

Experimental
Combustion

An Introduction

D.P. MISHRA

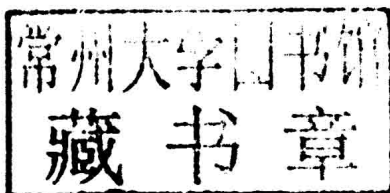


CRC Press
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Boca Raton London New York

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CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

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CRC Press is an imprint of Taylor & Francis Group, an Informa business

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Printed on acid-free paper
Version Date: 20140213

International Standard Book Number-13: 978-1-4665-1735-6 (Hardback)

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Library of Congress Cataloging-in-Publication Data

Mishra, D. P. (Aerospace engineer)
Experimental combustion : an introduction / author, D.P. Mishra.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4665-1735-6 (hardback)
1. Combustion--Experiments. 2. Combustion engineering--Research. I. Title.

QD516.M685 2014
541'.3610287--dc23

2014001308

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Experimental Combustion

An Introduction

*Dedicated to my research students who help me
to dabble in experimental combustion*

Preface

I believe that discovery of fire by human beings in the prehistoric era and subsequent mastery over the combustion process has propelled the development of science and technology, the fruits of which we enjoy today. Of course, the potential of combustion devices was realized during the industrial revolution. We use combustion devices, directly or indirectly, in many activities. Whether cooking by gas burners, transport by automobiles, locomotive, airplane, or spacecraft, winning a war, sending a satellite into its orbit, processing materials, and so forth, combustion plays a major role in each of these activities. Hence, combustion engineering has been an important area influencing every facet of human life and will continue to be an important deterministic factor in shaping the socioeconomic structure of our society in the future.

Nevertheless, blatant use of fossil fuels in combustion devices has depleted their reservoirs. Environmental pollution created by combustion systems is one of the major social concerns and stringent rules have been promulgated to check its impact. In order to meet the increasingly stringent emission regulations in the future, there is an urgent need to design and develop new eco-friendly, energy-efficient combustion devices and to retrofit existing combustion devices with minimum modifications, both of which demand immediate attention of researchers and engineers.

With this in mind, it is important to impart the basic skills in experimental combustion to students so that they can effectively carry out the onerous task of design and development of energy-efficient and low-emission combustion systems for the new generation of devices and processes in order to meet the current energy demand while mitigating the global ecological imbalance.

This book is intended as an introductory text on experimental aspects of combustion at the graduate and undergraduate levels. Various measurement systems are described systematically in simple and lucid language. Readers may refer to advanced books/monographs/manuals for more comprehensive and exhaustive

treatment on each topic, many of which are listed at the end of each chapter. It has been assumed that the readers have prior knowledge on combustion apart from thermodynamics, fluid mechanics, and mathematics. However, Chapter 1 reviews the fundamental aspects of combustion and Chapter 2 introduces the general characteristics of instruments essential for grasping the foundations of measurement systems employed in laboratory course work in the field of combustion. Chapter 3 introduces data acquisition systems and covers data sampling, signal conditioning, and data transmission for storage and further analysis. Subsequently, readers are exposed to data analysis in Chapter 4, which covers requisite statistical tools and experimental uncertainty analysis. In Chapter 5, several aspects of pressure, sound pressure level, velocity, and temperature measurements are discussed. Chapter 6 is devoted to the measurement of gas composition of fundamental importance to understanding of combustion. In this chapter, sampling systems and various probe design concepts are covered briefly for measurement of exhaust gases in combustion system. Some of the important modern optical methods used in combustion systems, including laser doppler velocimetry (LDV), particle image velocimetry (PIV), planar laser induced fluorescence (PLIF), and Rayleigh scattering thermometry, are covered in Chapter 7. Basic principles of light scattering are expounded sufficiently to facilitate the discussion on optical measurement systems. Types of light sources including laser are also discussed briefly. Schlieren, shadowgraph, and interferometric optical techniques used for flame visualization in combustion systems are discussed in detail. Several examples, review questions, and problems are provided at the end of each chapter to foster better understanding of the concepts covered in the text. I hope and wish that this book will make the learning process of experimental combustion very enjoyable.

Several individuals have contributed directly or indirectly during the preparation of this manuscript. I appreciate the help rendered by many students at IIT Kanpur and other institutes. I am indebted to my graduate students Ezhil, Mahesh, and Manisha for suggesting corrections in the manuscript. I am also thankful to my students Pravendra, Satish, Vikas, and Rahul who have helped in correcting the solution manuals. I am indebted to Dr. Swarup Y. Jejurkar, Mr. Indramani Dhada, IIT Kanpur, and Dr. Ranjan, assistant professor IIT Patna, India, who have gone through some of the chapters and suggested corrections in spite of their busy schedules. The official support provided by Mr. Ankit Upadhyay especially in preparing diagrams is highly appreciated. I am also thankful to Dr. Gagandeep Singh and Ms. Laurie Schlags of Taylor and Francis Books Pvt Ltd. for providing their support during the publication of this book. Lastly, the unwavering support of my family for this time consuming project is highly appreciated.

D. P. Mishra

Author

Dr. D. P. Mishra is a professor in the Department of Aerospace Engineering at the Indian Institute of Technology (IIT) Kanpur, Kanpur, India, where he was instrumental in establishing a combustion laboratory. His areas of research interest include combustion, computational fluid dynamics, atomization, and so forth. He has taught several undergraduate and postgraduate courses such as applied combustion, engineering thermodynamics, air breathing missile propulsion, aircraft propulsion, and rocket engine design. He is the recipient of several awards, including the Young Scientist Award (1991), INSA-JSPS Fellowship (2002), Sir Rajendranath Mookerjee Memorial award, and Samanta Chadrachekhar award. Currently he serves as an assistant editor for the *International Journal of Hydrogen Energy*, Elsevier, serves as an editorial board member of *Journal of the Chinese Institute of Engineers*, Taylor & Francis, and *International Journal of Turbo and Jet Engines*. Dr. Mishra has six Indian patents and more than 178 research papers in refereed journals and in conference proceedings to his credit. He has authored two textbooks, *Fundamentals of Combustion*, published by Prentice Hall of India, and *Engineering Thermodynamics*, published by Cengage India Pvt Ltd., New Delhi.

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