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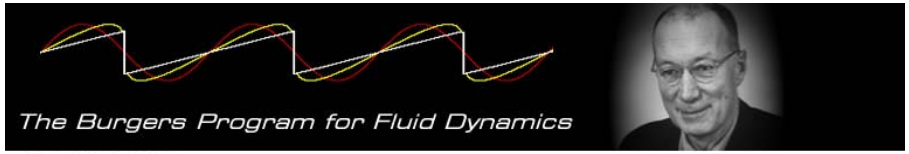

UNIVERSITY OF MARYLAND

Fourth Annual Symposium of the Burgers Program for Fluid Dynamics

University of Maryland, College Park
Jeong H. Kim Engineering Building
Rooms 1107 and 1111
November 15, 2007
1:00 - 5:30 p.m.

Institute for Physical Science and Technology

Computer, Mathematical and Physical Sciences

A. James Clark School of Engineering

PROGRAM

1.00 - 1.15: Welcoming Remarks
James M. Wallace
Burgers Program for Fluid Dynamics and Department of Mechanical Engineering
University of Maryland

1.15 - 2.15: **Burgers Lecture:**
Zipping Wetting—and Other Surface Phenomena
Detlef Lohse
J. M. Burgerscentrum
University of Twente
The Netherlands

2.15 - 2.50: Quasi-Balanced Hurricane Dynamics
Da-Lin Zhang
Department of Atmospheric and Oceanic Sciences
University of Maryland

2.50 - 3.50: Student Poster Session with Refreshments

Burgers Board

James M. Wallace
Chair
University of Maryland

Anil Deane
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Daniel P. Lathrop
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Gijs Ooms
J. M. Burgerscentrum
Delft, The Netherlands

Rajarshi Roy
University of Maryland

Jan V. Sengers
University of Maryland

Katepalli R. Sreenivasan
International Centre for Theoretical Physics
Trieste, Italy
and University of Maryland

Twenty Years of Experimental and DNS Access to the Velocity Gradient Tensor: What Have We Learned About Turbulence?

James M. Wallace
Burgers Program for Fluid Dynamics and Department of Mechanical Engineering University of Maryland

Twenty years ago there was no experimental or computational access to the velocity gradient tensor for turbulent flows. Without such access, knowledge of fundamental and defining properties of turbulence, such as vorticity, dissipation and strain rates and helicity, were inaccessible. In 1987 the results of the development and first successful use of a multi-sensor hot-wire probe for measurements of all the components of the velocity gradient tensor in a turbulent boundary layer were published by J.-L. Balint, P. Vukoslavcevic & J.M. Wallace (Advances in Turbulence, Proc. 1st Euro. Turb. Conf.). That same year the first DNS of a turbulent channel flow was successfully carried out and reported by J. Kim, P. Moin & R. Moser (J. Fluid Mech. 177). Since then several experimentalists have used multi-sensor hot- wire probes of increasing complexity in turbulent boundary layers, wakes, jets, mixing layers and grid flows. Numerous computationalists have employed DNS in a wide variety of turbulent flows at ever increasing Reynolds numbers. PIV has been developed and advanced during these two decades and has provided another means of access to these fundamental properties of turbulence. This presentation will review these remarkable developments and point out some of the most important things we have learned about turbulence as a result.

3.50 - 4.25: Quantitative Visualization of Oscillatory and Pulsatile Flows Using Temperature
Cila Herman
Department of Mechanical Engineering Johns Hopkins University

4.25 - 5.00: Twenty Years of Experimental and DNS Access to the Velocity Gradient Tensor: What Have We Learned About Turbulence?
James M. Wallace
Burgers Program for Fluid Dynamics and Department of Mechanical Engineering University of Maryland

5.00 - 5.30: Announcement of Best-Poster Awards and Reception

Jan Burgers grew up, together with his brother, the crystallographer W.G. Burgers, in a remarkable parental home in Arnhem, The Netherlands. His father, a post-office clerk, had been able to become a self-educated amateur scientist who gave public lectures on physics and assembled a large collection of scientific instruments, among others a good microscope that he had received from his wife as a wedding present.

