Contents

Author Biographies ix
Preface xiii

1 Introduction 1
Hartmut Brauer

1.1 Electromagnetic testing 9
1.1.1 Brief historical review 10
1.1.2 Electromagnetic NDT methods 11
1.1.3 Capabilities of electromagnetic techniques 14
1.1.4 Present state of eddy current inspection 15
1.2 Eddy current testing 18
1.2.1 Eddy current and ECT 18
1.2.2 ECT principles 19
1.2.3 Applications 34
1.3 Motion-induced ECT 35
1.3.1 Introduction 35
1.3.2 Lorentz force eddy current testing 36
1.3.3 Theory 38
1.3.4 Experiments 39
1.3.5 Comparison of ECT and LET 43

2 Forward simulation methods 47
Marek Ziolkowski, Mladen Zec and Konstantin Weise

2.1 Moving coordinate systems—transformations 48
2.2 Semianalytical methods used in LET systems 51
2.2.1 Calculation of forces in 2D LET systems 51
2.2.2 Lorentz forces acting on 3D permanent magnets above moving conducting plate without defects 62
2.2.3 Calculation of forces in 3D LET systems 70
2.2.4 Oscillatory motion of permanent magnets above a conducting plate 75
2.2.5 The simplest approach to calculate DRS 100
2.2.6 A hole in a thin, large, conductive sheet 103
2.2.7 An extended area approach in the calculation of DRS 105
2.3 Surface charge simulation method 110

2.4 Numerical simulations with FEM 116
2.4.1 Introduction and motivation 116
2.4.2 Computation of eddy current distributions including moving parts 117
2.4.3 Numerical modeling of conductivity anomalies 120
2.4.4 Comparison of numerical approaches 129

3 Sensors for MIECT 137
Matthias Carlstedt, Hartmut Brauer and Konstantin Weise

3.1 Force measurement systems 137
3.1.1 Principles of force transducers 137
3.1.2 Differential Lorentz force eddy current testing sensor 141
3.1.3 Characteristics and calibration of force measurement systems 146
3.2 Optimization of PM systems 147
3.2.1 Introduction and motivation 147
3.2.2 Methods 147
3.2.3 Optimization results and discussion 162
3.2.4 Prototypes of optimized LET magnet systems 168
3.2.5 Defect depth study 171
3.2.6 Conclusions 173

4 Experiments and LET measurements 175
Matthias Carlstedt and Konstantin Weise

4.1 Measurement procedure 175
4.1.1 Measurement principle 176
4.1.2 Measurement method 176
4.1.3 Experimental setup 179
4.2 Validation procedure 186
4.2.1 DSP and basic statistics 186
4.2.2 Autocorrelation on typical force signals 190
4.2.3 Program flowchart for DSP 192
4.2.4 Experimental study 198
4.2.5 Uncertainty analysis 204

5 Lorentz force evaluation 227
Hartmut Brauer

5.1 Identification of conductivity anomalies 227
5.2 Inverse solution techniques 229
5.2.1 Theory 229
5.2.2 Classification of inverse problems 230
5.2.3 Regularization 235
5.3 Lorentz force evaluation 236
5.4 Summary 242

6 Applications **243**
Robert P. Uhlig, Hartmut Brauer, Konstantin Weise and Marek Ziolkowski

6.1 Sigmometry 243
6.1.1 Introduction and motivation 243
6.1.2 Basic principle 244
6.1.3 Semianalytical and numerical calibration 246
6.1.4 Experimental validation 248
6.1.5 Findings 254
6.2 Defectocscopy of multilayered structures 255
6.2.1 LET measurements of alucobond specimen 255
6.2.2 Forward simulations 256
6.2.3 Defect identification 259
6.2.4 Results and discussion 261
6.3 Inspection of composites 265
6.3.1 Composite material 265
6.3.2 Glass laminate aluminum reinforced epoxy (GLARE) 267
6.3.3 Carbon fiber reinforced polymer (CFRP) 280
6.4 Defectoscopy of friction stir welding 290
6.4.1 Friction stir welding (FSW) 290
6.4.2 FSW experiments 294
6.4.3 NDT of friction stir welds 295
6.4.4 MIECT measurements of friction stir welds 298
6.4.5 Potential applications of MIECT 302
6.5 Application to ferromagnetic materials 303

References **307**
Index **337**