Aircraft Noise

Assessment, prediction and control

Oleksandr Zaporozhets Vadim Tokarev and Keith Attenborough



Jhr Nr. 234	Flugsysteme und Regelungsterheite
	rachbereich Maschinenbau
	Petersenstraße 30
B 1 (1)	64287 Darmstadt

First published 2011 by Spon Press

2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Simultaneously published in the USA and Canada by Spon Press 711 Third Avenue, New York, NY 10017

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

© 2011 Oleksandr Zaporozhets, Vadim Tokarev and Keith Attenborough

The right of Oleksandr Zaporozhets, Vadim Tokarev and Keith Attenborough to be identified as the authors of this Work has been asserted by them in accordance with sections 77 and 78 of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or reproduced or utilised in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

This publication presents material of a broad scope and applicability. Despite stringent efforts by all concerned in the publishing process, some typographical or editorial errors may occur, and readers are encouraged to bring these to our attention where they represent errors of substance. The publisher and author disclaim any liability, in whole or in part, arising from information contained in this publication. The reader is urged to consult with an appropriate licensed professional prior to taking any action or making any interpretation that is within the realm of a licensed professional practice.

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

British Library Cataloguing in Publication Data A catalogue record for this book is available from the British Library

Library of Congress Cataloging in Publication Data Attenborough, K. (Keith)

Aircraft noise propagation, exposure & reduction / Oleksandr Zaporozhets, Vadim Tokarev, Keith Attenborough. p. cm.

Includes bibliographical references and index. 1. Airplanes–Noise. I. Tokarev, V. I. (Vadim Ivanovich) II. Zaporozhets, Oleksandr. III. Title.

TL671.65.A88 2011 629.132'3-dc22

2010036182

ISBN 13: 978-0-415-24066-6 (hbk) ISBN 13: 978-0-203-88882-7 (ebk)

Typeset in Sabon by Glyph International Ltd.



Printed and bound in Great Britain by CPI Antony Rowe, Chippenham, Wiltshire

Contents

Preface

- 1 A review of the aircraft noise probl
 - 1.1 Environmental impacts of air1.2 Description of aircraft noise
 - 1.3 Basic equations 15
 - 1.5 Basic equations 15
 - 1.4 Criteria and methods of aircr1.5 Control of noise impact 38
 - 1.6 Regulations and standards fo

2 The main sources of aircraft noise

- 2.1 Jet noise 64
- 2.2 Fan and turbine noise 70
- 2.3 Combustion chamber noise
- 2.4 Airframe noise 77
- 2.5 Propeller and helicopter nois

3 Aircraft noise propagation

- 3.1 Factors influencing outdoor s
 - 3.1.1 Spreading losses 87
 - 3.1.2 Atmospheric sound a
 - 3.1.3 Ground effect 90
 - 3.1.4 Refraction by wind an gradients 90
- 3.2 Predicting the ground effect
 - 3.2.1 Homogeneous ground
 - 3.2.2 The surface wave 98
 - 3.2.3 Multipole sources nea
 - 3.2.4 Ground impedance m
 - 3.2.5 Effects of surface rou
 - 3.2.6 Effects of impedance
 - 3.2.7 Computation of later

Contents

	Pref	ace		viii
1	A re	A review of the aircraft noise problem		
•	1.1		mmental impacts of airports 1	1
	1.2		ption of aircraft noise 5	
	1.3		equations 15	
			a and methods of aircraft noise assessment 33	
			of noise impact 38	
			ttions and standards for aircraft noise 42	
2	The	main so	ources of aircraft noise	64
	2.1	Jet noi	se 64	
	2.2	Fan an	nd turbine noise 70	
	2.3	Combi	ustion chamber noise 75	
	2.4	Airfran	me noise 77	
	2.5	Propel	ler and helicopter noise 84	
3	Airc	raft noi	se propagation	87
	3.1	Factor	s influencing outdoor sound 87	
		3.1.1	Spreading losses 87	
		3.1.2	Atmospheric sound absorption 89	
		3.1.3	Ground effect 90	
a.		3.1.4	Refraction by wind and temperature	
			gradients 90	
	3.2	3.2 Predicting the ground effect 93		
		3.2.1	Homogeneous ground 93	
		3.2.2	The surface wave 98	
	È.	3.2.3	Multipole sources near the ground 99	
		3.2.4	Ground impedance models 101	
			Effects of surface roughness 103	
		3.2.6	Effects of impedance discontinuities 104	
		3.2.7	Computation of lateral attenuation 105	

