

Modern Impact and Penetration Mechanics

Do you want to understand how projectiles are stopped by, or go through, armors and other materials? Master the fundamentals of impact mechanics through the use of analytical modeling, large-scale numerical simulations, and experiments with this practical text. This book spans topics including continuum mechanics, waves and shocks, and the high-strain-rate and large deformation constitutive and failure modeling of solids, and addresses the mechanics of materials in extreme dynamic environments. It also covers the stress and strain tensors and provides understanding of how they are used in modeling large, high-rate deformations. Offering both a qualitative and a quantitative understanding, with an emphasis on solid mechanics, this is an essential text for graduates. In addition, it is perfect as a reference for academic researchers and professionals interested in wave motion, impact, and penetration.

Sales points

- Follows a step-by-step methodology
- Features end-of-chapter exercises
- Appropriate as a supplement to or as a required text for graduate level courses in solid and continuum mechanics and impact mechanics

Dr. James D. Walker is Director of the Engineering Dynamics Department in the Mechanical Engineering Division at Southwest Research Institute in San Antonio, Texas, where he is also an Institute Scientist. He is a Fellow of the American Institute of Aeronautics and Astronautics and the American Society of Mechanical Engineers and a Ballistics Science Fellow of the International Ballistics Society. His awards and honors include the Holley Medal from ASME for his work in support of the space shuttle *Columbia* accident investigation, NASA Group Achievement Awards for work on the space shuttle return to flight and the New Horizons mission to Pluto, and *Popular Science's* 2004 list of “Brilliant 10” scientists to watch. He is also an adjunct professor of mechanical engineering at the University of Texas at San Antonio, where he teaches graduate-level mechanical engineering courses.

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JAMES D. WALKER
Southwest Research Institute

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To Debbie, Brynn, and Tess

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Preface

This is an applied mechanics book about impact and penetration and includes the requisites in continuum mechanics, waves and shocks, and the high strain rate and large deformation constitutive and failure modeling of solids. It addresses the mechanics of materials in extreme dynamic environments. It is easy to envision impact and penetration applications, and these applications have the nice feature that the effects of nonlinear material response, inertia, large deformations, large rotations, and shock behavior can be quantified and appreciated at the macroscopic scale.

The first course I taught in shock waves was an internal course at Southwest Research Institute (SwRI) in 1992 using Dennis Hayes' notes. The first course I taught in plasticity theory was at the University of Texas at San Antonio (UTSA) in 1994. Thanks to Harry Millwater for encouraging me to return to teaching at UTSA in 2005. Chapters in this book have been used in a variety of graduate courses including Advanced Solid Mechanics, Continuum Mechanics, Theoretical and Computational Inelasticity, and Combustion. Penetration mechanics topics have been included in the SwRI Penetration Mechanics Short Course, which has been taught continuously since 1985, with my involvement beginning in the 1990s. The original concept was a joint book with Charlie Anderson, but as I used chapters of the book in my teaching at UTSA and as it grew in scope, it fell upon me to pursue the effort.

This book can be used as a stand-alone text for Continuum Mechanics, Solid Mechanics, and Plasticity courses. Since this book presents many practical computational results, it can be used as a text for Theoretical and Computational Inelasticity when supplemented with a numerical text, papers, or software. The book is written for graduate students in Engineering, Physics, and Mathematics. The big conceptual step is the stress and strain tensors and understanding how they are used in modeling large, high rate deformations. The text and appendices contain the mathematical background required to understand and pursue this material. The mathematical level is a bit uneven, as I chose to present things in the best logical order, which is not a mathematical sophistication order. If the mathematics seems too tedious, the reader is encouraged to skim to the conclusion of the argument or to move on to the next section. In teaching the material, Chapters 13 and 14 and Appendix A can be covered at any point after Chapter 2; I have used various orders, including Chapters 13 and 14 immediately following Chapter 2, then moving on to Chapter 3, etc., depending on when I wanted to present certain material and what background a course project required.

Three individuals have had a significant influence on my work: Charlie Anderson, Sidney Chocron, and Jack Riegel. Charlie hired me out of graduate school and we have worked together for many years. Sidney and I have worked together and

co-taught courses at the University of Texas at San Antonio. Jack Riegel asked me important questions about impact modeling as I began my career, and the process of answering them had a large influence on my research directions. Thank you Charlie, Sidney, and Jack, for our work together and your support and encouragement. Thank you also to my Ph.D. adviser at the University of Utah, Tim Folias, who steered my early work in wave propagation and fracture.

This book has taken two decades to write. I asked Werner Goldsmith how he finished his book *Impact* [77]. His reply was that the publisher asked him to do a second edition, which he vehemently refused to do, informing them the first edition had cost three years of his life and one marriage. Fortunately, for me, the cost has not been as high.

I have the privilege of working at Southwest Research Institute, a unique non-profit research center in San Antonio, Texas. It was founded in 1947 and currently has a staff of 2,700 on 1,500 acres. We are supported entirely by government and commercial research contracts. SwRI colleagues I've worked with include Charlie Anderson, Nathan Andrews, Janet Banda, Andrew Barnes, Hakan Başağaoğlu, Steve Beissel, Rory Bigger, Joe Bradley, Tim Brockwell, Ray Burghamy, Alex Carpenter, Sidney Chocron, Mary Ann Clark, Derrik Coffin, Hervé Couque, Kathryn Dannemann, Dan Durda, Joe Elizondo, Chris Freitas, Charles Gerlach, Walt Gray, Matt Grimm, Don Grosch, Tim Holmquist, Walter Huebner, Gordon Johnson, Ryan Keedy, Trent Kirchdoerfer, Kris Kozak, Jim Lankford, David Littlefield, John MacFarland, James Mathis, Katie McCloud, Michael Moore, Bruce Morris, Nick Mueschke, Scott Mullin, Art Nicholls, Dan Pomerening, Carl Popelar, Jack Riegel, David Riha, Scott Runnels, Erick Sagebiel, Nikki Scott, Dick Sharron, Diane Steiner, Mark Tapley, Ben Thacker, Suzanne Timmons, Randy Tullus, Hunter Waite, Wendy Walding, Greg Wattis, Carl Weiss, Greg Willden, and Bob Young. SwRI staff I reference but did not work with include John Gehring and William Ko. I thank two vice presidents at SwRI who provided a good working environment early in my career, Ulric Lindholm (Engineering and Materials Sciences Division) and Mel Kanninen (Structural Systems and Technology Division). My time at SwRI, particularly the early years, has felt like a golden age in mechanics.

People who helped with the book in particular include my wife, Charlie Anderson, Sidney Chocron, Mike Shearn, Dick Sharron, and Janet Banda.

Reviews of the text in its later stages with many helpful comments were by Sidney Chocron, Deb Deffenbaugh, Rebecca Brannon, an anonymous Cambridge University Press reviewer, and Alicia McAuley (Cambridge). Thank you to the many students who read the chapter drafts and provided feedback. Other colleagues at UTSA and elsewhere who read chapter drafts include John Foster, Hai-Chao Han, Jerry Liu, Dennis Orphal, James Wilbeck, and Justin Wilkerson.

In 2006–2007 my wife Debbie converted the draft from Word to L^AT_EX. She helped with other aspects of the text, including material property tables and proof-reading. She was also, over the many years, very supportive of the effort. The book is dedicated to her and our two daughters in small consolation for the time the book received instead of them.

Finally, thanks to God for this beautiful planet and the breath of life.

James D. Walker
San Antonio, Texas, 2000—2020