Chair for Computation in Engineering
Fakultät für Bauingenieur- und Vermessungswesen
Technische Universität München

High-order finite elements for material and geometric nonlinear finite strain problems

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Vollständiger Abdruck der von der Fakultät für Bauingenieur- und Vermessungswesen der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktor-Ingenieurs

genehmigten Dissertation.

Vorsitzender:		Univ.-Prof. Dr.-Ing. Dr.-Ing. habil. G. H. Müller
Prüfer der Dissertation:		
	1.	Univ.-Prof. Dr.rer.nat. E. Rank
	2.	Priv.-Doz. Dr.-Ing. St. Hartmann, Universität Kassel

Die Dissertation wurde am 24.09.2007 bei der Technischen Universität München eingereicht und durch die Fakultät für Bauingenieur- und Vermessungswesen am 31.01.2008 angenommen.

Berichte aus der Bauinformatik

Ulrich Heisserer

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Shaker Verlag
Aachen 2008

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., 2008

Printed in Germany.

ISBN 978-3-8322-7703-1
ISSN 1612-6262

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

Zusammenfassung

Finite Elemente hoher Ordnung (p-Version) werden zur Simulation von geometrisch und materiell nichtlinearen Problemen angewandt. Neben hyperelastischen Materialien wird ein viskoplastisches Modell mit inneren Variablen verwendet. Das Algebro-Differentialgleichungssystem, welches aus der räumlichen Diskretisierung der schwachen Form entsteht, wird mit der Backward-Euler Methode zusammen mit dem Mehrebenen-Newton-Verfahren gelöst. Um den Prozess des kalt-isostatischen Pressens effizient abzubilden, werden ein axialsymmetrisches Element für große Dehnungen, Reaktionskräfte und Folgelasten für die p-Version abgeleitet. Analytische Vergleichslösungen zeigen, dass die p-Version volumetrisches Locking auch für große Dehnungen überwindet. Die effiziente Anwendung der entwickelten Methoden auf einaxiales und isostatisches Pressen von Metallpulvern wird demonstriert. Ein komplexes Validierungsbeispiel zeigt gute Übereinstimmung mit dem Experiment.

Abstract

For the simulation of geometric and material nonlinear problems implicit high-order (p-version) displacement-based finite elements are applied. Beside hyperelastic materials a finite strain viscoplasticity model with internal variables is considered. We apply the combination of Backward-Euler integration and Multilevel-Newton algorithm to solve the system of differential-algebraic equations resulting from the space-discretized weak form. For an efficient modeling of the cold isostatic pressing process an axisymmetric finite strain element, reaction forces and follower loads are derived in the p-version context. We demonstrate that the p-version can overcome volumetric locking also in the finite strain case. An adaptive time-stepping algorithm is presented to perform simulations of metal powder compaction. We report applications to die-compaction and isostatic pressing processes, and a complex validation example where a good agreement to experimental data is achieved.

Acknowledgements

I would like to thank all those people who contributed in any way to this dissertation. First of all, I thank my supervisor Prof. Ernst Rank for his continuous support and the opportunity to work in a very stimulating environment on the GIF project. PD Dr.-Ing. Alexander Düster was not only significantly involved in the definition of the project, but also had always an open door for discussions and dared to join the adventures in Israel.

I owe Dominik Scholz very much for introducing me to the world of high-order finite elements and supervising my diploma thesis. Hanne Cornils not only managed to 'run' our chair, she indeed was the heart and soul, I wish her all the best. Especially, I want to thank my officemate Petra Wenisch for good times and her friendship. Thanks go to all colleagues, with whom I share many pleasant memories and look back to some thrilling (table) soccer games.

For a friendly and fruitful cooperation, I would like to thank all colleagues of this GIF project, namely Prof. Moshe P. Dariel, Prof. Nahum Frage, Prof. Stefan Hartmann, Prof. Stefan Holzer, and Prof. Zohar Yosibash as well as Wolfgang Bier, Idit Cohen, Magda Martins-Wagner, and Moti Szanto. I specially want to thank Zohar Yosibash and his group for the hearty hospitality during my stays in Israel.

Furthermore, I want to thank Stefan Hartmann for being the second reviewer of this thesis and his very constructive and detailed remarks. Additionally, I thank Prof. Gerhard Müller for chairing the examination.

With gratitude, I think of all those people who benevolently fostered my development — my family, teachers, and friends in Friedberg, Munich, and beyond. And Andrea, thanks for all the fish.

The support by the German-Israeli Foundation of Scientific Research and Development under grant I-700- 26.10/2001 is gratefully acknowledged.

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