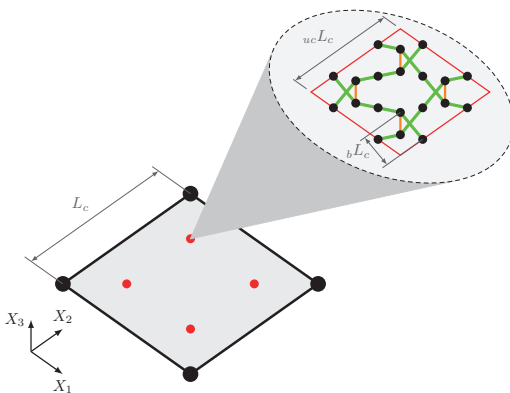




Benjamin Kaiser

A generalised interface for multi-level coupling of beam unit cell meso-models to macro finite elements in draping simulation



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Vollständiger Abdruck der von der Ingenieurfacultät Bau Geo Umwelt der
Technischen Universität München zur Erlangung des akademischen Grades eines

Doktor-Ingenieurs (Dr.-Ing.)

genehmigten Dissertation.

Vorsitzender: PD. Dr.-Ing. habil. Roland Wüchner

Prüfer der Dissertation: 1. Prof. Dr.-Ing. habil. Fabian Duddeck
2. Prof. Dr.-Ing. Kai-Uwe Bletzinger
3. Prof. Dr.-Ing. Thomas Pyttel

Die Dissertation wurde am 17.10.2019 bei der Technische Universität München
eingereicht und durch die Ingenieurfacultät Bau Geo Umwelt am 21.02.2020
angenommen.

Schriftenreihe des Fachgebiets für Computational Mechanics

Band 12

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**A generalised interface for multi-level coupling of
beam unit cell meso-models to macro finite elements
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Shaker Verlag
Düren 2020

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: München, Techn. Univ., Diss., 2020

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Printed in Germany.

ISBN 978-3-8440-7571-7

ISSN 2193-2700

Shaker Verlag GmbH • Am Langen Graben 15a • 52353 Düren

Phone: 0049/2421/99011-0 • Telefax: 0049/2421/99011-9

Internet: www.shaker.de • e-mail: info@shaker.de

Acknowledgments

This dissertation is the result of the research activities which I have been conducting at the Technische Hochschule Mittelhessen, Friedberg, Germany in cooperation with the Technische Universität München, Munich, Germany, and the ESI Group, Paris, France with I gratefully acknowledge for funding this research.

First of all, my sincere gratitude belongs to Professor Dr.-Ing. Thomas Pyttel who gave me the opportunity to do this dissertation, who inspired me to work hard, who challenged me, who gave me the confidence to complete this work, and I always could rely on. I am thankful for his guidance and advice over the last 13 years. Without him I would not be the person I am today.

Furthermore, I want to thank Professor Dr.-Ing. Fabian Duddeck for his supervision on behalf of the TU München and his contagious enthusiasm in all fields of research. Also, I want to thank Dr.-Ing. Eberhard Haug for providing the basic ideas to this work.

I am very grateful for all the discussions with my former colleague Dr.-Ing. Dominik Hühn for his personal words of encouragement in times when everything went wrong. Also, I would like to thank Dipl.-Ing. Dennis Bublitx and Dipl.-Ing. David Colin from the chair of Carbon Composites at TU München for the valuable discussions on the topic of fabric materials. To all the students I worked with in the past years, who supported me and made my days at University I wanted to say Thank you.

Finally, I would like to thank my family and friends for their backing and patience during my dissertation.

Abstract

The finite element simulation of structural components made of materials with inner structure, like woven fibre composites, is a challenging topic because of the dependence of the properties across scales. To overcome this challenge, usually either full-scale models are used, which model the full component in detail, or macroscopic finite elements with anisotropic continuum mechanical material laws are employed, which try to cover the behaviour by non-linear equations.

A coupled multi-scale approach brings the advantages of both methods together. Macroscopic finite elements are used to model the geometry of the component and a coupled detailed model delivers the behaviour of the inner structure.

This thesis presents a generalised interface, which couples a unit cell model of the inner structure to a macroscopic four node finite element by periodic boundary conditions. The unit cells are modelled by beam and bar finite elements. The method is generalised for unit cells with parallelogram-shaped unit cell geometries. As applications, unit cell models for plain woven fabric are presented, where the beam elements represent the fibre tows, as well as, a model for a bistable auxetic material.

