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Book Review

Mathematical Analysis of Continuum Mechanics and Industrial Applications. Proceedings of the International Conference CoMFoS15. Itou H., Kimura M., Chalupecký V., Ohtsuka K., Tagami D., Takada A. (Eds.). Springer, Springer Nature Singapore Pte Ltd. 2017. ISBN 978-981-10-2632-4

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The book contains the papers presented at the international conference CoMFoS15 (”Continuum Mechanics Focusing on Singularities”) held in Fukuoka, Japan, at the Nishijin Plaza of Kyushu University, November 16–18, 2015. The initial point of the conference series CoMFoS dates back to 23 years, when a small workshop on mathematical fracture mechanics was organized in Ishikawa, Japan, 1995. The authors of these meetings were scientists and practitioners, who invariably believed the great importance of mathematics for further development of engineering and industry, especially in the field of physics of continuum media. The basic purpose of the CoMFoS15 was to provide a wide forum for presentation and discussion of recent developments in mathematical modeling and techniques used in fracture mechanics, shape optimization for product design as well as in phenomena of earthquakes and inverse problems, fluid mechanics and interface dynamics, and in the industrial applications.

The text is organized in five parts containing 17 papers.

Part I, *Fracture Mechanics*, starts with an article by Tanaka and Nakamichi on *Strong but Slippery Adhesion of Mushroom-Shaped Polysaccharide Gels* who are studying the effect of the mushroom shape on the adhesive strength of a polysaccharide gel, taking the thickness of flange of the mushroom shape as a control parameter. An experimental setup is described first, and the results are discussed showing that there exists an optimal proportion of the mushroom shape to exhibit higher adhesive strength. The FEM analysis on the stress distribution over the interface and inside the gel, treated as an isotropic and incompressible linear elasticity material, is performed, and the mechanical reason for the optimal proportion is explained.

The next article by van Meurs, *Bridging the Scales Between Discrete and Continuum Dislocation Models*, concerns the many-particle limit passage of interacting particle systems that describe the collective motion of dislocations in metals. Two scenarios for discrete dislocation dynamics are considered, namely, the pile-ups of dislocation walls and the mixed positive and negative dislocations in two dimensions. The variational technique, so-called the Γ-convergence, was used to pass to the discrete-to-continuum limit of discrete dislocation models. Also, some remarks on the implications of given results to the current understanding of plasticity, are presented.

The subsequent paper by Takaishi on *Phase Field Crack Growth Model with Hydrogen Embrittlement* deals with the crack propagation model in elastic body. The crack growth model with chemical reaction which takes effect to the elastic properties and toughness is formulated, and the adaptive mesh FEM is used to calculate this phase field model. For this purpose, FreeFem++ is utilized, an effective, open-source partial differential equation solver (http://www.freefem.org/ff++/). Some numerical results of crack propagation with and without hydrogen effect are presented and discussed. The last article of Part I, *On Singularities in 2D Linearized Elasticity* by Itou is

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concerned with the solutions of boundary value problems for 2D linearized elasticity equation in domains with non-smooth boundaries. Three boundary value problems are considered for which the asymptotic behavior of the solutions near singular points is analyzed. For these cases, the convergent series expansions of the solution near the tip of a linear crack and a line rigid inclusion are derived.

Part II, *Shape Optimization*, is opened by the paper by Kovtunenko entitled *Two-Parameter Topological Expansion of Helmholtz Problems with Inhomogeneity*. The forward and inverse Helmholtz problems in inhomogeneous medium are formulated, and analyzed by singular perturbations and variational methods. These approaches are intrinsically connected with the methods of topological analysis. A related paper by Azegami, *Solution of Shape Optimization Problem and Its Application to Product Design*, applies the traction method to various shape optimization problems in engineering. This is a numerical method used for solving optimization issues of geometrical domains in which elliptic boundary value problems are defined. These include: the piston crank mechanism, the brake squeal problem, i.e., a vibration phenomenon caused by friction between the rotor and the pad; a method finding bead shapes in shell structure, a 2D Poiseuille flow with sudden expansion, and an electrostatic capacitive sensor used to detect fingers.

The next paper by Ohtsuka on *Shape Optimization by GJ-Integral: Localization Method for Composite Material* is focused on basic facts about the history and fundamental theorems on GJ-integral. This notion denotes Generalized J-integral, also called path-independent integral in fracture mechanics, i.e., the J-integral represents the energy release rate which is defined as the variational derivative of potential energies with respect to crack growth. GJ-integral was conceived as the tool for shape sensitivity analysis of sets of singular points in boundary value problems for partial differential equations. Some extensions of GJ-integral concept to composite materials are presented, and the method to solve shape optimization problem together with the finite element analysis of two examples, is demonstrated. Finally, the paper by Shioda et al. concentrates on *Shape Optimization Approach by Traction Method to Inverse Free Boundary Problems*, where an optimal shape design methodology adapted to free boundary problems governed by the Poisson equation, is described. After the formulation of the problem, the shape derivative of the cost functional is derived, and a weak formulation of the traction method (or H^1 gradient method), is presented. At last, the algorithm of traction method in five steps is outlined and three numerical examples which arise in the theory of quadrature surface are realized, to check the efficiency of the method.

