Aero Engine Combustor Casing

Experimental Design and Fatigue Studies

Sashi Kanta Panigrahi
Niranjan Sarangi

CRC Press
Taylor & Francis Group

Mechanical Engineering

Aero Engine Combustor Casing

Aero Engine Combustor Casing: Experimental Design and Fatigue Studies is focused on theoretical and experimental investigation aimed at detecting and selecting proper information related to the fundamental aspect of combustion casing design, performance, and life evaluation parameters. A rational approach has been adopted to the analysis domain underlying the complexities of the process.

Features

- Presents theoretical investigation of life evaluation techniques
- Illustrates exhaustive information about fatigue life of an aero engine combustor
- Adopts a rational approach to the analysis domain underlying the complexities of the process
- Includes fatigue life calculations and related experiments for a gas turbine combustor case
- Details about performing an experimental/numerical design of the combustor

CRC Press
Taylor & Francis Group
an **informa** business
www.crcpress.com

6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

K30751

ISBN: 978-1-138-03283-5

9 781138 032835 90000

www.crcpress.com

Panigrahi • Sarangi **Aero Engine Combustor Casing** CRC Press

Aero Engine Combustor Casing
Experimental Design and Fatigue Studies

Sashi Kanta Panigrahi and Niranjan Sarangi

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

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

© 2017 by Taylor & Francis Group, LLC,
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper

International Standard Book Number-13: 978-1-138-03283-5 (Hardback)

This book contains information obtained from authentic and highly regarded sources. While all reasonable efforts have been made to publish reliable data and information, neither the authors nor the publisher can accept any legal responsibility or liability for any errors or omissions that may be made. The publishers wish to make clear that any views or opinions expressed in this book by individual editors, authors or contributors are personal to them and do not necessarily reflect the views/opinions of the publishers. The information or guidance contained in this book is intended for use by medical, scientific or health-care professionals and is provided strictly as a supplement to the medical or other professional's own judgement, their knowledge of the patient's medical history, relevant manufacturer's instructions and the appropriate best practice guidelines. Because of the rapid advances in medical science, any information or advice on dosages, procedures or diagnoses should be independently verified. The reader is strongly urged to consult the relevant national drug formulary and the drug companies' and device or material manufacturers' printed instructions, and their websites, before administering or utilizing any of the drugs, devices or materials mentioned in this book. This book does not indicate whether a particular treatment is appropriate or suitable for a particular individual. Ultimately it is the sole responsibility of the medical professional to make his or her own professional judgements, so as to advise and treat patients appropriately. The authors and publishers have also attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged, please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (http://www.copyright.com/) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Library of Congress Cataloging-in-Publication Data

Names: Panigrahi, Shashi Kanta, author | Sarangi, Niranjan, 1946– author.
Title: Aero Engine Combustor Casing : Experimental Design and Fatigue Studies/ Shashi Kanta Panigrahi, Niranjan Sarangi.
Description: Boca Raton : Taylor & Francis, a CRC title, part of the Taylor & Francis imprint, a member of the Taylor & Francis Group, the academic division of T&F Informa, plc, [2017] | Includes bibliographical references and index.
Identifiers: LCCN 2016048815| ISBN 9781138032835 (hardback : alk. paper) | ISBN 9781138032842 (ebook)
Subjects: LCSH: Aircraft gas-turbines–Combustion chambers–Design and construction. | Aircraft gas-turbines–Combustion chambers–Materials–Fatigue.
Classification: LCC TL709.5.C55 P36 2017 | DDC 629.134/353–dc23
LC record available at https://lccn.loc.gov/2016048815

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

此为试读,需要完整PDF请访问: www.ertongbook.com

Aero Engine Combustor Casing

Experimental Design and Fatigue Studies

To our parents

and

loving family members

Preface

The combustion chamber in an aero engine is where the incoming air stream from the compressor is heated by the addition and combustion of fuel. A combustion chamber must therefore satisfy many conflicting requirements:

- It must be capable of initiating the easy ignition of fuel and must operate stably under a wide range of conditions.
- The fuel in the chamber must undergo complete combustion while producing the minimum of pollutants.
- To avoid damage to the turbine of the aero engine, the mixture of air and fuel must achieve an acceptable temperature distribution of exhaust gases.
- The combustor must operate with minimum pressure loss to maintain high overall performance.

