

# Contents

<b>1</b>	<b>Introduction to Turbocharging</b>	<b>1</b>
1.1	Introduction	1
1.2	Applying Turbochargers to Downsized Engines	4
1.2.1	Single-Stage Turbochargers with EGR	4
1.2.2	Biturbochargers	6
1.2.3	Two-Stage Turbochargers	7
1.2.4	Turbo Compounds	9
	References	9
<b>2</b>	<b>Induced Noise Types</b>	<b>11</b>
	References	14
<b>3</b>	<b>Acoustic Propagation Theory</b>	<b>15</b>
3.1	Aeroacoustic Characteristics	15
3.2	Acoustic Propagation Equations	22
3.3	Computation of Acoustic Propagations	27
3.3.1	Computational Methods	27
3.3.2	BEM for Aeroacoustics	29
3.3.3	FEM for Aeroacoustics	32
3.4	Frequency Modulations of Nonlinear Aeroacoustics	35
3.4.1	Responses of Nonlinear Aeroacoustic Systems	36
3.4.2	Modulated Noise Sideband Frequencies	37
	References	44
<b>4</b>	<b>Analyzing Root Causes of Noise</b>	<b>45</b>
4.1	Aerodynamic Noise	45
4.1.1	Root Causes of Aerodynamic Noise	45
4.1.2	Aerodynamics of Radial Compressors	47
4.1.3	Stall and Surge in Radial Compressors	54

4.2	Unbalance Whistle. . . . .	63
4.2.1	Root Causes of Unbalance Whistle . . . . .	63
4.2.2	Unbalance Types of Turbochargers . . . . .	64
4.2.3	Unbalance Change . . . . .	66
4.2.4	ICM Trim Balancing. . . . .	66
4.3	Subsynchronous Constant Tone. . . . .	68
4.4	High-Order Harmonic Noise . . . . .	69
4.5	Wear Noise. . . . .	70
	References . . . . .	72
<b>5</b>	<b>Computational Nonlinear Rotordynamics of Turbochargers . . . . .</b>	<b>73</b>
5.1	Vibration Equations of Automotive Turbocharger Rotors . . . . .	73
5.2	Two-Phase Reynolds Lubrication Equation. . . . .	75
5.3	Nonlinear Bearing Forces . . . . .	77
5.4	Boundary Conditions of Nonlinear Rotordynamics . . . . .	79
5.5	Computational Results of Turbochargers . . . . .	80
	References . . . . .	86
<b>6</b>	<b>Subsynchronous Constant Tone . . . . .</b>	<b>89</b>
6.1	Transmitting Way of Airborne Noise. . . . .	90
6.2	Constant Tone Root Causes . . . . .	91
6.3	Constant Tone Analysis . . . . .	95
6.4	Calculating Ring Speed Ratio . . . . .	97
6.5	Pre and Post Constant Tone . . . . .	102
6.6	Measures of Reducing Constant Tone Level. . . . .	103
6.6.1	Active Measures . . . . .	103
6.6.2	Passive Measures . . . . .	105
	References . . . . .	108
<b>7</b>	<b>Eigenfrequency Modifications to Reduce Constant Tone Level. . . . .</b>	<b>109</b>
	References . . . . .	112
	<b>Conclusions. . . . .</b>	<b>113</b>
	<b>Further Reading . . . . .</b>	<b>115</b>
	<b>Appendix A: Thermodynamic Characteristics of Perfect Gases. . . . .</b>	<b>117</b>
	<b>Appendix B: Transformation of Coordinates . . . . .</b>	<b>119</b>
	<b>Appendix C: Solutions of the Characteristic Equation with Complex Coefficients. . . . .</b>	<b>123</b>
	<b>Appendix D: Stability Condition of Linear Aeroacoustics . . . . .</b>	<b>125</b>

<b>Appendix E: Routh–Hurwitz Stability Criterion . . . . .</b>	<b>129</b>
<b>About the Author . . . . .</b>	<b>131</b>
<b>Index . . . . .</b>	<b>133</b>

Aero and Vibroacoustics of Automotive Turbochargers

Nguyen-Schäfer, H.

2013, XV, 136 p., Hardcover

ISBN: 978-3-642-35069-6