

Contents

<i>Abstract</i>	<i>i</i>
<i>Acknowledgements</i>	<i>v</i>
<i>Contents</i>	<i>vii</i>
<i>List of Figures</i>	<i>xiii</i>
<i>List of Tables</i>	<i>xxiii</i>
<i>Nomenclature</i>	<i>xxv</i>
<i>Preface</i>	<i>xxix</i>
Chapter 1. Introduction	1
1.1. Overview and motivation.....	1
1.1.1. Giant magnetostrictive materials (GMM).....	5
1.1.2. Fracture and Fatigue failure of giant magnetostrictive materials	9
1.1.3. Constitutive modelling.....	13
1.2. Research objectives.....	17
1.3. Scope of research	19
1.4. Dissertation outline	21
Chapter 2. Theoretical Background	25
2.1. Magnetism.....	25
2.1.1. Magnetic Field	26
2.1.2. Magnetic moment and Magnetization	26
2.1.3. Magnetic flux density and hysteresis loops	27
2.1.4. Exchange and Magnetic energy	30

2.1.5.	Demagnetization energy	31
2.1.6.	Magnetization processes	31
2.1.7.	Magnetic anisotropy	33
2.1.8.	Magnetostriction.....	34
2.1.9.	Maxwell equations	37
2.1.10.	Magnetic scalar and vector potentials	38
2.1.11.	Boundary conditions	40
2.2.	Nonlinear elasticity.....	43
2.2.1.	Stress-strain relations	44
2.2.2.	Equilibrium equation.....	45
2.3.	Magneto-elastic failure	46
2.3.1.	Fracture.....	47
2.3.2.	Fatigue.....	50
2.4.	Weibull strength theory	53
Chapter 3. A Novel Magneto-Thermoelastic Constitutive Model.....		55
3.1.	Introduction	55
3.2.	Coupled Nonlinear Hysteretic Constitutive Relationship	56
3.2.1.	Mathematical framework	57
3.3.	Qualitative Discussion.....	63
3.3.1.	On tensors S_{ijkl} and m_{ijkl}	63
3.3.2.	On $\lambda_{0ij}(\sigma_{mn})$ and $f_k^{-1}(M)$	64
3.4.	Simplified Hysteretic Constitutive Model.....	66
3.4.1.	2-D model for magnetostrictive thin films and plates.....	72
3.4.1.1.	For magnetic field parallel to film/plate	73

3.4.1.2.	For magnetic field perpendicular to film/plate.....	74
3.4.1.3.	For magnetic field parallel to film (Along the x -direction).....	75
3.4.1.4.	For magnetic field perpendicular to film (Along the z -direction).....	76
3.4.2.	1-D model for magnetostrictive rods.....	76
3.4.3.	Solution Algorithm.....	77
3.5.	Simulation Physics.....	79
3.5.1.	Model Definition.....	80
3.5.1.1.	For actuators based on rods.....	81
3.5.1.2.	For actuators based on films.....	81
3.6.	Verification With Experiments And Discussions.....	82
3.6.1.	Case Study 1: For magnetostrictive rods.....	84
3.6.2.	Case Study 2: For magnetostrictive thin films.....	99
3.7.	Summary.....	110
<i>Chapter 4. Three-Dimensional Path Independent Integral for Coupled Magneto-Thermo-Elastic Fracture Domain.....</i>		<i>113</i>
4.1.	Introduction.....	113
4.2.	Formulation of the path independent 3D J-Integral.....	114
4.2.1.	Coupled Magneto-Thermo-Elastic field contribution in J-integral.....	117
4.3.	Summary.....	122
<i>Chapter 5. Numerical and experimental analysis for calibration of the magneto-elastic material parameters.....</i>		<i>123</i>
5.1.	Introduction.....	123
5.2.	Experimental characterization.....	124

5.2.1.	Hysteretic magnetic response characterization set up	124
5.2.2.	Magneto-elastic compression test	126
5.3.	Numerical Analysis	128
5.3.1.	Solution method in COMSOL.....	131
5.3.2.	Numerical model for magneto-elastic response of material.....	132
5.4.	Results and Discussions.....	133
5.4.1.	Comparison between hysteretic magnetic response experiments and simulation.....	134
5.4.2.	Comparison between compression experiment and simulation	136
5.5.	Summary.....	138
Chapter 6. An experimental and numerical study for Mode I fracture parameter characterization of a cracked giant magnetostrictive material		139
6.1.	Introduction	139
6.2.	Fracture toughness experiment.....	141
6.3.	Experimental evaluation of strain energy release rate J_{Ic}	144
6.3.1.	For unimodular material	144
6.3.2.	For variable modulus material.....	146
6.4.	Numerical model for Terfenol-D SENB specimen	147
6.4.1.	Finite element computation procedure for J-integral	151
6.5.	Results and discussions	154
6.5.1.	Weibull statistical theory in the estimation of peak fracture load.....	157
6.5.2.	Experimental results for J_{Ic}	164
6.5.3.	Numerical results for J_{Ic}	165

6.6. Summary	180
Chapter 7. An experimental and numerical analysis for fatigue strength characterization and life prediction of giant magnetostrictive material.....	183
7.1. Introduction	183
7.2. Fatigue experiment.....	185
7.3. Numerical model.....	190
7.3.1. Computation of J -Integral.....	193
7.4. Results and discussions	195
7.4.1. Experimental results for crack growth.....	195
7.4.2. Numerical determination of updated Paris law constants.....	196
7.4.3. Numerical fatigue life prediction and experimental validation	203
7.5. Summary	209
Chapter 8. Conclusions and Future scope.....	211
8.1. General conclusions	211
8.2. Future scopes.....	217
References	219
Appendix A.....	230
List of Publications	233