

Contents

1	Introduction	1
	References	3
2	Magnetoquasistatic Approximation of Maxwell's Equations, Uncertainty Quantification Principles	5
2.1	Maxwell's Equations	5
2.2	Magnetoquasistatic Approximation	6
2.3	Magnetoquasistatic Model	8
2.4	Uncertainty Quantification, Verification and Validation	12
2.5	Conclusion	14
	References	14
3	Magnetoquasistatic Model and its Numerical Approximation	17
3.1	Weak Formulation	17
3.2	Reformulation as a Minimization Problem	21
3.3	Space Discretization	23
3.3.1	Higher Order Whitney Forms	24
3.3.2	Spline Finite Elements	25
3.3.3	Finite Element Formulation	26
3.3.4	Finite Element a Priori Error Analysis	27
3.4	Linearization	28
3.5	A Posteriori Error Analysis of Linearization and Discretization Error	31
3.6	Temporal Discretization	35
3.7	Conclusion	36
	References	36

4 Parametric Model, Continuity and First Order Sensitivity	
Analysis	39
4.1 Abstract Mathematical Reformulation of the Model	39
4.2 Definition of the Model Inputs and Parametrization	40
4.2.1 The Material Coefficient as a Model Input	41
4.2.2 Approximation of the Magnetic Material Coefficient.	42
4.2.3 The Shape of the Interface as a Model Input	43
4.2.4 Approximation and Representation of Shapes	45
4.2.5 The Source Current Density as a Model Input	47
4.2.6 Conductor Models.	47
4.3 Continuity with Respect to the Input Data	48
4.4 Sensitivity Analysis, Direct Approach	50
4.4.1 Magnetic Material Coefficient Sensitivity	51
4.4.2 Interface Sensitivity.	54
4.4.3 Source Current Sensitivity.	58
4.5 Sensitivity Analysis, Adjoint Approach	59
4.6 Sensitivity Analysis for the Time Transient Case	60
4.7 Conclusion	61
References.	62
5 Uncertainty Quantification	65
5.1 Uncertainty Modeling.	65
5.1.1 Probabilistic Description of Uncertainties	66
5.1.2 Karhunen-Loève Expansion	66
5.1.3 Stochastic Formulation and KL Modeling Error	70
5.2 Model Dimension Reduction and Uncertainty Propagation.	73
5.2.1 Dimension Reduction	74
5.2.2 Monte Carlo Sampling	76
5.2.3 Perturbation Methods for the Statistical Moments.	77
5.2.4 Collocation Based Polynomial Chaos Method.	83
5.2.5 Worst-Case Scenario	86
5.3 Conclusion	88
References.	88
6 Uncertainty Quantification for Magnets	91
6.1 Field Equations for Magnets and Multipole Coefficients.	92
6.2 Numerical Examples.	95
References.	103
7 Conclusion and Outlook	105
7.1 Conclusion	105
7.2 Outlook	106

Contents	xiii
Appendix A: Linearization	107
Appendix B: B-Splines and NURBS	109
Appendix C: Higher Order Sensitivity Analysis	111
Curriculum Vitae	113

<http://www.springer.com/978-3-319-41293-1>

Numerical Approximation of the Magnetoquasistatic
Model with Uncertainties

Applications in Magnet Design

Römer, U.

2016, XXII, 114 p. 20 illus., 8 illus. in color., Hardcover

ISBN: 978-3-319-41293-1