Rezensionen

Capriz, G.; Mariano, P.M. (Eds.):
Advances in Multifield Theories for Continua with Substructure
Series: Modeling and Simulation in Science, Engineering and Technology
Birkhäuser, 2004, 263 pp., 45 illustrations
ISBN 0-8176-4324-9, 115,56 €

The current work represents a collection of works dealing with multifield approaches to materials with microstructure. To say the least, this compendium is extremely diverse; in fact, so diverse that at least one of the contributions (i.e., that of Miroslav Silhavy), although extremely interesting, is neither multifield nor deals with continua with microstructure, at least not in Capriz's sense [4]. To be fair, as the editors point out in their preface, "research in multifield theories is vast, and there is little in the way of a comprehensive distillation of the subject from an engineer's perspective." On the other hand, exactly such a "comprehensive distillation" would have been much more useful for the engineer than the current work, which is for my taste much too disparate. From an engineering point of view, it would have also been quite desirable to have included one or two contributions having to do with numerical methods for the simulation of the effect of material microstructure on the continuum behaviour [works such as, e.g., 11, 12]. Again to be fair, as implied by the editors, this was not their intention; rather, they wish to "tackle some fundamental questions, suggest solutions of concrete problems, and strive to interpret a host of experimental evidence."

In this vein, the compendium begins with a work by M. Silhavy in Chapter 1 investigating the consequences of the (cyclic) second law and Ilyushin postulate for ideal elastic-plastic materials at finite deformation. In particular, he shows that this latter postulate leads to (extended) energy functions which satisfy stronger dissipation inequalities than those implied by the second law. This is followed by a contribution from G. P. Parry in Chapter 2 on a (generalized) elastic-plastic decomposition of the deformation gradient in the context of crystal plasticity. Here, the microstructural fields take the form of the lattice vectors (i.e., in the sense of the continuum theory of dislocations). Parry's approach is based on the idea that *compatible* deformations or changes of reference placement represent elastic deformations in the sense that they leave certain properties of the lattice vector fields and their gradients *unchanged.* Inelastic material behaviour is also the subject of Chapter 4, in which O. Nairmark considers a order-parameter-based approach to dynamic continuum defect and dislocation mechanics as a means of modeling dynamic plasticity and fracture phenomena. Such an order-parameter or phase-field-based approach to the modeling of materials undergoing solid-solid transformations between austenite and martensite phases is discussed in Chapter 9. Here, D. Bernardini and T. J. Pence consider three such fields. Two are of a scalar nature, and the third is a second-order tensor. Their approach accounts not only for pseudoelasticity and shape memory behavior, but also for the high temperature reorientation of martensitic variants.

Jumping to the mathematical side of things, the contribution in Chapter 3 from H. Cendra, J. E. Marsden, and T. S. Ratiu deals with the differential geometric Poisson (i.e., mathematical) structure of the infinite-dimensional phase space for complex fluids such as spin glasses. Analogously, R. Segev formulates in Chapter 7 a generalized differential geometric notion of flux field for extensive quantities on generalized structured material manifolds. In his approach, material elements are considered to be integral manifolds of the flux field. As a last contribution in this vein, G. Capriz and P. M. Mariano examine in Chapter 10 the modeling of sharp interfaces and junctions as structured surfaces or lines. This is done via the introduction of surface microstresses and self-forces, as well as line stresses and self-forces, and their balances.

