Some Applications of Phase-Field Approaches to Fracture (Need to somehow mention variational frameworks and nonlinearity)

by

Tianchen Hu

Department of Mechanical Engineering and Materials Science Duke University

Date:
Approved:
John Dolbow, Advisor
,
Wilkins Aquino
1
Johann Guilleminot
Johann Gumenmot
Manolis Veveakis
Manons veveakis
Beniamin W. Spencer

Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Mechanical Engineering and Materials Science

in the Graduate School of Duke University $2021\,$

Abstract

Some Applications of Phase-Field Approaches to Fracture (Need to somehow mention variational frameworks and nonlinearity)

by

Tianchen Hu

Department of Mechanical Engineering and Materials Science Duke University

Approved:
John Dolbow, Advisor
Wilkins Aquino
Johann Guilleminot
Manolis Veveakis
Benjamin W. Spencer

An abstract of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Mechanical Engineering and Materials Science

in the Graduate School of Duke University 2021

Abstract

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Sed porta finibus lacus venenatis varius. Proin luctus, est ac facilisis aliquam, leo est tempus velit, eu euismod mi nunc ut odio. Nulla porttitor velit vel dolor dapibus sollicitudin. Sed lobortis lorem ut dui bibendum pellentesque. Curabitur in volutpat ex, ut semper ipsum. In auctor ac ex euismod aliquet. Ut rutrum neque sed felis auctor luctus. Mauris nec lorem placerat, mattis turpis vel, lacinia purus. Maecenas nunc mauris, semper ut aliquam at, luctus sed justo. Proin porttitor cursus orci. Ut id vehicula massa, ac sagittis lectus. Sed eget justo faucibus, posuere purus.

Contents

A	bstra	ct		iv		
Li	st of	Table	${f s}$	viii		
Li	st of	Figur	es	ix		
\mathbf{A}	ckno	wledge	ements	X		
1	Intr	troduction				
2 The Variational Framework			ational Framework	2		
	2.1	Theor	retical backgrounds	2		
	2.2	Kinen	natics and Constraints	2		
	2.3	Thern	nodynamics	2		
	2.4	The m	ninimization problem	2		
	2.5	Discre	etization	2		
3	Brit	rittle Fracture: Fracture in Microstructures				
	3.1	3.1 Introduction				
	3.2	3.2 Theory				
		3.2.1	Constitutive choices	3		
		3.2.2	Approximation of the pressure boundary condition	3		
3.3 Verification			eation	3		
		3.3.1	Uniaxial traction of a bar	3		
		3.3.2	Pressurized crack propagation	3		

3.4 Numerical examples			rical examples	3
		3.4.1	Effects of pore geometry, porosity, and loading conditions	3
		3.4.2	High burnup structure fragmentation	3
4	Coh	esive 1	Fracture: Soil Dessication	4
	4.1	Introd	uction	4
	4.2	Theor	y	4
		4.2.1	Constitutive choices	4
		4.2.2	Enforcing the traction-free boundary condition	4
		4.2.3	Stochastic models for fracture properties	4
	4.3	Verific	ation	4
		4.3.1	Edge-notched specimen	4
		4.3.2	Crack propagation under biaxial tension	4
		4.3.3	Reconstruction of the marginal PDF	4
	4.4	Nume	rical examples	4
		4.4.1	One-dimensional simplification: side view	4
		4.4.2	Two-dimensional simplification: Stochastic aspects of fracture	4
		4.4.3	Inverse identification based on three-dimensional physical experiments	4
5	Tow	ards I	Ouctile Fracture	5
	5.1 Introduction			5
5.2 Theory			y	5
		5.2.1	Constitutive choices	5
		5.2.2	A power-law approximation to the yield surface	5
		5.2.3	Variational constitutive updates	Ę
5.3 Verification			ation	5
		5.3.1	A homogeneous example: uniaxial constitutive response	Į.

		5.3.2	A nonhomogeneous example: uniaxial load-displacement curves	5	
		5.3.3	Crack resistance curves	5	
5.4 Numerical examples				5	
		5.4.1	Three-point bending	5	
		5.4.2	The Sandia Fracture Challange	5	
		5.4.3	Spallation of oxidation scale	5	
6	Con	clusio	n	6	
A	A Code availability			7	
В	3 On the phase-field irreversibility constraint			8	
\mathbf{C}	The flooding algorithm for counting fragments			9	
Bibliography 10					
Ri	Riography 1				

List of Tables

List of Figures

Acknowledgements

I am thankful for the many people.

1

Introduction

Introduction placeholder.

The Variational Framework

- 2.1 Theoretical backgrounds
- 2.2 Kinematics and Constraints
- 2.3 Thermodynamics
- 2.4 The minimization problem
- 2.5 Discretization

Brittle Fracture: Fracture in Microstructures

- 3.1 Introduction
- 3.2 Theory
- 3.2.1 Constitutive choices
- 3.2.2 Approximation of the pressure boundary condition
- 3.3 Verification
- 3.3.1 Uniaxial traction of a bar
- 3.3.2 Pressurized crack propagation
- 3.4 Numerical examples
- $\it 3.4.1 \quad Effects \ of \ pore \ geometry, \ porosity, \ and \ loading \ conditions$
- 3.4.2 High burnup structure fragmentation

Cohesive Fracture: Soil Dessication

- 4.1 Introduction
- 4.2 Theory
- 4.2.1 Constitutive choices
- 4.2.2 Enforcing the traction-free boundary condition
- 4.2.3 Stochastic models for fracture properties
- 4.3 Verification
- 4.3.1 Edge-notched specimen
- 4.3.2 Crack propagation under biaxial tension
- 4.3.3 Reconstruction of the marginal PDF
- 4.4 Numerical examples
- ${\it 4.4.1} \quad One\mbox{-}dimensional \ simplification: \ side \ view$
- 4.4.2 Two-dimensional simplification: Stochastic aspects of fracture
- ${\it 4.4.3} \quad Inverse \ identification \ based \ on \ three-dimensional \ physical \ experiments$

Towards Ductile Fracture

- 5.1 Introduction
- 5.2 Theory
- 5.2.1 Constitutive choices
- 5.2.2 A power-law approximation to the yield surface
- 5.2.3 Variational constitutive updates
- 5.3 Verification
- 5.3.1 A homogeneous example: uniaxial constitutive response
- 5.3.2 A nonhomogeneous example: uniaxial load-displacement curves
- 5.3.3 Crack resistance curves
- 5.4 Numerical examples
- 5.4.1 Three-point bending
- 5.4.2 The Sandia Fracture Challange
- $5.4.3 \quad Spallation \ of \ oxidation \ scale$

Conclusion

Appendix A

Code availability

Appendix B

On the phase-field irreversibility constraint

Appendix C

The flooding algorithm for counting fragments

Bibliography

Biography

About myself.