

DROPS AND SPRAYS**FOR BEGINNERS AND ADVANCED LEARNERS****Pavia, Italy, 10th – 14th June 2024**

International Course Directors
A. Amirfazli, V. Bertola, M. Marengo

COURSE DESCRIPTION

LIDESP is a well-known International Advanced Course meant to familiarise on the topic of Interfaces, Drops and Liquid Sprays Physics, which is held every year in different locations around the world. The core of the lecture plan is provided by three well-known and highly recognized experts in the field: Prof. Amirfazli, York University, Toronto, Canada, Prof. Bertola, University of Liverpool, UK, Prof. Marengo, University of Pavia, Italy. They not only deliver part of the instructional module, but also every year, depending on the venue, different modules of the program are taught by other international experts, under the coordination of the Host Directors.

LIDESP is not a workshop or a conference, it is an educational venue on the physics of liquid drops and sprays, which is essential for many applications, from aeronautics (icing) to oil extraction (effervescent spray, drop collisions in pipes), from electronics (spray cooling) to agriculture (pesticide distribution), from microfluidics (droplet management) to painting processes (spray coating), from biology (blood droplets, sterilization) to thermal transfer (condensation in heat exchangers), from chemistry (drying tower) to medical applications.

The primary objective of this course is to deliver an in-depth and didactic understanding of the physics of drops and sprays, drawing upon the latest research advancements and cutting-edge methodologies for predicting dynamic outcomes, heat transfer phenomena, wettability effects, and their broad range of applications in the realms of technology and industry. Moreover, this course places significant

emphasis on the critical role of drops and sprays in chemical processes, recognizing their substantial industrial relevance.

It is important to note that this course is designed to cater to individuals at an advanced academic level, comparable to that of a proficient Postgraduate or Ph.D. student. The content and rigor of the course are geared towards providing a comprehensive and intellectually demanding educational experience.

In addition to the aforementioned topics, this course also boasts a special segment dedicated to the captivating field of microfluidics and microdroplet control, particularly in the context of pharmaceutical and biomedical applications. Participants will have the unique opportunity to explore the intricate dynamics and intricacies of microfluidics, uncovering its profound impact on the control and manipulation of microdroplets within the pharmaceutical and biomedical sectors.

The course is addressed to scientists, professionals, company engineers, R&D managers and graduate students in the fields of Engineering, Chemistry, Biology, Medicine, Applied and Fundamental Sciences.

The pre-requisites are a preparation in Mathematics and Physics equivalent to a Master Degree in Engineering, Physics or Chemistry and a good university preparation in fluid-dynamics and heat transfer.

The course is sponsored by the Italian company PNR Atomiser.

COURSE PROGRAM

	Mo - 10/6	Tue - 11/6	Wed - 12/6	Thu - 13/6	Fri - 14/6
	Introduction	Drop Physics	Spray Physics	Microdroplet management & Applications	Numerical simulations and industrial example
8.30-9.10	Registration	Welcome	Welcome	Welcome	Welcome
9.10-10.00		D3 - VB2	S1 - MM5	A1 - AA6	NS1 - MB1
10.00-10.50	I1 - AA1	D3 - VB3	S1 - MM6	A1 - AA7	NS1 - MB2
10.50-11.10	I1 - AA2	Coffee break	Coffee break	Coffee break	Coffee break
11.10-12.00	I2 - MM1	D4 - SS1	S2 - MM7	A2 - BA1	NS1 - MB3
12.00-12.50	I2 - MM2	D4 - SS2	S2 - MM8	A2 - BA2	NS2 - PNR
12.50-14.00	Lunch	Lunch	Lunch	Lunch	Lunch
14.00-14.50	I3 - VB1	D5 - VB4	S3 - LA1	A3 - BA3	PERSONAL CONSULTATION
14.50-15.40	D1 - AA3	D5 - VB5	S3 - LA2	A3 - BA4	PERSONAL CONSULTATION
15.40-16.00	Coffee break	Coffee break	Coffee break	Coffee break	CLOSURE
16.00-16.50	D2 - MM3	D6 - AA4	NN1 - VB6	AI1 - AA8	
16.50-17.40	D2 - MM4	D6 - AA5	NN2 - VB7	AI1 - AA9	
20:00-23:00		WINE&CHEESE	SOCIAL DINNER		

CONTENTS

I1 Introduction and basic concepts. Gallery of basic phenomena, micro- to macro- scale (molecular dynamics/continuum approaches), contact angle, Young equation, Laplace pressure, Free Gibbs Energy, Marangoni effects. **Amirfazli**

I2 Introduction to fluid mechanics of liquid interfaces. Basic equations, Navier-Stokes equations for capillary flows, liquid jet break-up. **Marengo**