The basis of many modern-day multifield models (and in particular those for materials with microstructure) can in a sense be traced back to statistical mechanics or to the kinetic theory of gases as based on a *distribution function.* For example, the kinetic theory of gases has been generalized in the last twenty years or so into the approach of extended thermodynamics. As pointed out by I. Müller in Chapter 5, extended thermodynamics represents in a sense the paradigm of a multifield model, i.e., at least for ideal gases and simple fluids. Using a standard Langevin-Fokker-Planck-based approach to model the probability distribution function of macromolecular chains in polymer fluids, E. De Angelis, C. M. Casciola, P. M. Mariano, and R. Piva discuss in Chapter 6 the case of turbulence in such fluids. In particular, when turbulence is present in such fluids, drag is reduced as a result of interaction between the macromolecules. In the semidense case, ensemble averaging results in a multifield approach in which one can introduce spatial gradients of the order parameter fields to represent contact interactions between neighboring families of polymer chains resulting in such drag reduction. Another type of ensemble averaging in continuum mechanics to obtain effective or "mean-field" behaviour is that represented by homogenization theory. This is the subject of the contribution of Y. Grabovsky in Chapter 8. As discussed by him, in general, there is no guarantee that the tensors of effective material properties need be symmetric. Nevertheless, exact relations among material constants can be obtained giving us information on the resulting composite, regardless of the complexity of the material texture.

The individual contributions in this compendium are certainly quite interesting and worth reading. Since it was never their intention to do otherwise, I'm not going to criticize the editors for this hodgepodge of contributions. Nevertheless, the compendium could have profited tremendously from an introductory

chapter attempting to place (at least some of them) into the large scheme of things. For example, one can portray the "mean-field" approaches to materials with microstructure (examples of which appear in Chapters 2, 3 and 7-10), as based in a sense on the seminal work [4] of Capriz himself, as special cases of the more general statistical-mechanics-based-approach (examples of which appear in Chapters 4-6). Indeed, a "mean" description is obtained from the "distributed" one via ensemble averaging, a process referred to by physicists as "coarse-graining". Here, "microscopic" or generalized balance relations depending on the standard continuum as well as additional "microscopic" degrees-of-freedom are postulated and then averaged over the "microscopic" or additional degrees-of-freedom to eliminate these and obtain "standard" continuum forms plus interaction terms having to do with the microstructure at hand. For example, the use of a distribution function to describe evolving anisotropic behaviour began (to my knowledge) in the late 1970's and early 1980's in the area of rheology and polymer solutions [e.g., 7, 6, 5, 2]. In the 1990's, this use was extended into the area of liquid crystals with variable orientation [e.g., 9, 3, 8], to the description of induced anisotropy in polycrystals [e.g., 1], as well as to engineering applications [e.g., 11, 12]. Statistical mechanical or analogous derivations of continuum balance relations [e.g., 15, 13, 16, 14], averaging approaches in multicomponent and multiphase systems [e.g., 10], or distribution-function-based approaches [e.g., 3, 8] to the modeling of uniaxial and biaxial nematic liquid crystals having variable orientation, also represent examples of this. As shown in [17, 18], all of these are special cases of a very general approach applying to many other kinds of microstructure (e.g., grain structure and texture, dislocation structures, chain structures in polymers, molecular ordering in liquid crystals) having in common the fact that the *distribution* of microstructure or of microstructural states in a material point directly influences the macroscopic behaviour.
In any case, maybe next time.

B. Svendsen

References

[1] Adams, B. L., Boehler, J. P., Guidi, M., Onat, T., Group theory and representation of microstructure and mechanical behaviour of polycrystals, *Journal of the Mechanics and Physics of Solids,* 40, 723-737, 1992.

[2] Bird, R. B., Curtiss, C. F., Kinetic theory and rheology of solutions of rigid rodlike molecules, *Journal of Non-Newtonian Fluid Mechanics,* 14, 85–101, 1984.

[3] Blenk, S., Muschik, W., Orientation balances for nematic liquid crystals, *Journal of Non-Equilibrium Thermodynamics,* 16, 67–87, 1991.

[4] Capriz, G., *Continua with microstructure,* Springer Tracts in Natural Philosophy, 37, 1989.

[5] Clement, A., Prediction of deformation texture using a physical principle of conservation, *Material Science and Engineering,* 55, 203–210, 1982.

[6] Doi, M., A model for macromolecular liquids at high concentration, *Journal of Polymer Science and Polymer Physics Edinburg,* 19, 229–243, 1981.

