

Contents and Subject Index

ULTRASONIC NONDESTRUCTIVE MATERIALS

CHARACTERIZATION	1
----------------------------	---

Robert E. Green, Jr.

Introduction	1
Ultrasonic Waves in Solid Materials	1
Linear Elastic Wave Propagation	2
Attenuation of Nearly Linear Elastic Waves	3
Nonlinear Elastic Wave Propagation	5
Ultrasonic Waves in Inhomogeneous Materials	6
Contact or Water Coupled Transducers	6
Non-Contact Transducers	7
Laser Beam Ultrasound Generation	7
Laser Generation Piezoelectric Detection	8
Laser Beam Interferometric Ultrasound Detectors	8
Laser Generation Laser Detection of Ultrasound	9
High-Power Ultrasonic Waves	9
X-Ray Diffraction Topography	11
Conclusions	12
References	12

ULTRASONIC CHARACTERIZATION OF MICROSTRUCTURE IN

POWDERMETALALLOY	30
----------------------------	----

B.R. Tittmann, L.A. Ahlberg, and K. Fertig

Introduction	30
Sample Characterization	31
Micrographical Characterization	31
Ultrasonic Characterization	35
Analysis	38
Comparison Between Theory and Experiment	39

x Contents and Subject Index

Formal Approach to Inverse Problem	42
Conclusion	45
References	45
STUDIES OF ACOUSTIC EMISSION FROM POINT AND EXTENDED SOURCES 47	
<i>Wolfgang Sachse, Kwang Yul Kim, and C.P. Chen</i>	
Introduction	47
Theory and Waveform Processing	47
Results	49
Extended Source	51
Conclusions	51
Acknowledgments	51
References	52
RESIDUAL STRESS MEASUREMENTS IN CARBON STEEL 58	
<i>Joseph S. Heyrnan and Min Narkung</i>	
Introduction	58
Acoustic Measurements	59
Preliminary Experiments and Results	60
Measurements with Carbon Steels and Results	61
Discussion	66
Conclusion	69
References	70
ULTRASONIC MEASUREMENT OF POROSITY IN CASTS AND WELDS 72	
<i>Laszlo Adler and Shao-Wen Wang</i>	
Sample Preparation	72
Theoretical Considerations	73
Experimental System and Procedure	74
Ultrasonic Spectroscopy System	74
Attenuation in Measurements and Results	75
References	78
ANALYTICAL ULTRASONICS FOR CHARACTERIZATION OF METALLURGICAL MICROSTRUCTURES AND TRANSFORMATIONS 79	
<i>Moshe Rosen</i>	
Introduction	79
Ultrasonic Waves: Generation and Detection Techniques	80
Nondestructive Characterization of Precipitation Hardening Phenomena in Aluminum Alloys	86
NDC of Crystallization Processes in Amorphous Materials	88
NDC of Microstructurally Modified Surface Layers	93
References	97
ANALYTICAL ULTRASONICS FOR STRUCTURAL MATERIALS 99	
<i>David S. Kuperman</i>	
Introduction	99

Ultrasonic Characterization of Cast Stainless Steel	99
Background	99
Technical Progress	100
Variation of Sound Velocity with Microstructure	100
Microstructure and Deviation of Ultrasonic Beams	102
Visualization of Ultrasonic Beam Distortion	105
Ultrasonic Characterization of Green Ceramics	106
Background	106
Technical Progress	107
Elastic Anisotropy	107
Variation of Velocity with Density	109
References	111
 ULTRASONIC CHARACTERIZATION OF STRUCTURAL CERAMICS . . 112	
<i>Stanley J. Klima and George Y. Baaklini</i>	
Introduction	112
Materials and Test Procedure	113
Materials	113
Velocity Measurements	113
Attenuation Measurements	114
Results and Discussion	114
Microstructures	114
Velocity-Density Relations	115
Ultrasonic Attenuation	117
Concluding Remarks	118
References	118
 ON THE INTERACTION OF ULTRASOUND WITH CRACKS:	
APPLICATIONS TO FATIGUE CRACK GROWTH 122	
<i>O. Buck, R.B. Thompson, and D.K. Rehbein</i>	
Introduction	122
Experimental Techniques	123
Observations and Interpretations	123
Conclusions	127
References	129
 ANALYTICAL ULTRASONICS FOR EVALUATION OF	
COMPOSITE MATERIALS RESPONSE 136	
Part I: Physical Interpretation	
<i>Edmund G. Henneke // and John C. Duke, Jr.</i>	
Introduction	136
Wave Propagation in Anisotropic Materials	137
Characterization of Physical Properties by Ultrasonics	141
Conclusions	142
References	143
Part II: Generation and Detection	
<i>John C. Duke, Jr., and Edmund G. Henneke //</i>	
Introduction	148