I3 Surface tension & measurement techniques. Equilibrium and dynamic surface tension. De Nouy/Wilhelmy, sessile drop and pendant drop (ADSA), maximum bubble pressure. **Bertola**

D1 Dynamics of drops deposited on a surface. Sessile drops, spreading law, apparent and real contact angles. Drop shedding, contact angle hysteresis – **Amirfazli**

D2 Introduction to drop-wall interactions. Drop impact on dry and wetted surfaces. Morphology. Shallow and thick layers. Splashing correlations. **Marengo**

D3 Drop impact with a solid surface. Impact regimes, impact models, drop rebound. **Bertola**

D4 Heat and mass transfer in drops. Mono-component droplet heating and evaporation. Abramzon and Sirignano model. **Sazhin**

D5 Drop impact on heated surfaces. Introduction to drop impact onto heated surfaces. Impact regime maps. Transitions. Dynamic Leidenfrost temperature. Control of secondary atomization and splashing. **Bertola**

D6 Superhydrophobicity. Application of superhydrophobic surfaces. Cassie-Wenzel and competing theories. Types of SHS and manufacturing techniques. Impact on SHS surfaces. Impalement transition. **Amirfazli**

S1 Fundamentals of Atomization. Breakup and Atomization Models. **Marengo**

S2 Spray Applications. Atomisers. **Marengo**

S3 Measurement of Drops and Sprays. Basis of matter-light interaction, properties of coherent light. Diffraction based instruments, basis and applications to droplet and spray size measurements. Interferometry based Instruments, the fringe model; basis and applications to single particle velocity and droplet size measurements. Velocity and size averages in sprays: possibilities, problems and procedures. **Araneo**

NN1 Introduction to non-Newtonian fluids. Constitutive models and practical examples (polymer solutions and melts, gels, etc.). Power-law fluids, viscoplastic fluids, viscoelastic fluids. Non-Newtonian fluid design. Elements of rheological measurements. – **Bertola**

NN2 Non-Newtonian Sprays. **Bertola**

A1 Applications of what you learned in the course: (a) Inkjet technology: Design of printheads, waveforms, ink formulations (b) Metal deposition, (c) 3D printing, (d) Microlens manufacturing. **Amirfazli**






A2 Introduction to microfluidics. Concept, physical motivation, tools, applications. **Bazargan**

A3 *Droplet management in microfluidics.* **Bazargan**
 NS1 *Introduction to numerical simulations of sprays.*
 Eulerian and Lagrangian approaches for two-phase flows.
 Mass, momentum and energy exchange. Nozzle flow and
 spray models. **Battistoni**

NS2 *Numerical simulations of atomizers - Applications and
 examples -* **Bruni - PNR company**

AI1 *Use of Artificial Intelligence in the field of fluid
 mechanics.* **Amirfazli**

LECTURERS

	<p>Prof. Alidad Amirfazli Before joining the York University as the founding Chair of the Department of Mechanical Engineering, Alidad Amirfazli held the Canada Research Chair in Surface Engineering at the University of Alberta, Canada. Amirfazli has produced exciting results in wetting behaviour of surfaces, drop adhesion and shedding, understanding and application of superhydrophobic coatings. He has more than 200 scientific contributions, many in prestigious peer reviewed journals; he is the Editor for the Advances in Colloid and Interface Science. Dr. Amirfazli has been the recipient of the Martha Cook Piper Research prize, Killam Annual Professorship, and Petro-Canada Young Innovator Award. He also served in the board of Professional Engineers of Alberta, and been a consultant with various companies in USA, Europe, and Canada.</p>
	<p>Prof. Volfango Bertola Joined the University of Liverpool in 2011, after holding a Lectureship at the University of Edinburgh (2004-2011) and a Marie Curie Fellowship at the Ecole Normale Supérieure in Paris (2001-2004). In 2009-10 he was Visiting Professor and Lagrange Fellow at Polytechnic of Turin (Italy). He has more than 100 scientific publications in the areas of soft matter, multiphase flows, and thermodynamics, including several contributions on non-Newtonian drops and on the dynamic wetting of complex fluids. He has been the recipient of a Royal Academy of Engineering Global Research Award (2009) and the UIT Young Scientist Prize (2001).</p>
	<p>Prof. Marco Marengo Graduated in Physics at the University of Turin cum laude and completed his Ph.D. studies at the Polytechnic of Milan, Italy, and University of Erlangen, Germany, with a thesis about "Drop Impingement on Liquid Film". He has been the Director of the Advanced Engineering Centre at the University of Brighton and he is now Full Professor of Thermal Physics at the University of Pavia. He is the Vice-President of the European Association of Liquid Atomization and Spray Systems, and he serves as Associate Editor of Int. J. Multiphase Flows and other journals. He published more than 250 scientific papers, many in peer-reviewed journals about liquid sprays, drop impact, heat pipes, building physics. He has received more than 30 invitations for plenary lectures and department seminars.</p>
	<p>Prof. Sergei Sazhin Professor Sergei Sazhin received his PhD (candidate of physical and mathematical sciences) in St Petersburg State University (Russia) in 1977. Currently, he is working as Professor of Thermal Physics at the University of Brighton (UK). He has authored more than 600 publications, including 5 monographs and more than 270 papers in international refereed journals. His current ISI Web of Science (Scopus, Google scholar) citation index is 40 (45, 54). He is a Fellow of the Institute of Physics (UK) since 1994. Leadership in Research Excellence Awardee at the University of Brighton in 2017. Member of the Scientific Council of the International Centre for Heat and Mass Transfer (ICHMT) since 2018.</p>
	<p>Prof. Lucio Araneo Graduated in Mechanical Engineering at the Polytechnic of Milan 1993, and later in 1996 at the IFP-School. He completed his PhD at the Polytechnic of Milan in 1999 with a Thesis on "Optical Techniques applied to Automotive Sprays". At the University of Darmstadt; Germany (1999-2001) he was in charge to develop Laser Doppler and Phase Doppler instrumentation and application. Since 2000 he joined the Italian National Research Council for applications in the spray laboratory, with cooperation with major industrial companies. In 2005-2007 he was awarded with a Marie Curie Fellowship, to join the Technical University of Valencia at the automotive spray laboratory. Since 2008 he is a tenure Assistant Professor at the Polytechnic of Milan, where his activity extended to a collaborating with ESA on the topic of two phase heat exchange and phenomena in microgravity, leading experiments on board of 15 Parabolic Flight Campaigns.</p>