[7] Doi, M., Edwards, S. F., A model for macromolecular liquids at high concentration, *Journal of the Chemical Society Faraday Transactions II 74,* 560–570 and 918–932, 1978.

[8] Ehrentraut, H., Muschik, W., Balance laws and constitutive equations of microscopic rigid bodies: A model for biaxial liquid crystals, *Molecular crystals and liquid crystals,* 262, 561–568, 1995.

[9] Ericksen, J. L., Liquid crystals with variable degree of orientation, *Archive for Rational Mechanics and Analysis,* 113, 97–120, 1991.

[10] Hassanizadeh, M., Gray, W. G., General conservation equations for multiphase systems: 1. Aver-aging procedure, *Advances in Water Research*, 2, 131–144, 1979.

[11] Kumar, A., Dawson, P., The simulation of texture evolution with finite elements over orientation space, I. Development, *Computer Methods in Applied Mechanics and Engineering,* 130, 227–246, 1996a.

[12] Kumar, A., Dawson, P., The simulation of texture evolution with finite elements over orientation space, II. Application to planar crystals, *Computer Methods in Applied Mechanics and Engineering,* 130, 247–261, 1996b.

[13] Murdoch, A. I., A corpuscular approach to continuum mechanics: basic considerations, *Archive for Rational Mechanics and Analysis,* 88, 291–321, 1985.

[14] Murdoch, A. I., Bedeaux, D., On the physical interpretation of fields in continuum mechanics, *International Journal of Engineering Science,* 31, 1345–1373, 1993.

[15] Noll, W., Die Herleitung der Grundgleichungen der Thermomechanik der Kontinua aus der Statistischen Mechanik, *Journal for Rational Mechanics and Analysis,* 4, 627–646, 1955.

[16] Pitteri, M., Continuum equations of balance in classical statistical mechanics, *Archive for Rational Mechanics and Analysis,* 94, 291–305, 1986.

[17] Svendsen, B., A fibre bundle model for structured continua, *Zeitschrift für Angewandte Mathematik und Mechanik,* 76, S209-S210, 1996.

[18] Svendsen, B., On the continuum modeling of materials with kinematic structure, *Acta Mechanica,* 152, 49-80, 2001.

Hollburg, U.:
Maschinendynamik
Oldenbourg Verlage
1. Auflage 2002, 339 S.
ISBN 3-486-24643-7, 29.80 €

Das Buch „Maschinendynamik“ von Udo Hollburg ist in der Reihe „Lehrbücher für Ingenieure“ im Oldenburg Verlag erschienen. In 8 Kapiteln gibt der Autor eine Einführung in die Maschinendynamik und deckt dabei die große Bandbreite der zu dieser Fachrichtung gehörenden Themen nahezu vollständig ab. Von den Grundlagen der Kinematik und Dynamik, der linearen Schwingungsmechanik mit einem und Systemen mit mehreren Freiheitsgraden, die eine gelungen Darstellung der mechanisch-elektrischen Analogien enthält, wird der Bogen bis zu einer Einführung in die Rotordynamik geschlagen. Breiten Raum nehmen hierbei die unwuchterregten Schwingungen ein und wie in einem Buch zur Maschinendynamik zu erwarten, wird auch die Problematik des Auswuchtens starrer Körper behandelt. Im Abschnitt über die Biegeschwingungen von Wellen gibt der Autor eine kurze Einführung in numerische Methoden und beschreibt ausführlich ein FEM- Element mit Massenexzentrizität und Kreiselwirkung. Insgesamt sehr positiv ist zu vermerken, dass trotz der Fülle des behandelten Stoffes nur sehr wenige Gleichungen „vom Himmel fallen“. Da das Buch eine Vielzahl von nachvollziehbaren praktischen Rechenbeispielen enthält, kann die vermittelte Theorie sehr schnell zur Anwendung gelangen.

