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# Book Reviews

## *Structures Under Shock and Impact V*

Edited by N. Jones, D. G. Talaslidis, C. A. Brebbia, and G. D. Manolis, Computational Mechanics, Inc., Billerica, MA, 1998, 829 pp., $248.00

This book documents the proceedings of the fifth biennial conference on the subject of the response of structures to explosive shocks and high-, as well as low-, velocity impacts and includes most of the papers presented at the June 1998 meeting at the Aristotle University of Thessaloniki, Greece. There are keynote addresses by T. Krauthammer (Pennsylvania State University) and by A. N. Kounadis (National Technical University of Athens, Greece), with the remaining 69 papers being arranged according to 10 thematic topics: 1) surface structures under blast and explosive shock (4 papers); 2) buried structures under explosions (3 papers); 3) structural crashworthiness and energy absorbing systems (6 papers); 4) dynamic behavior of structures (6 papers); 5) full and scale-model testing (4 papers); 6) interaction between analytical and experimental research (7 papers); 7) seismic engineering applications (5 papers); 8) material response to high rate loading (21 papers) organized into four subtopics: composite laminates (2 papers), brittle materials response (7 papers), deformation and fracture under impact loading (7 papers), and shock wave phenomena (5 papers); 9) behavior of steel and composite structures (3 papers); and 10) behavior of concrete material and structures (10 papers).

Topics 1 and 2 investigate the general area of response of structures to both above- and below-ground explosive loading. The first includes papers on risk analysis of industrial structures to explosions, failure of glass windows impacted by gaseous shock waves, and new architectural "forms" to reduce blast and fragment loading effects. A paper regarding blast-resistant structural steel connections, by T. Krauthammer and G. J. Oh, assesses the structural response and current design practices for steel connections under the influence of blast. The authors' approach is based on adopting current blast-resistant design procedures and advanced numerical simulations for evaluating the behavior of modified seismic-resistant steel connections under blast-induced loads from internal explosions. Papers in this topical area generally rely on the finite element method (FEM) to describe the structural response, with load pulses typically described as a short, intense shock pressure and a longer-duration, lower-intensity gas pressure. Topic 2 focuses primarily on the response of underground pipelines to explosive loading. Because of the extensive problem domains and somewhat prohibitive cost of three-dimensional FEM modeling, as well as complications involving the details of soil-structure interaction, other modeling methodologies are employed to study the behavior of underground pipelines to various explosive loading scenarios.

Six papers appear in topic area 3, structural crashworthiness and energy absorbing systems. These address roadside impact attenuation devices, the impact of ice floes on coastal structures, the effects of cutouts on axially loaded square aluminum extrusions, and the energy absorption capability of foam-cored composite sandwich panels. An interesting paper by N. S. Marshall and G. N. Nurick deals with the effect of induced imperfections on the formation of the first lobe of symmetric progressive buckling of thin-walled square tubes. Purposely induced indentations in thin-walled square tubes are used to decrease the ultimate peak force and to induce controlled, systematic progressive buckling. The tubes are used as energy-absorbing devices. Results of this work indicate that the ultimate buckling load of the tube decreases with an increase in the severity of the imperfection. Furthermore, combining a hole with an indentation has a cumulative effect on both the ultimate buckling load and the size of the first lobe of buckling.

Six papers constitute topic area 4 on the dynamic behavior of structures. Four are dedicated to the use of analytical and finite element models as tools to investigate the behavior of structural elements in response to dynamic stimuli. In the paper by D. Karagiozova and N. Jones, dynamic axisymmetric buckling of cylindrical shells loaded by a Kolsky (split-Hopkinson pressure) bar is studied to analyze the influence of stress wave propagation on the initiation of buckling. The deformation process is studied in detail via numerical simulations, with comparisons to experimental data. An elastic-plastic, strain-rate-insensitive material with linear strain hardening and Bauschinger effect is modeled, with the Tresca yield criterion being used. It was found that the final buckling shape depended strongly on the axial impact velocity and the geometry of the shell and, in general, the entire shell is involved in the deformation process.

Topic 5, on full and scale-model testing, consists of four papers dealing with the development of novel experimental techniques for simulating a variety of dynamic loading environments including explosive welding, pressure pulse loading, techniques for pressure and accelerometer transducer calibration, and simulation of pyrotechnical shocks.

Seven papers appear in topic area 6 on the interaction between analytical and experimental research. Four are dedicated to the use of numerical simulations to simulate impact events. One of these papers, by D. R. Scheffler and L. S. Magness, compares the differences that three individual target constitutive models, Johnson–Cook, modified Johnson–Cook, and Zerreli–Armstrong, make on the finite difference numerical results. The authors compare the results with those of an experimental study that delineated the effect of ogival and hemispherical nose shapes on the threshold velocity at which tungsten alloy penetrators transition from rigid body to eroding rod while perforating finite aluminum targets. The target constitutive model was found to have a greater influence on the predicted residual velocities than on the predicted threshold velocity. The simulations all predicted a much higher rigid-body-to-eroding-rod transition velocity for the ogival nose penetrator vs the hemispherical nose penetrator. Other papers in this session address the theoretical buckling behavior of elastic composite rings, development of an expert system for blast and hazard analysis, orbital debris impact analysis, and foreign object damage to plate structures.