The coupled unit cell model can improve finite element simulations, in terms of calculation time and modelling effort, because the major characteristics can be described in detail by the unit cell without using full-scale models.

Zusammenfassung

Die Finite-Elemente-Simulation von Strukturbauteilen aus Materialien mit innerer Struktur, wie zum Beispiel gewebten Faserverbundwerkstoffen, ist wegen der skalenübergreifenden Eigenschaften ein anspruchsvolles Thema. Um diese Herausforderung zu meistern, werden in der Regel entweder Modelle der Meso Ebene verwendet, die die gesamte Struktur detailliert modellieren, oder es werden makroskopische finite Elemente mit anisotropen kontinuumsmechanischen Materialgesetzen verwendet, die versuchen, das Verhalten durch nichtlineare Gleichungen abzubilden.

Ein gekoppelter Multi-Scale-Ansatz bringt die Vorteile beider Methoden zusammen. Makroskopische finite Elemente dienen zur Modellierung der Geometrie des Bauteils und ein gekoppeltes detailliertes Modell der Meso-Ebene liefert das Verhalten der inneren Struktur.

Diese Arbeit stellt eine verallgemeinerte Schnittstelle vor, die ein Einheitszellenmodell der inneren Struktur durch periodische Randbedingungen an ein makroskopisches finites Element mit vier Knoten koppelt. Die Einheitszellen werden mit Stab- und Balken-Finite-Elementen modelliert. Das Verfahren ist für Einheitszellen mit parallelogrammförmigen Geometrien verallgemeinert beschrieben. Als Anwendungen werden Einheitszellenmodelle für Gewebe mit Leinwandbindung vorgestellt, bei denen die Balkenelemente die Faserbündel darstellen, sowie ein Modell für ein bistabiles auxetisches Material.

Das gekoppelte Einheitszellenmodell kann die Finite-Elemente-Simulation verbessern in Bezug auf Rechenzeit und Modellierungsaufwand, da die Einheitszelle Hauptmerkmale der inneren Struktur detailliert beschreibt, ohne die Meso-Skala komplett zu modellieren.

Contents

1	Introduction	1
2	State of the art and research questions	5
2.1	Draping simulation with the finite element method . . .	5
2.2	Coupled multi-scale approach in fabric forming	10
2.3	Aims and objectives	17
3	Prerequisites from continuum mechanics	19
3.1	Kinematics	19
3.1.1	Configurations and motion of deformable continuum bodies	19
3.1.2	Deformation	21
3.1.3	Rate of deformation tensor	23
3.1.4	Strain tensors	24
3.2	Kinetics	25
3.2.1	Concept of stress	25
3.2.2	Objective stress rates	27
3.2.3	Balance principles	28
3.3	Constitutive equations	30
4	Coupled multi-scale solution strategy	32
4.1	Solution strategies for non-linear problems	32
4.2	Coupling approach vs. constitutive relation	42
4.3	Consequences of coupled multi-scale solution	47
5	A finite element with coupled parallelogram-like unit cell	52
5.1	Definitions for the finite element and the unit cell model	52
5.2	Kinematics interface of the coupled approach	60
5.3	Solution method for unit cell finite element model . . .	64
5.4	Kinetics interface of the coupled approach	66

6	Capabilities of the interface - Unit cell models	69
6.1	Capabilities of the interface	69
6.2	Unit cell models for fabrics	82
6.2.1	Two-dimensional unit cell model for plain woven fabric	82
6.2.2	Three-dimensional unit cell model for plain woven fabric including shear	93
6.3	Generalisation for non-draping	100
7	Examples	105
7.1	Tensile test of plain woven fabric	105
7.2	Double dome draping benchmark example	117
7.3	Double diaphragm forming process	120
8	Conclusions	125
8.1	Critical reflection	125
8.2	Summary of the main contributions	127
8.3	Outlook	127
	Bibliography	137
	List of figures	157
	List of tables	165
A	Testing interface	166
A.1	Interface kinematics	167
A.2	Interface kinetics	169
B	Tensile test of patch with auxetic bistable UCM	173
C	Bias extension test	176
D	Implementation of periodic boundary conditions	179