So bleiben wirklich nur wenige Kritikpunkte. Es wäre sicherlich sinnvoll im Zusammenhang mit der Behandlung des elastisch gelagerten Rotors und der gyroskopischen Terme der Bewegungsgleichung beispielhaft eine Darstellung der drehzahlabhängigen Eigenfrequenzen aufzunehmen. Auch gelingt es nicht immer, die zahlreichen Übungsbeispiele lediglich auf der Basis der zuvor präsentierten Theorie zu bearbeiten. Kleinere Fehler und Unklarheiten z.B. im Abschnitt über die Fouriertransformation werden sicher in einer 2. Auflage bereinigt.

Wie bei einem Lehrbuch nicht anders zu erwarten, werden dem Leser keine wissenschaftlichen Neuheiten präsentiert, aber die Qualität einer solchen Publikation ergibt sich aus der Auswahl und Präsentation des zu vermittelnden Stoffes. In diesem Sinne ist das von Udo Hollburg geschriebene Buch Maschinendynamik als gelungen zu bezeichnen. Dies ist um so wichtiger, da die fraglos wichtigen Lehrinhalte der Maschinendynamik und Schwingungslehre an vielen Hochschulen im Moment eher zum Gegenstand von Kürzungen im Vorlesungsumfang werden. Gute Lehrbücher können da in keinem Fall schaden.

J. Strackeljan

Hartmann, F.; Katz, C.:
Structural Analysis with Finite Elements
Springer Verlag Berlin-Heidelberg New York 2004
484 pages, 345 figures
ISBN 3-540-40416-3, 85,55 €

This book explains the theoretical foundations of the finite element method and its application in civil engineering. It is essentially a revised and slightly extended English version of the authors German counterpart “Statik mit finiten Elementen” published by Springer in 2002. As the title suggests, the finite element method for linear-elastic problems is illuminated here in a language which is familiar to civil engineers.

The book is subdivided into 7 chapters. The first chapter with the title “What are finite elements?” provides the introduction into various aspects of the method as, e.g., potential energy, the principle of virtual displacements, the error of a finite element solution, singularities, numerical integration and interpolation polynomials. It is followed by a short chapter on “What are boundary elements?”. About 200 pages later both questions seem to be answered and the remaining part of the book concentrates on“ Frames”, “Plane problems”, “Slabs” and “Shells” as the typical applications of finite element analysis. The concluding chapter “Theoretical details” summarizes the mathematical foundations from vector algebra and Green’s functions up to the basic concepts of a posteriori error analysis.

The book focuses on ideas and concepts rather than a consequent derivation of the finite element technique. By means of many examples (e.g., taut ropes, shear walls, hinged slabs, chords, belly shaped beams, columns, reinforced walls, etc.) the fundamentals of the finite element method are explained and explored. Special emphasis is posed on the question of accuracy and error of the numerical solution. At the same time, the structural mechanics behind the finite element method is illuminated. This approach may provide new inside to the reader but may as well be a drawback: the very specific language of civil engineering is not necessarily familiar to engineers from neighbouring subjects.

The authors presume the reader to know the basic techniques and terms of finite element analysis; the text is addressed to practitioners who wish to gain inside into a method which is widely applied in today’s design processes. But although the book is hardly suited as an introductory textbook many detailed derivations of stiffness matrices, coincidence tables etc. are provided. Especially in the first chapter the mathematical background is explained in detail. Some illustrative subtitle are, e.g., “Why finite element results are wrong”, “Why stresses jump” or just “Warning”. Many problems are well explained, for example, the question of convergence, the coupling between beams and slabs and why reduced integration may cause hourglass modes. Unfortunately, the fact that the chapter is divided into 43 sections (without subsections) does not ease reading. It also makes it impossible to look up something quickly. That is a pity, especially because the text summarizes and interprets many results of recent mathematical literature.

