Flow Phenomena in Nature
Volume 2
Inspiration, Learning and Application

Design and Nature

Objectives

Our understanding of the modern world is largely based on an ever increasing volume of scientific knowledge. Engineering designers have at their disposal a vast array of relationships for materials, mechanisms and control, and these laws have been painstakingly assembled by the observation of nature. As space activity accustoms us to cosmic scales, and as medicine and biology to the molecular scale of genetics, we have also become more aware of the rich diversity of the structural world around us.

The parallels between human design and nature has inspired many geniuses through history, in engineering, mathematics and other subjects. Much more recently there has been significant research related to design and invention. Even so, current developments in design engineering, and the huge increase in biological knowledge, together with the virtual revolution in computer power and numerical modelling, have all made possible more comprehensive studies of nature. It is these developments which have led to the establishment of this international book series.

Its rationale rests upon the universality of scientific laws in both nature and human design, and on their common material basis. Our organic and inorganic worlds have common energy requirements, which are of great theoretical significance in interpreting our environment.

Individual books in the series cover topics in depth such as mathematics in nature, evolution, natural selection, vision and acoustic systems, robotics, shape in nature, biomimetics, creativity and others. While being rigorous in their approach, the books are structured to appeal to specialist and non-specialist alike.

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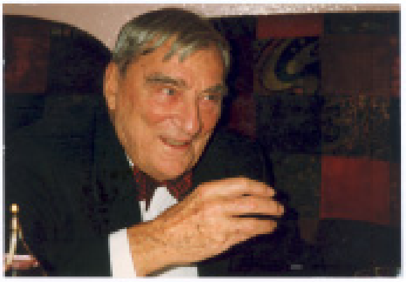
Dedication



Professor Wolfgang Liebe
(1911-2005)

This book is dedicated to the memory of Prof Wolfgang Liebe, father of the Editor, Roland Liebe, and an outstanding scientist, who recently passed away.

It is difficult to summarise in just a few paragraphs the long and very successful career of Profesor Wolfgang Liebe, who worked on fluid dynamics for 65 years. He ended up as Professor Emeritus at the Technical University of Berlin, having started as a Research Engineer at DVL Berlin before the War. He acted as a Consultant to the Yugoslavian Aircraft industry and was Manager of Siemens in Berlin.

Before graduating from the Technical University of Danzig in 1936, he worked as a trainee at the Junkers Aircraft Company helping to produce the legendary aeroplane. He obtained his Doctorate from the University of Hannover in 1953, before becoming Professor at the Technical University of Berlin in 1957.

Among his many honours, he designed the best glider plane (The ORAO) for the Yugoslavian aircraft industry, and developed the technique known as "boundary layer fence" to improve flight safety preventing stall.

Professor Liebe was the author of numerous scientific papers and had several patents to his credit.

His research concentrated on aircraft engineering, focusing on Vortex dynamic (he is credited with the development of the finite vortex method) but he also worked on thrust and lift generation in nature, particularly applied to bird flight and fish propulsion.

Professor Liebe had many interests outside engineering, such as music, enjoying nature and sailing.

In 2004, on the occasion of the 2nd International Conference on Design and Nature, Professor Wolfgang Liebe was awarded the Eminent Scientist Medal by the Wessex Institute of Technology, an award given annually to outstanding scientists who are also people of integrity. On this occasion, Professor Liebe referred to his early interest in finding out how a plane could fly, which led to him studying aeronautical engineering. He said that it took him 65 years of patience and research to be able to answer that question to his entire satisfaction.

Preface

The text of “Flow Phenomena in Nature“ is easy to understand, and mathematical details as well as specialized terminology are avoided. The authors contribute in a unique manner to a transdisciplinary exchange of their latest findings. This approach eliminates the barriers of thought between different research communities.

This book presents the latest results from fluid dynamics, which are applied to swimming and flying in nature as well as to human engineering, medicine and other fields. The topics range from up-to-date research to innovative product design. Most of the findings are published here for the first time.

The respected authors come from very different fields: biology, mathematics, medicine, engineering, zoology, physics etc. They represent well-known international research institutions and companies in England, Germany, the USA, Sweden, Holland and Japan.

This book is written for experienced researchers, lecturers and postgraduates from any background. Further target readers are non-specialists and students who are keen to understand nature and evolution. Developers of new products in engineering, medicine or other fields of application will also be interested in the practical side as well as for research and development proposals for the future.

Roland J. Liebe
Monheim a. Rh., Germany, 2006

Acknowledgements

The initiative for this work came in 2003 from Professor Carlos Brebbia, Director of the Wessex Institute of Technology (WIT) in England. I would like to thank him for initiating and supporting this book project as part of his successful “Design and Nature” series.

I am grateful for the contributions, the inspiring discussions and stimulations from my father Wolfgang Liebe in Berlin. He worked on two papers for this book until August 2005. Unfortunately he was unable to finish his contribution.

I would also like to thank Axel Liebe-Picard for his striking creative designs for the book covers, which represent the contents extremely well.

I am indebted to all authors for their excellent contributions. In particular I wish to thank the following authors for their stimulating discussions and engagement, which mutually generated new ideas during the review process: Frank Fish, Peter Freymuth and Max Platzer from the USA; Volker Simon and Bernhard Weigand from Germany; Anders Hedenström from Sweden and Keiji Kawachi from Japan.

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Last but not least, my most sincere thanks go to my wife Luda A. Liebe for her open-minded, steady, encouraging support, for her valuable improvements and for her patient appreciation.

Roland J. Liebe
Monheim a. Rh., Germany, 2006

Nomenclature

A	m^2	area, cross section
a, b, c	m	length (radius, wing span, chord)
C	–	dimensionless force coefficient $C = F/(Av^2\rho/2)$ (drag, lift, thrust)
C_D, C_L, C_T	–	drag, lift and thrust coefficients
E	W s	energy
E	N/m^2	Young's modulus, modulus of elasticity
F	N	force
F_L, F_D, F_T, F_W	N	lift, drag, thrust and weight force
f	Hz	frequency
Fr	–	Froude number
g	m/s^2	acceleration due to gravity
I	kg m/s	(translatoric) momentum
K	–	reduced frequency $= v_\infty/(2\,\text{amplitude}\,\omega)$
L, l	m	length
M	N m	moment
M, m	kg, kg/s	mass, mass flow
Ma	–	Mach number
Nu	–	Nusselt number
p, p_s	bar	pressure, static pressure
P	W	power
R	m	radius
Re	–	Reynolds number = (velocity L/v)
s	m	distance, translation
Str	–	Strouhal number $= 1/K = 2$ amplitude ω/v_∞ (standard definition)
t	s	time
T	s	period of oscillation $= 1/f = 2\pi/\omega$
u, v, w	m/s	velocity components, speed
W	N	weight force
x, y, z	m	Cartesian coordinates

r, φ, z	m	cylindrical coordinates
α, β, γ	rad	angle
δ	mm	thickness, boundary layer thickness
ε	–	strain, angle
ζ	–	coefficient of friction, profile quality $= C_L/C_D$
η	–	efficiency
ν	m^2/s	kinematic viscosity
ρ	kg/m^3	mass density
σ	N/m^2	normal stress
τ	N/m^2	shear stress
φ, Φ	rad	rotation, angle
χ, ψ	rad	phase difference, angle
ω	1/s	circular frequency of oscillation (rotation)
θ	$kg\ m^2$	polar moment of inertia

Contents

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