	<p>Prof. Vahid Bazargan Dr. Bazargan is an Assistant Professor at the College of Engineering, University of Tehran, specializing in microfluidics and encapsulation. With a focus on microfabrication of fluidic devices, his expertise extends to active and passive flow control within integrated lab-on-a-chip devices. He pioneers microencapsulation technology for personalized medicine. Noteworthy accolades include the Banting Fellowship, R Howard Webster Foundation Fellowship, Kashmir Singh Manhas Scholarship in Applied Science, Grand Challenges Explorations Grant for Innovative Global Health Research, and the British Columbia Innovation Council Award. He earned his MSc and PhD in Mechanical Engineering from the University of British Columbia in 2008 and 2014, respectively. Following this, he contributed as a postdoctoral fellow at the Melville Laboratory for Polymer Synthesis, University of Cambridge, focusing on supramolecular encapsulation for drug delivery applications.</p>
	<p>Prof. Michele Battistoni Associate Professor in the Department of Engineering at the University of Perugia. He was appointed Visiting Professor at KAUST (Saudi Arabia) in 2019, and Visiting Researcher and Mechanical Engineer at Argonne National Laboratory in Chicago in 2012-2014, then 2016 and 2018. He has 100+ papers in the areas of thermo-fluid dynamics, multiphase flow, CFD modeling, mainly applied to engines, fuel sprays, cavitation and combustion. He serves as SAE organizer for the Fuel Injection and Sprays sessions, and he is actively involved in the Engine Combustion Network activities where he is leader of the primary atomization and ammonia as fuel topics. He has been invited to give presentations at several Universities and Research Institutes in EU, US and China. In his early career he also worked at Fiat Powertrain in Turin as a design engineer. He is also founder of two spin-off companies. Battistoni received his MS cum laude and his PhD in Mechanical Engineering from the University of Perugia.</p>
	<p>Dr. Mattia Bruni He is an engineer with a degree in industrial engineering, specializing in energy systems. His field of work involves conducting studies on the application of spraying systems to meet customer needs, with a particular focus on cooling, pollution control, and washing in various industrial sectors (such as food, chemical, steel, and naval industries). His commitment also extends to studying and analyzing new products, with a continuous inclination towards innovation. Dr. Bruni works in R&D of the company PNR as responsible for the computed design of nozzles.</p>

REGISTRATION FEES (Euro)

	FULL early bird / std. (EURO) VAT INCLUDED
Academic (tenure, post-doc, researcher)	500/600
Ph.D students	300/400
Industry	1000/1200

LIDESP is in person only course. The fees are all inclusive, except for the accommodation.

The lectures will be recorded and the files will be given to the participants.

Registration is open from the 1st of February 2024 to the 30th April 2024. **Early bird: 30th March 2024.**

Maximum number of participants: **30.**

TO REGISTER: ONLINE REGISTRATION SITE WILL BE READY SOON

For more information, please ask. Prof. Marco Marengo, marco.marengo@unipv.it

VENUE

The workshop will take place at the University of Pavia, Italy