This lack of structure is also found in the following shorter chapters. Nonetheless, innovative interpretations, detailed explanations and many illustrations make the book worth reading. For example, in chapter 5 ("Slabs") the fundamentals of plate theory are summarized for Kirchhoff plates as well as for Reissner-Mindlin plates. Both theories are discussed and artifacts, as, e.g., corner singularities of the stress resultants are compared in tables. In particular, the different boundary conditions are nicely illustrated.

All in one, the book gives a state of the art overview on finite element analysis for static, linear elastic problems. Questions which arise in modelling structures are discussed from the civil engineering point of view. Dynamical problems, vibrations, nonlinear material laws, stability of structures and large deformations are either not or only in passing mentioned. The book seems mainly intended for the civil engineer who already applies finite element software, but it also offers interesting insight for those studying numerical methods in engineering.

K. Weinberg

Oertel, H.; Laurien, E.:
Numerische Strömungsmechanik
Vieweg Verlag, 2., neu bearbeitete Aufl. 2003,
257 S., 145 Abb.
ISBN 3-528-03936-1, 26,90 €

Das Buch „Numerische Strömungsmechanik" von Herbert Oertel jr. und Eckart Laurien ist in seiner zweiten Auflage im Jahre 2003 beim Vieweg Verlag erschienen. Seit der ersten Auflage von 1995 hat sich auf diesem schnell wachsenden und sich immer erneuernden Gebiet viel verändert. Diese 2. Auflage beinhaltet wesentliche Veränderungen, insbesondere eine Vielzahl von Erweiterungen. Die Spektralmethoden werden nicht mehr diskutiert, und anstatt des Kapitels „Rechnerarchitekturen und Rechnertechnik" kommen mehrere interessante Anwendungs- und Verifikationsbeispiele vor. Die Grundgleichungen der Strömungsmechanik sind für viele verschiedene Fälle dargestellt.
Die Ingenieure, die sich mit numerischer Strömungsmechanik beschäftigen, müssen sehr viele verschiedene Gebiete ausführlich kennen. Diese weit verzweigten Kenntnisse zusammenzufassen ist keine einfache Aufgabe, den Autoren ist es aber im Rahmen dieses Werkes sehr gut gelungen, wenn auch über die Direkte Numerische Simulation und über die Großwirbelsimulation nicht viele Informationen zu finden sind. Die Lösung von Gleichungssystemen wird konzentriert und kurz gehalten.
Die meisten verwendeten numerischen Verfahren, wie z.B. die Finite-Differenzen, Finite-Volumen und Finite Elementen Methode, sind ausführlich behandelt und die wichtige Rolle der Konvergenz und Fehleranalyse wird eingehend diskutiert.
Dieses Buch ist sicherlich ein „Muss" für Anfänger auf diesem Gebiet, weil es über die relevanten Methoden eine Vielzahl nützlicher Informationen beinhaltet und alle wichtigen Definitionen darin vorkommen. Dieses Werk kann auch sehr gut für die Lehre als Hilfsmittel verwendet werden.

D. Thevenin

Czichos, H.; Habig, K-H.:
Tribologie-Handbuch ('Tribology Manual')
Vieweg Verlag, 2nd edition, Wiesbaden 2003
666 S., 471 Abb., 115 Tab.
ISBN 3-528-16354-2, 99,00 €

A second revised and extended edition of the *Tribology Manual* has been published. It has been edited by Prof. E. Santner and Dr. M. Woydt, both from the Federal Institute for Materials Research and Testing (BAM) in Berlin, with contributions by other specialists in the field.

Chapters 1 to 5, which deal with basic principles, have been left more or less unchanged, with the exception of the new section on microcontacts which has been added. In light of the increasing importance of nano- and microtribology, the chapter on test engineering has been complemented by a section on test engineering for micro and nanotribology. The key chapter on tribotechnical materials has been updated and extended to cover innovative materials, and contains results from recent trials. The manual now also includes chapters compiled by outside experts on hydrodynamic lubrication, elastohydrodynamic lubrication, fluid film and dry rubbing bearings, rolling-element bearings, micromechanical systems (magnetic data recording) and cutting tools.