In 1914, Burgers entered the University of Leiden, where he came to know Hendrik Lorentz, Heike Kamerlingh Onnes, Albert Einstein, and Niels Bohr and was part of a group of students of P.T. Ehrenfest that included D. Coster, H.A. Kramers, and D.J. Struik. Burgers, the first of Ehrenfest's students in Leiden to complete a Ph.D. thesis (1918), wrote his dissertation on the Rutherford-Bohr model of the atom, completing Ehrenfest's work on the connection between the Bohr-Sommerfeld quantification rules and the adiabatic invariants of classical mechanics.

At the age of 23, before receiving his Ph.D. degree, Burgers was appointed as Professor in the Department of Mechanical Engineering, Shipbuilding and Electrical Engineering at the Technical University in Delft, where he founded the Laboratory

Quantitative Visualization of Oscillatory and Pulsatile Flows Using Temperature

Cila Herman
Department of Mechanical Engineering
Johns Hopkins University

Applications of holographic interferometry to the simultaneous visualization of oscillatory and pulsatile flow and temperature fields in complex geometries are discussed. Self-sustained oscillatory flows are considered in grooved and communicating channels as well as oscillatory heat transfer in the stack region of a thermoacoustic refrigerator model. Visualization images generated using real-time holographic interferometry combined with high-speed cinematography showing the unsteady temperature fields suggest that the temperature distributions can accurately mirror the flow structures in a class of complex unsteady flows. This allows, in addition to the measurement unsteady of temperature profiles and heat transfer, also the measurement of oscillatory amplitudes, frequencies, wavelengths, as well as the speed of the of propagation of traveling waves.

In the second part of the talk I focus on the opposite effect, namely bubble nucleation at surfaces which is a poorly understood phenomenon. We did visualization experiments at structured hydrophobic surfaces and compared the results with model calculations, in particular focusing on bubble-bubble interactions. It is demonstrated that in the many bubble case the bubble collapse is delayed due to shielding effects. We succeed in making cavitation totally reproducible in space and time. Finally, I will address the question on whether surface nanobubbles play a role in the bubble nucleation.

Quasi-Balanced Hurricane Dynamics

Da-Lin Zhang
Department of Atmospheric and Oceanic Sciences
University of Maryland

Despite the presence of intense latent heat release and vertical motion in the eyewall, hurricane vortices can be approximated, after azimuthal average, by gradient-wind and hydrostatic balance equations within an error of less than 10%, except in the boundary layer and the upper outflow layer.

In this presentation, I will show how to isolate and quantify the contributions of dry dynamical, latent heat release and frictional processes to the hurricane's quasi-balanced transverse circulations in three dimensions. The impact of the vertical shear-induced transverse circulations on the hurricane inner-core dynamics is presented. Hurricane eye dynamics will also be

of Aero- and Hydrodynamics. It was probably without precedent that a professor was appointed in a field of study that was practically incognita for the appointee. However, the nominating committee could base its recommendation on the warm appreciation of Ehrenfest, his Ph.D. advisor, the admiration of Lorentz for Burgers' essay on Rutherford's hypothesis concerning the structure of the atom (for which Burgers had won a prize from the Taylor Society) and the testimony of Kamerlingh Onnes that Burgers was a person who could be entrusted with any task he would feel called upon to make his own. In his characteristically modest account of his early years in Delft for the *Annual Review of Fluid Mechanics* (**Vol. 7**, 1975), Burgers wrote that one of his reasons for accepting the position in Delft was his fear of "having insufficient fantasy for making fruitful advances in Bohr's theory".

While at Delft, Burgers quickly became one of the world's leading authorities on fluid dynamics. His first work was devoted to Oseen's theory of flow at low Reynolds numbers and its connection with Ludwig Prandtl's work on air-foils. In 1921 he met Theodore von Kármán, with whom he had a long and close professional and personal association that stimulated his work on turbulence. In this field he was a pioneer in using the hot-wire anemometer to probe velocity fluctuations in turbulent flows. His work on the theory of turbulence was devoted in large part to developing a statistical theory of turbulence and to treating theoretical models of turbulent flow. In this connection he studied what has now become known as the Burgers' Equation, which is a one-dimensional, nonlinear partial differential equation similar in structure to the Navier-Stokes Equation for the hydrodynamic velocity field.