Topic 7 deals with seismic engineering applications, and five papers are present in this subject area. Topics addressed in this section include analysis of building motion when two adjacent buildings collide under seismic loading; seismic performance testing of high-strength concrete columns using an axial reinforcement technique called the "main bar post-insertion system"; FEM analysis of brittle, anisotropic masonry panels in reinforced concrete frames; and development of a mathematical model for studying the seismic motion of weakly coupled modular buildings.

Topic 8, on material response to high-rate loading, includes a large number of papers and was subdivided into four subsections. The first subsection addresses composite laminates, and two papers appear in this subject area. N. Chandra and A. M. Rajendran review micromechanical modeling of high-velocity impact and shock damage in polymeric matrix composites. The various stages of projectile penetration, damage mechanisms, and modeling approaches are briefly covered. The modeling efforts include an outline of the various relationships developed for individual damage mechanisms, followed by phenomenological constitutive relations used in modeling the penetration process. The other subject addressed in this subsection deals with underwater shock wave loading of wood, which is used to selectively fracture the wood to improve permeability and drying time.

The next subsection deals with brittle materials response, and seven papers were contributed in this area. Materials investigated include ceramics and concrete. Five papers are experimental studies investigating the high-strain-rate behavior of cementitious materials; the remaining two are involved with the development of constitutive models to model the shock and impact response of ceramics and concrete. A. M. Rajendran and D. J. Grove describe the dynamic response of aluminum oxide subjected to shock loading conditions. Deformation of this material under such loading has been established, via microscopy, as being due to the mechanisms of microcracking, microplasticity, pore collapse, and twinning. A constitutive model is proposed to describe the stress-strain response of this material to these deformation modes, and the model is implemented in a well-known finite element code used to investigate shock and impact behavior. The dynamic behavior of the aluminum oxide ceramic is then modeled under three types of loading conditions: planar plate impact at velocities below and above the Hugoniot elastic limit, a metal plate impacting an aluminum oxide rod, and a tungsten alloy projectile penetrating a layered ceramic target. The FEM numerical simulations utilizing the constitutive model for aluminum oxide correlated very well with the measured and observed experimental response of the ceramic material.

Seven papers are included in the next subsection, which deals with deformation and fracture under impact loading. A pleasing mix of theoretical, experimental, and numerical papers addressing scaling issues in dynamic fragmentation, high-rate testing with a torsional split-Hopkinson bar and the symmetric Taylor test, evaluation of microstructures on the high-rate-loading response, modeling material failure, and numerical simulation of composite structures under impact loading are offered. An interesting paper by D. Grady explores the complex scaling issues in dynamic fragmentation. The discussion points out that size scaling depends on specific fragmentation mechanisms and the possible changes in these mechanisms with regard to deformation rates and length scales. Consequently, different scaling laws for different material types should not be entirely unexpected. Another paper, by A. Gilat and C. S. Cheng, explores very high rates of loading (to $6.4 \times 10^4$/s) in 1100 aluminum using a torsional split-Hopkinson (or Kolsky) bar. This strain rate is about an order of magnitude higher than what is typically achieved with this experimental technique and is obtained using a very short specimen length, which introduces some error in the measurements. The observed increase in strain rate sensitivity is compared with results obtained from experiments utilizing the pressure-shear plate impact technique at strain rates of $10^5$/s.

The last subsection deals with shock wave phenomena. The five papers in the area deal with subjects such as high-speed metal forming using a liquid shock tube, shock wave validation experiments for an arbitrary Lagrangian–Eulerian code, behavior of quartzite subjected to spherically divergent shock waves, fatigue crack growth analyses, and development of a strain-history-dependent model for concrete.

Three papers are included under topic area 9 on the behavior of steel and composite structures. These papers address ballistic impact on ceramic composite armors, a study of the residual life of a bridge damaged by fragment impact, and a detailed description of a new experimental setup for ballistic penetration studies.

The behavior of concrete material and structures is covered in topic area 10 and is the last and largest (10 papers) thematic topic addressed in the book. Subjects include studies of the transverse (out-of-plane) strength of unreinforced masonry infills, the behavior of prestressed concrete beams under rapid loading, three-dimensional numerical simulations of reinforced concrete slabs subjected to impact and explosive loading, experimental studies on the inelastic behavior of reinforced concrete panels subjected to high-speed loading, the development of a rate-dependent concrete damage model, and a review of concrete penetration models. An interesting paper by G. R. Johnson, S. R. Beissel, T. J. Holmquist, and D. J. Frew describes numerical simulations of radial stresses in a concrete target when penetrated by a steel projectile. The FEM simulations compared computed results to published experimental results for radial stresses and depth of penetration in concrete targets. The concrete model is described in some detail, and the relevant constitutive parameters in the model are compared with triaxial data. The unusual feature of this work is the unique comparison of the computed radial-strain histories with actual experimental measurements of the temporal-strain histories in the target media, which are quite difficult to obtain. In all instances, the FEM numerical simulation results provided good agreement with the experimental results. The numerical simulations also provided estimates of the damage and crack patterns in the concrete.