Czichos' and Habig's *Tribology Manual* in its revised, updated edition is now even more interesting than before, both as an up-to-date reference work for design engineers and machine or unit developers, production engineers, materials and process technicians, maintenance engineers, and physicists and chemists dealing with tribological issues, and as a textbooks for students of tribology.

The *Tribology Manual* sets out the basic principles of tribotechnical systems and their characteristic parameters, as well as of friction and wear. It offers an insight into methods of friction and wear testing, illustrated with case studies. It also presents the fundamental principles of lubrication and lubricants. Once again, a central theme of the book is the friction and wear behaviour of tribotechnical materials (metallic, ceramic and polymeric materials, but also carbides and surface protection layers). As well as the chapters on basic principles, lubrication and materials, however, applied tribology is also discussed at length. Thus the book deals with tribotechnical components used in mechanical engineering (bearings, gearwheel pairs, slide ring seals, piston rings/cylinder barrels, cams/cam followers), micromechanical systems, and cutting tools and forming dies used in production engineering. The comprehensive appendix, which contains illustrations of signs of wear, the friction and wear parameters of selected tribological pairing systems and standards of tribology, is also very valuable and of great assistance to its audience.

This 2nd edition of the *Tribology Manual* can be highly recommended to anyone with a tribological problem to solve, and is essential reading for anyone specialising in the field of tribology.

L. Deters

Truesdell, C.; Noll, W.:
The Non-Linear Field Theories of Mechanics
3rd edition, 602 pp.
Springer-Verlag Berlin Heidelberg New York 2004
ISBN 3-540-02779-3, 85,55 €

The Springer-Verlag now published the third edition of the historical Volume III/3 of the Encyclopedia of Physics The Non-Linear Field Theories of Mechanics (NFTM). The first edition published in 1965 was sold out soon. The second edition published in 1992 contained only minor changes and Truesdell and Noll emphasized that they did not intend to bring the book up to date. The third edition published in 2004 has been edited by S. Antman and similar to the second edition contains only a few changes. Antman only incorporated handwritten correction and additions made by C. Truesdell in his personal copy.

The NFTM is one of the fundamental works on non-linear continuum mechanics and in the late sixties it represented the state of the art. Here the intention is not to review this masterpiece of science. I would just like to mention two valuable texts by Antman and Noll which have been placed in front of the book.

The first text is a 6-page paper by W. Noll where he discusses the genesis of the The Non-Linear Field Theories of Mechanics. Presenting several citations from his personal communications with Truesdell, Noll describes his relation to Truesdell during the period both of them were writing the book. This text gives interesting insights into the genesis of their work.

The second text is the preface to the third edition by Antman. Antman briefly discusses some of the subsequent developments in continuum mechanics in the spirit of the work of Truesdell and Noll. According to Antman, these developments concern for example constitutive restrictions in non-linear elasticity, homogenization theory, thermodynamics, and non-simple materials. Antman presents a list of references for each of these topics 'which offers an entree to a voluminous literature'. He concludes: 'The advances beyond the permanent scientific conquests collected in NFTM proved to be slow and painful, many requiring technically difficult mathematics or refined numerical techniques... Consequently there are numerous open problems of rational continuum mechanics awaiting analysis. Truesdell and Noll have established a firm basis foundation for such research. It is interesting to note that their system of notation, symbols, and terminology has been widely adopted, even by scientific descendents of critics of their enterprise. The availability of powerful computers has made it feasible to conduct numerical studies of precisely formulated non-linear problems of continuum mechanics, and has thus endowed theoretical works like NFTM with a practical permanence that its authors may not have intended. No doubt, these arguments justify the reprint of the The Non-Linear Field Theories of Mechanics.

T. Böhlke