Part III, *Earthquakes and Inverse Problems*, is devoted to the geophysical aspects of natural phenomena. Emoto presents his paper on *Synthesis of Seismic Wave Envelopes Based on the Markov Approximation*, where the development of the Markov approach and its applications in seismology in the case of 2D random heterogeneous media, is reviewed. The Markov approximation is a powerful statistical method to synthesize mean square envelopes for quasi-monochromatic waves in random heterogeneous media. By analyzing the envelope-broadening effect, the statistical properties of the small-scale heterogeneities in the Earth, are estimated. Hirano addresses *Propagation Velocity of Pulse-Like Rupture Along Earthquake Faults*. The basic philosophy of the methods of Rice et al. for modeling the propagation of the pulse-like rupture with the slip-weakening friction law is reviewed and extended [Bull. Seism. Soc. Am. 95(1), 109–134 (2005)]. The model to determine rupture velocity by considering a friction law based on a numerical experiment connected with the observed microscopic fault structures by Hakano is presented and discussed. The last paper of the part III is *Inverse Source Problem for a Wave Equation with Final Observation Data*, in which Jiang et al. investigate the inverse source question for an initial-boundary value problem for a hyperbolic equation with the homogeneous Neumann boundary condition. A generic well-posedness result concerning the uniqueness of such problem based mainly on the analytic Fredholm theory is established and proven, in three steps. Finally, an effective algorithm for the numerical reconstruction of the source term is presented, and some numerical experiments to identify the spatial component in the source term are performed.

Part IV concerns the *Fluid Mechanics and Interface Dynamics*. The paper by Fukumoto et al. on *The Contribution of Kawada to the Analytical Solution for the Velocity Induced by a Helical Vortex Filament and Modern Applications of Helical Vortices*, exposes Kawada's achievements in the field of helical vortices with application to the propeller theory. Prof. Sandi Kawada (1899–1970) was an initiator of aeronautics engineering in Japan, and played a leading role in development of this field in Japan. The Kawada's exact analytical solution for the velocity field induced by an infinite right-handed helical vortex filament is derived, and discussed. Some of von Kármán remarks on Kawada's contribution to development of the vortex model for the wake of rotors are also presented. The subsequent paper, titled *A New Model for Fungal Hyphae Growth Using the Thin Viscous Sheet Equations* by Jong et al. deals with the description of hyphae growth modeled as traveling wave solutions, which correspond to steady tip growth. The system of the first-order ordinary differential equations is constructed with the assumptions that the cell wall building material is transported in straight lines by an isotropic point source (the Spitzenkörper = apical body), and of that the cell wall is a thin viscous sheet. A novel equation which models the hardening of the cell wall with age is also included. The numerical computation of the steady tip growth solutions is preformed, together with the asymptotic expansions of these solutions near the apex and the base of the cell. It should be emphasized that there is no full reference to the literature [6] in page 184; it should be as follows: Confocal microscopy of FM4-64 as a tool for analysing endocytosis and vesicle trafficking in living fungal hyphae. *Journal of Microscopy* **198**, 246–259 (2000). The final paper by Tani entitled *On Boundary Conditions for Hele-Shaw Problem* focuses on the motion of a free boundary in a Hele-Shaw cell. This term refers to the device for investigating two-dimensional flow of a viscous fluid in a narrow gap between two parallel plates. From the mathematical point of view, Hele-Shaw problem is equivalent to solve the Laplace equation for velocity potential under the appropriate kinematic and dynamical boundary conditions. The weakly non-linear stability analysis for the Hele-Shaw problem in radial geometry is performed based on the boundary conditions including the Young–Laplace relation, the effect of viscous normal stress (VNS), and the wetting-layer effect, respectively. The numerical computations indicate that the normal stress balance including the VNS effect is more adequate as the dynamical boundary condition, than others.

Part V, *Industrial Applications*, is devoted to the technologically advanced aspects of continuum mechanics. The paper by Aoyagi on *Computer Simulation of the Phase Separation of Polymeric Materials for Industrial Applications*, discusses the computational issues connected with the phase separation dynamics of thermoplastic elastomers, and of hollow fibers. The used computational methodologies are based on the self-consistent field theory, where the free energy of the system is evaluated using the path integrals of the chain conformations and the ternary Cahn–Hilliard phase field formulation incorporating a Flory–Huggins homogeneous free energy function with hydrodynamics. The succeeding paper by Ide et al. on *Highly Parallel Computation of Generalized Eigenvalue Problem in Vibration for Automatic Transmission of Vehicles Using the Sakurai–Sugiura Method and Supercomputers*, concentrates on the efficient method to solve large-scale eigenvalue problem in vibration analysis. The generalized Sakurai–Sugiura solver implemented on highly parallel supercomputers is used to demonstrate the effectiveness of the method in a vibration problem of an automatic transmission of vehicle. The last paper of the book, by Honda and Tani on *Mathematical Analysis of Synchronization from the Perspective of Network Science*, studies a partial integro-differential equation called the Kuramoto–Sakaguchi equation, which describes the behavior of the probability density of the phase of oscillators as an infinite limit of population, in the context of network science. The local and global-in-time solvability of this equation is analyzed, and the existence of the solution to the vanishing diffusion limit problem is proved.

This book gives the reader a representative view of an enormous variety of continuum mechanics topics. It provides an excellent overview of the current state of research on applied continuum mechanics, and in particular on Computer Aided Engineering, which is becoming a more important methodology to reduce, e.g., the product design time. The required prerequisites for this book are at a level of the advanced researchers; experts in applied mathematics, mathematical fluid dynamicists, and mathematically oriented geophysicists. The book will be also suitable for use in specialized courses for doctoral students.