In addition to his work on turbulence during his years in Delft, Burgers collaborated with his brother in work on dislocation in crystal lattices; in 1939 he introduced the Burgers' vector, which is a measure of the strength of a dislocation in a lattice. He also studied the fluid dynamics of dilute polymer solutions and wrote some of the fundamental papers on the intrinsic viscosity of suspensions. This work, like those on turbulence and on dislocations, provided the foundation for much subsequent work on this topic.

In the 1940's Burgers was instrumental in establishing the Inter-

national Union of Theoretical and Applied Physics, which was admitted to the International Council of Scientific Unions in 1947. He served as general secretary of the Union from 1946 to 1952, was a member of its general assembly and served as secretary of its Joint Committee on Viscosity and Plasticity.

In 1955, at age 60, Burgers left Delft to join the faculty of the University of Maryland. There he developed his interest in the relation of the Boltzmann Equation to the equations of fluid dynamics. His book *Flow Equations for Composite Gases* (1969) represents some of his work during that period. His studies in plasma physics, shock waves, and related phenomena were recognized at his retirement by a symposium and volume, *The Dynamics of Fluids and Plasmas* (1965), edited by S. I. Pai. At age 79 he published a book on *The Nonlinear Diffusion Equation*.

In addition to his purely scientific work, Burgers found the time to work on subjects of wider social and/or philosophical interest. He always was trying to find ways to use science to improve society, and he had a deep interest in the most fundamental problems – the structure of the universe and the origin and proper description of life. His preoccupation with such philosophical issues led him to the writings of A. N. Whitehead, whose ideas he tried to develop in his own book, *Experience and Conceptual Activity* (1965).

Jan Burgers was an exceptionally kind and thoughtful man. He took seriously anyone who presented an idea to him, and he devoted a large fraction of his time to trying to understand new ideas and new developments. His devotion to both science and society is an inspiration to all of us at the University of Maryland.

Reference:

Selected Papers of J.M. Burgers, edited by F.T.M. Nieuwstadt and J.A. Steketee (Kluwer, Dordrecht/Boston/London, 1995).
Experience and Conceptual Activity; a Philosophical Essay based upon the writing of A.N. Whitehead. MIT Press, 1965.
Flow Equations for Composite Gases. Academic Press, 1969.
The Nonlinear Diffusion Equation: Asymptotoic Solutions and Statistical Problems.

Burgers Lecture: Zipping Wetting—and Other Surface Phenomena

Detlef Lohse
J. M. Burgerscentrum,
University of Twente, The Netherlands

Micro-structured materials can show a superhydrophobic behavior with effective contact angles of 160° and beyond ("Lotus effect"), while the contact angle of the smooth surface is much smaller. Such materials are used e.g. for medical applications, coatings, self-cleaning, textiles, and microfluidics. However, under certain conditions, the superhydrophobicity ("Cassie-Baxter state") spontaneously breaks down: fluid enters in between the micro-structures and spreads, resulting into a smaller contact angle ("Wenzel state"). Ultra-high-speed imaging allows us to analyze the dynamics of this breakdown. Depending on the scales of the micro-structure, the wetting fronts propagate smoothly and circularly or – more interestingly – in a stepwise manner, leading to a growing square-shaped wetted area: entering a new row perpendicular to the direction of front propagation takes milliseconds, whereas once this has happened, the row itself fills in microseconds ("zipping"). The time scale separation of this zipping-wetting originates from a divergence in the characteristic wetting time (critical slowing down) which can analytically be derived by balancing capillary and viscous effects. Numerical simulations confirm this view and are in quantitative agreement with the experiments. Our results provide design criteria for superhydrophobic surfaces.

(Cont.➔)