In recent years, advances in our fundamental understanding of the response of materials and structures to dynamic loading environments have resulted in a number of symposia and conferences dealing with this exciting subject area. The longstanding success of this biennial conference is a further testimony to the interest in this research area and, as such, presents a number of interesting papers dealing with the relevant theoretical, numerical, analytical, and experimental issues. It should be a welcome addition to the library of every scientist and engineer with an interest in this technology.

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## ***Boundary Integral Equation Methods for Solids and Fluids***

Marc Bonnet, Wiley, New York, 1999, 391 pp., $69.95

Until quite recently, introductory engineering textbooks on boundary integral equations (also known as boundary elements) have been virtually nonexistent. The well-known books by Banerjee and by Brebbia, Telles, and Wrobel are comprehensive but, arguably, more suitable as reference books for specialists. The less known (but excellent) book by Crouch and Starfield (1983) is on a more introductory level but is devoted exclusively to two-dimensional elasticity and is, moreover, showing its age. This gap was evidently recognized, as a number of suitable introductory textbooks have been published over the past few years. Marc Bonnet's contribution is ambitious: along with the required basic material, advanced topics at or near the forefront of current research are also presented. The result is a very readable and unique book and one that is, with a few exceptions, highly successful.

The book is divided into four parts, and as has become standard practice the first part covers the boundary element analysis for potential and linear elasticity problems. However, before jumping directly into the subject, an initial chapter provides a brief overview of what a boundary integral equation looks like and the types of problems for which this formulation is appropriate. Readers new to the subject are likely to find this preview very helpful. Useful discussions of this sort, and motivation for why things are done a certain way, are present throughout the book. Specifically, the discussions of singular integral evaluation, the most difficult aspect of boundary elements, are clear, straightforward, and nonintimidating. Another nice feature of this opening section is the inclusion of derivations of the Green's function (or fundamental solution) for the equations considered (including anisotropic elasticity). Green's functions are the basis for boundary integral methods, but most books simply write down the formulas without giving even a hint of how they were obtained.

The penultimate chapter in Part I is entitled "Representation of Gradients and Stresses on the Boundary." This important topic is generally ignored, as it requires a discussion of hypersingular equations and hypersingular integrals. These beasts have been fully domesticated only over the past decade but are an indispensable tool in "modern" boundary elements. (Note, however, that the book by Crouch mentioned earlier contains early work on hypersingular equations that, unfortunately, is often overlooked.) Incorporating, early on, a complete discussion of the definition and computation of hypersingular integrals is an excellent and novel feature and ensures that this book will remain useful for many years to come. The discussion of the core material is concluded in Part II, which is concerned with acoustic and elastic wave problems. One chapter deals with time domain solutions, and one with (what is more natural for an integral formulation?) frequency domain techniques. Most textbooks will cover only the frequency domain approach, and so it is most welcome to have both approaches discussed. Part II concludes with a miniscule chapter entitled "Diffusion, Fluid Flow," which is essentially the entire discussion of fluid problems in the book. Although it can be argued that the numerical techniques presented for elasticity carry over to some types of fluid analysis, the presence of "fluids" in the book title is nevertheless a little surprising.

The advanced or nonstandard material is in two parts: Part III consists of three chapters on general techniques, whereas the two chapters in Part IV concern themselves with specific topics in elasticity. Most of the selections are quite naturally areas of the author's research. Although much of this material is too narrowly focused (e.g., fracture mechanics, domain differentiation) to be of interest to a wide audience, the chapter on the symmetric-Galerkin approximation is of general interest and an important aspect of the book. This method is essentially a weak-form solution of the integral equations and is an alternative to the more common collocation approach. As the author points out, symmetric-Galerkin is rapidly gaining adherents in the community, and thus this chapter provides a good introduction to a possible future for boundary elements.

The book is very successful in combining both core and more exotic material. The two weak points are the short (four pages) sixth chapter ("Some Classical General Results") and Chapter 11 ("Exploitation of Geometrical Symmetries"). The former, uncharacteristically, is an unmotivated collection of disconnected results, and one wonders why it is there at all. The latter, by far the least interesting chapter in the advanced topics section, brings in some imposing (and likely foreign) mathematics (group representations) in a discussion of symmetry in full generality. It would have been more in keeping with the rest of the book to dispose of generality and explain the main idea in a lighter, more intuitive fashion. These flaws are, however, minor and are far outweighed by the many strengths of the book. It is highly recommended for anyone interested in learning about the subject, and it would be an excellent choice for a classroom textbook.

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