To achieve these functionalities together with an acceptable operating life while keeping size, weight, and cost to a minimum represents a considerable design challenge.

It is widely accepted that there is limited literature available in the public domain on the methodology for the life evaluation of a combustion chamber due to the technologies of the various aero engine developers being classified. The only reliable approach through which to determine the fatigue life of a combustion chamber is to design and develop experiments that replicate operational conditions and that are capable of verifying whether an assessment of a combustion chamber life evaluation is correct.

The development of such a test facility is a complex matter as it must respond sensitively and provide detailed results. Various companies have used different approaches. Some industries tried to replicate engine conditions using hot gases; this approach was not only costly, but also very difficult to operate. Other test facilities have been based on pressure cycling; these are technically more convenient and yield better results.

Over recent years, different types of combustor configuration have been widely used in existing aero engines. Of them, the annular combustor is prevalent in modern aero engine designs and is used prolifically in a number of industrial applications. The requirements of a combustor chamber for an aero engine are the provision of high combustion efficiency, sufficient fatigue strength, maximum durability, better reliability and smooth ignition, good stable operation at varied pressures and air/fuel ratios, and a long operational life.

To address all the issues and challenges pertaining to the design, analysis, and development of a combustor chamber for an aero engine, this book discusses a variety of aspects. Among others, these include

- Theoretical investigation
- Thermodynamic processes in a combustion chamber
- Mechanical and manufacturing design consideration and stress analysis
- Various life evaluation methods
- The performance of a combustion chamber
- An experimental approach to determining the fatigue life of a chamber
- Fatigue life testing of a combustion chamber
- Analysis of test data

The focus of this book is on all aspects of experimentation, the development of a test facility, manufacturing procedures, and the analytical and experimental study of fatigue life prediction for an aero engine combustor casing. Many mathematical expressions have been put in a clear and straightforward way and, usually, do not require knowledge of a more mathematical nature. A large number of research articles are provided at the end of this book and provide the opportunity for further reading. The authors have also provided a considerable number of images associated with combustion chambers and hope that those involved with the topic—students, academicians, researchers, industry professionals, and scientists—will take advantage of these images in their work in this field. The authors take this opportunity to thank all their friends and family members who assisted in the preparation of this book. They are also indebted to CRC Press for reviewing and accepting this book for publication.

Sashi Kanta Panigrahi
Niranjan Sarangi

此为试读,需要完整PDF请访问: www.ertongbook.com

Authors

Dr. Sashi Kanta Panigrahi (PhD, IIT Kharagpur) is working as dean (SA) and professor in the Department of Mechanical Engineering of Defence Institute of Advanced Technology (under DIAT), Pune, India. Before he joined DIAT, he was working in many other universities/Institutions within the country. He has also worked as an international visiting academic with the University of New South Wales at the Australian Defence Force Academy (UNSW@ADFA). He has a wide and intensive teaching, research, training, and administrative experience after completing his PhD from Indian Institute of Technology, Kharagpur. He obtained his bachelor's degree and master's degree in mechanical engineering from Veer Surendra Sai Technical University (VSSUT), formerly known as University College of Engineering (UCE), Burla, and National Institute of Technology (NIT), Rourkela. His research works are primarily in the areas of analysis and design of composite materials, characterization of FRP composite materials, finite-element analysis of FRP composite materials and composite structures, natural fiber reinforced composite (NFRC) materials, fracture mechanics principle applicable to modeling and simulation of damages in orthotropic and isotropic materials, and material characterization/stress analysis/solid mechanics/machine design. He has been working on the development of advanced finite-element methods and nonlinear finite-element modeling and analyses of engineering structures with functionally graded/monolithic adhesively bonded joints. He has published over 150 research articles in peer-reviewed scholarly research papers international journals/conferences, including 2 books/monograph/conference proceedings/many lecture materials. He has been awarded with "Bharat Jyoti" in the year 2012 and conferred with fellow, Institution of Engineers, India, and fellow, Indian Society of Mechanical Engineering. Recently, he has been awarded with "Distinguished Scientist" by Venus International Research Foundation, India. Many PhD and MTech students have already been graduated under his direct guidance/supervision. He is a member of many international/national professional bodies and has been a frequent reviewer for many leading peer-reviewed international journals of high standards. He has also served as technical committee member or advisory board member in several national/international conferences.

