bohr Department of Physics, Technical University of Denmark, Kgs. Lyngby, Denmark

R. Cantero-Rodelo Faculty of Environmental Sciences, Universidad de la Costa, Barranquilla, Colombia

H. Cardoso Sakamoto Facultad de Ciencias, UNAM, Delegación Coyoacán, D.F., Mexico

J.E. Hiroki Cardoso Facultad de Ciencias, UNAM, Ciudad Universitaria, D.F., Mexico

H. Carmona Universidad Aeronáutica en Querétaro, Colón, Mexico

J.M. Casillas Navarrete Instituto Politécnico Nacional SEPI-ESIME. U.P. Azcapotzalco, Delegación Azcapotzalco, Mexico

- A. Cházaro** Universidad Aeronáutica en Querétaro, Colón, Mexico
- A.J.C. Crespo** EPhysLab Environmental Physics Laboratory, Universidad de Vigo, Ourense, Spain
- A. Cros** Physics Department CUCEI, Universidad de Guadalajara, Guadalajara, Jalisco, Mexico
- A. Cuevas-Otero** DEPMI-UNAM, Mexico City, Mexico; SEPI-ESIA, IPN, Mexico City, Mexico
- S. Cuevas** Instituto de Energías Renovables, Universidad Nacional Autónoma de México, Temixco, Morelos, Mexico
- Y.N. Domínguez-del Ángel** Departamento de Matemáticas Aplicadas y Sistemas, DMAS, Universidad Autónoma Metropolitana, Mexico, D.F., Mexico
- G. Domínguez** Instituto Mexicano Del Petróleo, Del. Gustavo A. Madero, Mexico, D.F., Mexico
- J.M. Domínguez** EPhysLab Environmental Physics Laboratory, Universidad de Vigo, Ourense, Spain
- L. Díaz Barriga Arceo** ESIQIE, Instituto Politécnico Nacional, México D.F., Mexico
- C. Echeverría Arjonilla** Facultad de Ciencias, UNAM, Coyoacán, Mexico D.F., Mexico
- N. Falcón** Laboratorio de Física de la Atmósfera Y El Espacio Ultraterrestre, Universidad de Carabobo, Valencia, Venezuela
- A. Figueroa** Centro de Investigación en Ciencias, Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos, Mexico
- J. Flores-Velázquez** Coordinación de Riego y Drenaje, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor, Mexico
- M.A. Fontelos** Campus de Cantoblanco, Instituto de Ciencias Matemáticas (CSIC—UAM—UC3M—UCM), Madrid, Spain
- B. Franco Llamas** Physics Department CUCEI, Universidad de Guadalajara, Guadalajara, Jalisco, Mexico
- C. Fuentes** Instituto Mexicano de Tecnología del Agua, Jiutepec, Morelos, Mexico; Instituto Mexicano de Tecnología del Agua. Paseo Cuauhnahuac 8532 Progreso, Jiutepec, MOR, Mexico
- S.R. Galván-González** Faculty of Mechanical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Ciudad Universitaria, Morelia, Michoacán, Mexico

L.B. Gamboa Universidad Autónoma de Yucatán Periférico Norte, Mérida, Yucatán, Mexico

A.R. Garcia Centro de Ciencias de la Atmósfera, UNAM, Circuito de la Investigación Científica s/n, Mexico, D.F., Mexico

O. García-Feal EPhysLab Environmental Physics Laboratory, Universidad de Vigo, Ourense, Spain

C.D. García-Molina Facultad de Ciencias, Universidad Nacional Autónoma de México Ciudad Universitaria, Mexico, D.F., Mexico

J. García Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

A. Gómez López Facultad de Ingeniería, Universidad Nacional Autónoma de México, México, DF, Mexico

M. Gómez-Gesteira EPhysLab Environmental Physics Laboratory, Universidad de Vigo, Ourense, Spain

J.G. González-Santos Posgrado en Ciencias Naturales e Ingeniería, Universidad Autónoma Metropolitana, Mexico, D.F., Mexico

G.J. Gutiérrez Paredes Instituto Politécnico Nacional SEPI-ESIME. U.P. Azcapotzalco, Delegación Azcapotzalco, Mexico

G.L. Gutiérrez-Urueta Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Zona Universitaria Poniente, Av. Manuel Nava 8, San Luis Potosí, Mexico

J. Hernández Universidad Aeronáutica en Querétaro, Colón, Mexico

L.A. Ibarra-Bracamontes Faculty of Mechanical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Ciudad Universitaria, Morelia, Michoacán, Mexico

A. Iturbe Universidad Aeronáutica en Querétaro, Colón, Mexico

C.A. Jiménez García Instituto Politécnico Nacional SEPI-ESIME. U.P. Azcapotzalco, Delegación Azcapotzalco, Mexico

