Contents

Ti	itle p	age			i
A	cknov	vledgn	nents		xi
Abstract				3	ciii
N	omen	clatur	e	3	xix
\mathbf{Li}	st of	Figure	es	3	xxi
\mathbf{Li}	st of	Tables	5	хy	xix
1	Intr	oducti	ion		1
	1.1	Mater	ial damping and relevant prior work $\ldots \ldots \ldots \ldots \ldots$		3
	1.2	Contri	ibutions of the thesis		8
	1.3	Outlin	e of the thesis	•	12
2	Mod	lal daı	mping via dissipation from frictional microcracks		13
	2.1	Introd	uction		13
2.2 Frictional dissipation in a single micro		Frictic	onal dissipation in a single microcrack		15
		2.2.1	Finite element simulations		18
		2.2.2	Dissipation formula using a spring-block system \ldots .		19
	2.3	2.3 Dissipation due to multiple cracks: Monte Carlo method .			20
		2.3.1	Random orientations		22
		2.3.2	Nondimensionalization		23
		2.3.3	Building block: a single average dissipation calculation		25

	2.4	Fitted formula				
		2.4.1	A comment on prior efforts	28		
		2.4.2	Inputs to the fitted multivariate polynomial formula	29		
		2.4.3	Multivariate polynomial fit	29		
	2.5	Finite element computation of modal damping				
		2.5.1	Effective damping ratio (ζ_{eff})	36		
		2.5.2	Finite element prediction of effective damping ratio	37		
		2.5.3	Details of ζ_{eff} computation using ANSYS	38		
		2.5.4	Results for an arbitrary solid object	41		
	2.6	Summ	ary	44		
~						
3	Dis	sipatio	n due to individual microscopic elasto-plastic flaws	47		
	3.1	Introd	uction	47		
	3.2	Unidin	nensional dissipation model	47		
	3.3	Elasto-	-plastic inclusion under far-field stresses	50		
		3.3.1	Finite element calculation	50		
		3.3.2	Semi-analytical approach	57		
	3.4	Two special cases				
		3.4.1	Spherical inclusions	62		
		3.4.2	Flat and thin ellipsoidal flaws $\ldots \ldots \ldots \ldots \ldots \ldots \ldots$	66		
	3.5	Summ	ary	69		
	ъл			F 1		
4	Ma	croscop	bic dissipation due to dispersed elasto-plastic flaws	71		
	4.1	Introduction		71		
	4.2	2 Spherical flaws		72		
	4.3	3 Flat and thin flaws		73		
		4.3.1	Averaging over a single plane orientation	74		
		4.3.2	Averaging over plane orientations	74		
		4.3.3	Dissipation: Special cases and symmetries	77		
		4.3.4	Relation to distortional strain energy $\ldots \ldots \ldots \ldots \ldots$	78		
		4.3.5	Approximation for large m	81		

	4.4	Summary	84
5	Mo	dal damping computation examples with solid and shell ele-	
	mer	nts	85
	5.1	Introduction	85
	5.2	Computation of ζ_{eff} using solid elements $\ldots \ldots \ldots \ldots \ldots \ldots \ldots$	86
		5.2.1 Validation of $\zeta_{e\!f\!f}$ computation with known analytical results $~$.	87
	5.3	Computation of ζ_{eff} using shell elements $\ldots \ldots \ldots \ldots \ldots \ldots \ldots$	91
		5.3.1 Analysis method	91
		5.3.2 Comparison with known analytical results	93
5.4 Normalization for $m > 2$		Normalization for $m > 2$	94
	5.5	Matlab GUI for automated computation of ζ_{eff}	96
	5.6	Effects of stress concentration on damping	96
	5.7	Summary	100
6	Con	Inclusions	101
A	Sup	plementary materials for Chapter 2	105
	A.1	On possible waveforms within the dissipation calculation	105
	A.2	Simulation results from 2D finite element analysis	105
A.3 The dissipation formula from the spring block m		The dissipation formula from the spring block model	109
		A.3.1 Case 1: zero mean normal stress $(\beta = 0)$	110
		A.3.2 Case 2: $-1 < \beta < 1$	110
		A.3.3 Case 3: $\beta < -1$	111
		A.3.4 Case 4: $\beta > 1$	111
		A.3.5 Single formula	111
	A.4	Simulation results from 3D finite element analysis	112
		A.4.1 Circular crack	112
		A.4.2 Triangular crack	114
	A.5	Matrix \mathbf{B} for the constitutive model	118
	A.6	Brief review of some topics in vibration theory	118

		A.6.1	Response of a typical damped harmonic oscillator $\ . \ . \ .$. 118	
		A.6.2	Modal damping	. 119	
В	Sup	pplementary materials for Chapter 3			
	B.1	Eshelb	by tensor for an ellipsoidal inclusion $\ldots \ldots \ldots \ldots \ldots \ldots$. 123	
	B.2	Detail	s of 6×6 matrices G and H	. 125	
С	Sup	pleme	ntary materials for Chapter 4	127	
	C.1	D from	m Eq. (4.10) for even integer m	. 127	
	C.2	Mathe	ematical details of the large m approximation $\ldots \ldots \ldots \ldots$. 128	
		C.2.1	Corrections terms for $\chi = 0$ or $1 \dots \dots \dots \dots \dots$. 129	
D	Sup	pplementary materials for Chapter 5			
	D.1	Torsio	n of a circular rod	. 131	
		D.1.1	Analytical calculation	. 131	
		D.1.2	Finite element computations of ζ_{eff}	. 132	
	D.2	2 Bending of a thin rectangular plate		. 134	
		D.2.1	Analytical approach	. 134	
		D.2.2	Computational solution	. 136	
	D.3	D.3 Radial mode of a thin-walled spherical shell		. 137	
		D.3.1	Analytical calculation	. 137	
		D.3.2	Computational solution	. 138	
	D.4	Longit	tudinal vibration of a laterally constrained rod	. 140	
		D.4.1	Analytical approach	. 140	
		D.4.2	Computational solution	. 141	
	D.5	First r	radial mode of a solid sphere	. 142	
		D.5.1	Analytical calculation for the radial mode	. 142	
		D.5.2	Computational solution	. 144	
_					

References