vi Contents

- 3.3 Comparisons of measured and predicted ground effects 106
 - 3.3.1 Short range 106
 - Parkin and Scholes' data 107 3.3.2
 - 3.3.3 Noise from aircraft engine testing 108
- 3.4 Shadow zones 109
- 3.5 Classification of meteorological effects 113
- 3.6 Typical sound speed profiles 116
- Sound propagation in a turbulent atmosphere 122 3.7
- 3.8 Sound propagation over noise barriers 128
 - 3.8.1 Deployment of noise barriers 128
 - 3.8.2 Single-edge diffraction 130
 - 3.8.3 Effects of the ground on barrier performance 132
 - 3.8.4 Diffraction by finite length barriers and buildings 135
- 3.9 Sound propagation through trees 136

Methods for aircraft noise prediction 4

- 4.1 Introduction 140
- 4.2 An acoustic model of an aircraft 146
- 4.3 Evaluation of an acoustic model of an aircraft 158
- 4.4 Prediction of noise under the flight path: trajectory models 166
- 4.5 Effects of ground, atmosphere and shielding by wing and fuselage 180
 - 4.5.1 Ground effects 180
 - 4.5.2 Refraction effects 182
 - 4.5.3 Shielding and reflection by wings 192
 - 4.5.4 Refraction through jet exhaust 204
 - 4.5.5 Refraction, interference and comparisons with data 206
 - 4.5.6 Scattering of sound by the fuselage 213
- 4.6 Prediction of aircraft noise during ground operations 216
- 4.7 Prediction of noise in the vicinity of an airport 239

The influence of operational factors on aircraft noise levels 5

- 5.1 Aircraft on the ground 253
- 5.2 Under the flight path 258
- 5.3 Takeoff and climbing 270
- 5.4 Descent and landing 277

- Methods of aircraft noise reduction 6
 - 6.1 Reduction of noise at source 2 6.1.1 Power plant 283
 - Simultaneous noise redu 6.1.2
 - Simultaneous noise redu path and inside the aircr
 - 6.1.3 Use of noise mufflers du
 - 6.2 Noise reduction under the fligh 6.2.1 The mathematical form
 - 6.2.2 The approach and land
 - 6.2.3 The takeoff stage 304
 - 6.3 Noise reduction in the vicinity
 - 6.4 The efficiency of acoustic scree
 - from airport ground operation
 - 6.5 Reduction of noise impact by aircraft operations 325

Monitoring of aircraft noise 7

- 7.1 Reasons for noise monitoring
- Instrumentation for aircraft no Uncertainties in measurements 7.2
- 7.3
- 7.4 Identifying sources of noise eu
- 7.5 Interdependencies and tradeo other environmental factors as aviation 383

Notes Index

253

140

Contents vii

283

1	Mat	1 - 1 - Colored Constant 1 - C	
6	wiet	hods of aircraft noise reduction	
	6.1	Reduction of noise at source 283	
		6.1.1 Power plant 283	
		6.1.2 Simultaneous noise reduction under the flight path and inside the aircraft cabin 287	
		6.1.2 Use of main and the anciant cabin 20/	
		6.1.3 Use of noise mufflers during engine testing 293	
	6.2	Noise reduction under the flight path 294	
		6.2.1 The mathematical formulation 294	
		6.2.2 The approach and landing stage 298	
		6.2.3 The takeoff stage 304	
	6.3	Noise reduction in the vicinity of an airport 307	

6.4 The efficiency of acoustic screens for reducing noise from airport ground operations 314

6.5 Reduction of noise impact by optimum scheduling of aircraft operations 325

7 Monitoring of aircraft noise

332

7.1 Reasons for noise monitoring 332

7.2 Instrumentation for aircraft noise monitoring 3407.3 Uncertainties in measurements and predictions 356

- 7.3 Oncertainties in measurements and produce 7.4 Identifying sources of noise events 370
- 7.5 Interdependencies and tradeoffs between noise and other environmental factors associated with civil aviation 383

Notes Index 397 411

253

a Children and the

40