J. Klapp Departamento de Física, Instituto Nacional de Investigaciones Nucleares, Ocoyoacac, Estado de México, Mexico; ABACUS-Centro de Matemáticas Aplicadas y Cómputo de Alto Rendimiento, CINVESTAV-IPN, Ocoyoacac, Estado de México, Mexico

Benny Lautrup Niels Bohr International Academy, The Niels Bohr Institute, Copenhagen, Denmark

A. López Villa Instituto Politécnico Nacional SEPI-ESIME. U.P. Azcapotzalco, México D.F., Mexico

M. López-L Universidad del Norte, Barranquilla, Colombia

A.A. López-Lambrano Facultad de Ingeniería, Universidad Autónoma de Baja California (UABC), Mexicali, BC, Mexico

A. López-Ramos Escuela de Ingenierías y Arquitectura Facultad de Ingeniería Civil, Universidad Pontificia Bolivariana-Seccional Montería, Montería, Córdoba, Colombia

E.J. López-Sánchez Facultad de Ciencias, Universidad Nacional Autónoma de México Ciudad Universitaria, Mexico, D.F., Mexico; ESIME-Azcapotzalco, Instituto Politécnico Nacional, Mexico, D.F., Mexico

B.E. Mar-Morales Centro de Ciencias de la Atmósfera, UNAM, Circuito de la Investigación Científica s/n, Mexico, D.F., Mexico

N. Martínez-Gutiérrez Faculty of Mechanical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Ciudad Universitaria, Morelia, Michoacán, Mexico

A. Medina ESIME Azcapotzalco, Instituto Politécnico Nacional, Santa Catarina, Mexico, D.F., Mexico

G. Mejía-Rodríguez Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Zona Universitaria Poniente, Av. Manuel Nava 8, San Luis Potosí, Mexico

C. Monreal-Jiménez Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Zona Universitaria Poniente, Av. Manuel Nava 8, San Luis Potosí, Mexico

G. Monsivais Galindo Instituto de Física, UNAM, Delegación Coyoacán, D.F., Mexico

J.G. Morales-Nava Facultad de Ingeniería Arquitectura Y Diseño, Universidad Autónoma de Baja California, Ensenada, BC, Mexico

N. Mujica Facultad de Ciencias Físicas y Matemáticas, Departamento de Física, Universidad de Chile, Santiago, Chile

M. Núñez-López Escuela Superior de Física y Matemáticas ESFM-IPN, Mexico, D.F., Mexico

W. Ojeda B Coordinación de Riego y Drenaje, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor, Mexico

A. Ortiz Facultad de Ingeniería, Universidad Autónoma de Baja California, Blvd. Unidad Universitaria, Mexicali, Mexico

G.E. Ovando-Chacon Depto. de Metal Mecánica Y Mecatrónica, Instituto Tecnológico de Veracruz, Veracruz, Mexico

S.L. Ovando-Chacon Depto. de Química Y Bioquímica, Instituto Tecnológico de Tuxtla Gutiérrez, Tuxtla Gutiérrez, Chiapas, Mexico

F. Oviedo-Tolentino Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Zona Universitaria Poniente, Av. Manuel Nava 8, San Luis Potosí, Mexico

J. Padilla Coba Faculty of Environmental Sciences, Universidad de la Costa, Barranquilla, Colombia

R. Peña Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico

I. Pérez Reyes Facultad de Ciencias Químicas, Universidad Autónoma de Chihuahua, Chihuahua, Chih, Mexico

J. Pérez-Barrera Instituto de Energías Renovables, Universidad Nacional Autónoma de México, Temixco, Morelos, Mexico

M. Pliego-Díaz Instituto Tecnológico de Querétaro, Santiago de Querétaro, Qro, Mexico; Instituto Tecnológico de Querétaro. Ciencias Básicas. Av. Tecnológico S/N, Centro, Santiago de Querétaro, Mexico

J.T. Ponce-Palafox Universidad Autónoma de Nayarit, Tepic, Nayarit, Mexico

D. Porta Zepeda Facultad de Ciencias, UNAM, Delegación Coyoacán, México D.F.

J.C. Prince-Avelino Depto. de Metal Mecánica Y Mecatrónica, Instituto Tecnológico de Veracruz, Veracruz, Mexico

H. Ramírez-León Instituto Mexicano del Petróleo, Mexico City, Mexico

J.M. Ramírez-Velasquez Physics Centre, Venezuelan Institute for Scientific Research (IVIC), Caracas, Venezuela; Departamento de Matemáticas, Cinvestav del I.P.N., Mexico, D.F., Mexico

G. Rangel Paredes Facultad de Ciencias, Departamento de Física, Universidad Nacional Autónoma de Mexico, Ciudad Universitaria, Delegación Coyoacán, Mexico D.F., Mexico

J.E. Rivera López Instituto Politécnico Nacional SEPI-ESIME. U.P. Azcapotzalco, Delegación Azcapotzalco, Mexico

J.N. Rivera Olvera Centro Conjunto de Investigación en Química Sustentable UAEM-UNAM, Carretera Toluca-Atlatomulco, Toluca, Estado de México, Mexico