Niranjan Sarangi received his first class BE in mechanical engineering in 1992 from University College of Engineering, Burla, Odisha, India. He completed his MTech with specialization in production engineering in the Mechanical Engineering Department at the Institute of Technology, Banaras Hindu University (IT-BHU), Varanasi, Uttar Pradesh, India in July 1995. From August 1995 to 1996, he was a faculty member of the Mechanical Engineering Department of Gangamai College of Engineering, Dhule, Maharashtra, India. In September 1996, he joined the Institute of Armament Technology (IAT) of the Defence Research and Development Organisation (DRDO), Pune, Maharashtra, India, as Scientist-B. He was posted to the Gas Turbine Research Establishment (GTRE) of DRDO in Bangalore in March 1997 and continues there as a scientist. At present, he is working as a Scientist-F in GTRE. During his tenure at GTRE, he has been involved in the structural integrity testing of critical aero engine components for their design validation and airworthiness certification. His research interests also include the evaluation of the fatigue life and safety capability of aero engine components for their airworthiness certification.

Between 2007 and 2013, he was engaged in PhD dissertation "Fatigue life evaluation of an aero engine combustor casing" at the Defence Institute of Advanced Technology (deemed university), Pune, Maharashtra, India, while in service at GTRE, Bangalore. He has published good-quality research papers in peer-reviewed international journals and has presented several research papers at various national and international conferences.

Contents

Preface xi
Authors xiii

1. Introduction 1
1.1 Background and Motivation 1
1.2 Outline of this Book 2
1.3 Initial Phase of Aero Engine Development 4
1.4 Working Principle of Aero Gas Turbine Engines 6
1.5 Critical Components of an Aero Engine 7
1.6 Aero Engine Compressor 7
1.7 Aero Engine Combustion Chamber 10
1.8 Aero Engine Turbine 10
1.9 Aero Engine Propelling Nozzle 12
1.10 Design Philosophy of an Aero Engine Combustion Chamber 14
1.11 Types of Combustion Chamber in Aero Engines 15
1.11.1 Multiple Combustion Chambers 15
1.11.2 Tubo-Annular Combustion Chamber 16
1.11.3 Annular Combustion Chamber 16
1.12 Complexities in Combustion Chamber Design 17
1.13 Materials Used for Combustion Chamber 19
1.14 Significant Contributions 20
1.15 Summary 21

2. Fatigue Design Philosophy of an Aero Engine Combustor Casing 23
2.1 Introduction 23
2.2 Combustion Chamber Design 23
2.3 Fatigue Failure in Aero Engines 25
2.4 Fatigue Cycle Counting Methods 29
2.5 Fatigue Life Evaluation Methods 34
2.6 Fatigue Damage Assessment 37
2.7 Nondestructive Testing Methods 39
2.7.1 Radiography Inspection 40
2.7.2 Magnetic Particle Inspection 42
2.7.3 Dye Penetrant Inspection 44
2.7.4 Ultrasonic Inspection 45
2.7.5 Eddy Current and Electromagnetic Inspection 47
2.8 Summary of the Design Philosophy 49
2.9 Important Design Considerations for Combustor Casing 50
2.10 Summary 51