Experimental Methods of Ultrasound Generation	149
Methods of External Ultrasound Generation.	149
Piezoelectric Devices	149
Spark Discharge Methods	150
Methods of Internal Ultrasonic Mechanical Wave Generation	150
Electromagnetic Acoustic Transducers (EMAT).	150
Laser Generation.	150
Impulsive Methods.	151
Experimental Methods of Detecting Ultrasound	151
Piezoelectric Devices	151
Capacitance Displacement Measurement	152
Optical Methods	152
X-Ray Measurement.	153
Data Analysis	153
Experimental Investigation of Wave Propagation in Composite	
Materials.	154
Future Directions	156
References.	157
INFERENCE OF STRESS AND TEXTURE FROM ANGULAR DEPENDENCE OF ULTRASONIC PLATE MODE VELOCITIES	164
<i>R.B. Thompson, J.F. Smith, and S.S. Lee</i>	
Introduction.	164
Theory of the Angular Dependence of Ultrasonic Velocity	164
Determination of Stress	168
Determination of Texture.	170
Concluding Remarks	173
References.	174
EFFECT OF STRESS ON ULTRASONIC PULSES IN FIBER REINFORCED COMPOSITES.	176
<i>John H. Hemann and George Y. Baaklini</i>	
Introduction.	176
Experimental Procedure.	177
Material.	177
Apparatus	177
Experimental Loading	178
Results	178
Dispersion	178
Attenuation vs. Tensile Stress	179
Wave Speed vs. Tensile Load	180
Conclusion.	180
References.	180
PATTERN RECOGNITION CHARACTERIZATIONS OF MICRO- MECHANICAL AND MORPHOLOGICAL MATERIALS STATES VIA ANALYTICAL QUANTITATIVE ULTRASONICS.	187
<i>James H. Williams, Jr., and Samson S. Lee</i>	
Introduction.	187

Classification by Pattern Recognition	188
Data Generation	188
Feature Extraction	189
Classification	191
Conclusions	194
References	195
 ULTRASONIC VERIFICATION OF MICROSTRUCTURAL CHANGES DUE TO HEAT TREATMENT	
<i>Edward R. Generazio</i>	
Introduction	200
Theory	201
Experiment	203
Material Samples	203
Microstructure Modification	203
Attenuation Measurement	204
Results	204
Experimental Generating Functions	204
Mean Grain Size Ratios	205
Discussion	205
Conclusions	206
References	206
 ULTRASONIC MATERIAL PROPERTY DETERMINATIONS	
<i>Steven Serabian</i>	
Introduction	211
Velocity Based Correlations	211
Attenuation Based Correlations	214
Summary and Conclusions	216
References	217
 DYNAMIC MODULI AND LOCALIZED DAMAGE IN COMPOSITES	
<i>L.S. Fu</i>	
Preliminaries	225
Displacement Field Due to Presence of Mismatch	225
Eigenstrains	226
Volume Average and Time Average	227
Isolated, Flat Ellipsoidal Inclusion	228
Formulation	228
Far-Field Scattered Quantities	229
Determination of A_j^* and B_{jk}^*	230
Numerical Calculations and Graphical Displays	232
Dynamic Moduli and Damage of Composites	233
Average Theorem	233
Self-Consistent Scheme for Determining Effective Properties	235
Effective Properties of Two-Component Media: Randomly Distributed Spheres	235
Example: Spherical Inclusion Materials	236
Concluding Remarks	238

References	238
TRANSFER FUNCTION CONCEPT FOR ULTRASONIC CHARACTERIZATION OF MATERIAL MICROSTRUCTURES. 249	
<i>Alex Vary and Harold E. Kautz</i>	
Background and Theory	249
General	249
Pulse-Echo Method	250
Material Transfer Function	250
Attenuation Coefficient	251
Attenuation Mechanisms.	251
Extrinsic Mechanisms.	252
Intrinsic Mechanisms	252
Combined Expressions	253
Microstructure Considerations	254
Grain Size	254
Scattering Centers	255
Empirical Correlations	255
Grain Interfaces	256
Transfer Function Synthesis	256
Approach.	256
Interface Transfer Function.	256
Lattice Model Transfer Function	257
Lattice Model with Scattering	257
Generalization for Polycrystallines	258
Generalization for Grain-Size Distribution	259
Verification and Applications of Model	260
Comparison with Scattering Theory	260
Comparison with Experiment	261
Data Simulation for Curve Fitting.	262
Interrelation of Parameters	263
Discussion	264
General	264
Microstructure Encompassed.	264
Probability Distribution Functions	264
Interface Transfer Function.	265
Multiple Reflection Term	265
Power Functions of Frequency	265
Elastic Anisotropy and Related Factors.	266
Concluding Remarks	266
Appendix A: Reflection Coefficient and Acoustic Impedance	267
Appendix B: Reflection Coefficient Transfer Function	269
Appendix C: Development of Lattice Model Equation.	270
References	273
ADHESIVE JOINT EVALUATION BY ULTRASONIC INTERFACE AND LAMB WAVES. 290	
<i>S.I. Rokhlin</i>	
Elastic Interface Waves.	290

The Concept of the Effective Shear Modulus–Strength Prediction	293
Evaluation of the Curing of Structural Adhesives by Ultrasonic	
Interface Waves	294
Lamb Wave Method	297
Evaluation of Adhesive Curing Using Lamb Waves	299
Conclusion	300
References	301
 INPUT-OUTPUT CHARACTERIZATION OF AN ULTRASONIC	
TESTING SYSTEM BY DIGITAL SIGNAL ANALYSIS	302
<i>James H. Williams, Jr., Samson S. Lee, and Hira Karagulle</i>	
Introduction	302
Fundamentals of Digital Signal Processing	303
Experimental System	308
Digital Characterization of Experimental System	309
Results and Discussion	313
Conclusions	314
References	315
 QUANTITATIVE FLAW CHARACTERIZATION WITH SCANNING	
LASER ACOUSTIC MICROSCOPY	331
<i>Edward R. Generazio and Don J. Roth</i>	
Introduction	331
Scanning Laser Acoustic Microscopy	332
Effect of Surface Roughness on Flaw Depth Determination	333
Background	333
Experiment	333
Results	334
Diffraction Effects Observed in Acoustic Images of Flaws	335
Background	335
Experiment	335
Results	336
Discussion	336
Conclusions	337
References	338