P. Rodríguez-Aumente Departamento de Ingeniería Térmica y de Fluidos, Universidad Carlos III de Madrid, Leganés, Madrid, Spain

C. Rodríguez-Cuevas Faculty of Engineering, University of San Luis Potosí, San Luis Potosí, Mexico

A. Rodriguez-León Depto. de Metal Mecánica Y Mecatrónica, Instituto Tecnológico de Veracruz, Veracruz, Mexico

A. Rojano Coordinación de Riego y Drenaje, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor, Mexico

A. Rojas Instituto de Investigación en Ciencias Básicas Y Aplicadas, Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos, Mexico

R. Romero-Méndez Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Zona Universitaria Poniente, Av. Manuel Nava 8, San Luis Potosí, Mexico

J. Rosales Instituto de Investigación en Ciencias Básicas Y Aplicadas, Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos, Mexico

A. Ruiz-Angulo Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Mexico, Mexico

G. Ruiz-Chavarría Facultad de Ciencias, Universidad Nacional Autónoma de México Ciudad Universitaria, Mexico, D.F., Mexico

L.G. Ruiz-Suárez Centro de Ciencias de la Atmósfera, UNAM, Circuito de la Investigación Científica s/n, Mexico, D.F., Mexico

E. Sandoval Hernández Natural and Exact Sciences Department CU-Valles, Universidad de Guadalajara, Ameca, Jalisco, Mexico

D.A. Serrano ESIME Zacatenco, Instituto Politécnico Nacional, Zacatenco, Mexico, D.F., Mexico

A. Servin-Martínez Depto. de Metal Mecánica Y Mecatrónica, Instituto Tecnológico de Veracruz, Veracruz, Mexico

R. Soto Facultad de Ciencias Físicas y Matemáticas, Departamento de Física, Universidad de Chile, Santiago, Chile

C. Stern Forgach Facultad de Ciencias, UNAM, Delegación Coyoacán, México D.F., México

F. Sánchez-Silva ESIME Zacatenco, Instituto Politécnico Nacional, Zacatenco, Mexico, D.F., Mexico

P. Tamayo ESIME Azcapotzalco, Instituto Politécnico Nacional, Santa Catarina, Mexico, D.F., Mexico

F. Torres-Bejarano Faculty of Environmental Sciences, Universidad de la Costa, Barranquilla, Colombia

A. Traslosheros Universidad Aeronáutica en Querétaro, Colón, Mexico

R.O. Vargas Aguilar Escuela Superior de Ingeniería Mecánica y Eléctrica, Azcapotzalco, Instituto Politécnico Nacional, Mexico, D.F., Mexico

F. Vázquez Centro de Investigación en Ciencias, Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos, Mexico

J.J. Villegas-León Facultad de Ingeniería, Universidad Autónoma de Baja California (UABC), Mexicali, BC, Mexico

G. Viramontes-Gamboa Faculty of Physics and Mathematics, Universidad Michoacana de San Nicolás de Hidalgo, Ciudad Universitaria, Morelia, Michoacán, Mexico

A. Zarazúa Cruz Facultad de Ciencias, UNAM, Ciudad Universitaria, Mexico D.F., Mexico

J. Zavala-Hidalgo Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Mexico, Mexico

Contents

Part I Vortex and Circulation Phenomena

Numerical Study of the Cross Flow in a Non-isothermal Open Cavity	3
G.E. Ovando-Chacon, S.L. Ovando-Chacon, J.C. Prince-Avelino, A. Rodriguez-León and A. Servin-Martínez	
Oscillations of a Flexible Plate Immersed in a Vortex Street	15
E. Sandoval Hernández and A. Cros	
Experimental Study of a Vortex Generated at the Edge of a Channel with a Step	25
E.J. López-Sánchez, C.D. García-Molina, G. Ruiz-Chavarría and A. Medina	
Fluid Forces on a Flexible Circular Cylinder in Vortex-Induced Vibrations	37
C. Monreal-Jiménez, F. Oviedo-Tolentino, G.L. Gutiérrez-Urueta, R. Romero-Méndez and G. Mejía-Rodríguez	
Vortical Structures Generated Behind Flapping Foils with Different Aspect Ratios	51
B. Franco Llamas, E. Sandoval Hernández and A. Cros	
Circulation Control: A Comparative Study of Experimental and Numerical Investigation	57
H. Carmona, A. Cházaro, A. Traslosheros, A. Iturbe and J. Hernández	
CFD RANS Simulation of 2D Circulation Control Airfoil	81
H. Carmona, A. Cházaro, A. Traslosheros, A. Iturbe and J. Hernández	
Calibration of a Background Oriented Schlieren (BOS)	103
A. Aguayo Ortiz, H. Cardoso Sakamoto, C. Echeverría Arjonilla, D. Porta Zepeda, C. Stern Forgach and G. Monsivais Galindo	