3. Development of Test Facility and Test Setup 53
3.1 Introduction 53
3.2 Airworthiness and Certification 55
3.3 Description of the Test Facility and Its Subsystems 56
3.3.1 Hydraulic Power Supply 57
3.3.2 Servo Valve with Manifold 58
3.3.3 Safety Relief Valve 59
3.3.4 Servo Controller 59
3.3.5 Pressure Transducer 59
3.4 Integration of the Subsystems 60
3.5 Design and Manufacturing of Adaptors 61
3.5.1 Bottom Fixing Plate 62
3.5.2 Bottom Sealing Drum 62
3.5.3 Inner Bottom Fixing Plate 63
3.5.4 Special Tie Rod 64
3.5.5 Top Sealing Plate 65
3.5.6 Top Fixing Plate 65
3.5.7 Top Support Plate 65
3.5.8 Top Holding Plate 66
3.5.9 Special Studs 67
3.5.10 Seals 68
3.6 Summary 68

4. Manufacturing of an Aero Engine Combustor Casing, the Experimental Evaluation of Its Fatigue Life, and Correlation with Numerical Results 69
4.1 Introduction 69
4.2 Manufacturing Method of the Combustor Casing 70
4.2.1 Metal Spinning Process 70
4.2.1.1 Advantages of the Metal Spinning Process 71
4.2.1.2 Disadvantages of Metal Spinning Process 72
4.2.2 Electron Beam Welding Method 72
4.2.3 Tungsten Inert Gas Welding Method 74
4.3 Configuration of the Combustor Casing 75
4.4 Experimental Evaluation of Fatigue Life 76
4.4.1 Instrumentation 77
4.4.2 Inspection Methodology 79
4.5 Mechanical Properties of Combustor Casing Material 81
4.6 Numerical Analysis of the Combustor Casing 82
4.6.1 Details of the Finite Element Model 83
4.6.2 Finite Element Model Quality Parameters 84
4.6.3 Boundary Conditions 85
4.6.4 Load 85
4.6.5 Pressure Load 85
4.6.6 Thermal Load 85

4.6.7 Nusselt Equation 87
4.6.8 Dittus Boelter Equation 87
4.7 Numerical Analysis of the Igniter Boss and Its Correlation with Experimental Data 89
4.8 Results and Discussions 98
4.9 Summary 98

5. Reassessment of Fatigue Life of the Modified Combustor Casing 101
5.1 Introduction 101
5.2 Modified Manufacturing Methodology 101
5.2.1 Forging Process: Benefits and Drawbacks 101
5.3 Instrumentation of the Modified Combustor Casing 106
5.4 Assembly and Trial Run 106
5.5 Testing 109
5.6 Results and Discussion 109
5.7 Summary 110

6. Safety Test on Modified Combustor Casing 113
6.1 Introduction 113
6.2 Test Component Details 114
6.3 Instrumentation and Testing 115
6.4 Results and Discussion 117
6.5 Summary 118

7. Effect of Fatigue on the Proof Strength of an Aero Engine Combustor Casing 119
7.1 Introduction 119
7.2 Metallographic Techniques in Failure Analysis 120
7.2.1 Stereo Zoom Microscopy 121
7.2.2 Scanning Electron Microscopy 121
7.2.3 Optical Microscopy 125
7.3 Details of the Test Component 126
7.4 Experimental Procedure 127
7.5 Observation 128
7.5.1 Visual Observation 128
7.5.2 Stereo Zoom Microscopy 128
7.5.3 Scanning Electron Microscopy 129
7.5.3.1 Fractography 129
7.5.3.2 Energy Dispersive X-Ray Analysis 131
7.5.4 Optical Microscopy 131
7.5.5 Microhardness Measurement 131
7.6 Discussions 137
7.7 Summary 137

8. Conclusions 139
8.1 Certification and Acceptance of the Combustor Casing 139
8.2 Specific Conclusions 139
8.3 Scope for Further Work 140

References 143

Index 153

此为试读,需要完整PDF请访问: www.ertongbook.com