COMPUTATIONAL
BALLISTICS II

WIT Press publishes leading books in Science and Technology.
Visit our website for the current list of titles.
www.witpress.com

WIT eLibrary
Home of the Transactions of the Wessex Institute.
Papers presented at Computational Ballistics 2005 are archived in the
WIT eLibrary in volume 40 of WIT Transactions on
Modelling and Simulation (ISSN 1743-355X).
The WIT eLibrary provides the international scientific community with immediate and
permanent access to individual papers presented at WIT conferences.
Visit the WIT eLibrary at www.witpress.com.
SECOND INTERNATIONAL CONFERENCE ON
COMPUTATIONAL BALLISTICS

COMPUTATIONAL BALLISTICS II

CONFERENCE CHAIRMEN

V. Sanchez-Galvez
Univ. Politecnica de Madrid, Spain

C.A. Brebbia
Wessex Institute of Technology, UK

A.A. Motta
Brazilian Navy, Brazil

C.E. Anderson
Southwest Research Institute, USA

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE

D J Benson
E Brizuela
E Dick
N Ishikawa
N Jones
Y Kato
Y Katz
M L Langseth
P J Lu
A Peratta
W P Schonberg

ORGANISED BY
The Wessex Institute of Technology, UK

IN ASSOCIATION WITH
Universidad Politecnica de Madrid

SPONSORED BY
WIT Transactions on Modelling & Simulation
Editors

V. Sanchez-Galvez
*Univ. Politecnica de Madrid, Spain*

C.A. Brebbia
*Wessex Institute of Technology, UK*

A.A. Motta
*Brazilian Navy, Brazil*

C.E. Anderson
*Southwest Research Institute, USA*
Preface

This book contains most of the papers presented at the International Conference on Computational Ballistics held in Cordoba, Spain, in 2005 organised by the Wessex Institute of Technology in collaboration with the Universidad Politecnica de Madrid. The objective of the Meeting was to bring together engineers, scientists and managers from laboratories, industry, government and academia to interchange knowledge in the field of ballistics. The contents stressed the importance and possibilities of numerical simulation on internal, external and terminal ballistics, to describe, analyse, predict and subsequently reduce the experimental requirements in ballistics.

Ballistics as a science relates to a great variety of phenomena that occurs from the moment an object or projectile is fired until its effects are observed in a target. Ballistic studies include applications as varied as the study of the structural and control behaviour of rockets and satellites; strikes on aircraft, terrorist attacks and automobile crashworthiness modelling, to name but a few.

Many of the basic problems of ballistics are similar to those in other fields of applications, such as combustion, heat conduction, in-flight structural behaviour, trajectory related issues, contact, impact, penetration, structural response to shock waves and many others.

The developments in Ballistics are closely related to the Advances in Computational Mechanics but in spite of this, there are currently no open conferences other than the ones organised by the Wessex Institute of Technology on Computational Ballistics.

This book, which is an important addition to the literature, contains the following sections:

- Terminal ballistics
- Fluid-structure interaction
- Perforation and penetration mechanics
- High rate loads, shock and impact
- Interior ballistics
- Fluid flow and Aerodynamics
- Systems and Technology

The organisers are grateful to the members of the International Scientific Advisory Committee who have helped in selection of the papers included in this book. The quality of the material makes this volume a most valuable tool for scientists and research workers in the field to appreciate the state of the art in this important discipline.

The Editors, Cordoba, 2005
Contents

Section 1: Terminal ballistics

Analytical and numerical simulations of ballistic impact on composite lightweight armours
V. S. Gálvez .............................................................................................................. 3

Impact behavior of hybrid rubber materials under rifle shooting
N. Ishikawa, N. Tanaka, Y. Nishimoto & T. Ohno ............................................. 11

Numerical simulation of the tumbling of kinetic energy projectiles after impact on ceramic/metal armours
F. Gálvez, S. Chocron, D. Cendón & V. Sánchez-Gálvez .................................. 21

Analysis of the kinetic energy transfer to the target during impact of the antitank projectiles
A. Morka & J. W. Wekezer .................................................................................... 31

Simulation of a ballistic impact of a deformable bullet upon a multilayer fabric package
R. Barauskas, A. Abraitiene & A. Vilkauskas ..................................................... 41

The use of 3D numerical simulations for the interaction of long rods with moving plates
Z. Rosenberg & E. Dekel ....................................................................................... 53

Modeling the 14.5 mm BS41 projectile for ballistic impact computations
T. J. Holmquist, G. R. Johnson & W. A. Gooch ............................................... 61

Reinforcement through retrofit of fiber/epoxy composites
R. Anaya, O. T. Inal, P. F. Gerity & D. H. Lopez .............................................. 77

Recent advances in Lagrangian computations for ballistics problems involving severe distortions
G. R. Johnson, R. A. Stryk, S. E. Ray & A. A. Johnson ................................... 87
Section 2: Fluid structure interactions

Response of model structure to the proximity of an underwater explosion

Simulation of sympathetic detonation by a CIP Eulerian code

Modelling missile impact and explosion by a finite/discrete element gas-solid interaction
S. Mohammadi .................................................................................... 115

Numerical analysis of the interactive behavior of concrete structures under explosive loading
M. Beppu, M. Katayama, M. Itoh, T. Ohno & T. Krauthammer ............... 127

GRALE2D – an explicit finite element code for two-dimensional plane and axi-symmetric multi-material ALE simulations
L. Olovsson & A. Helte ........................................................................... 137

Section 3: Perforation and penetration mechanics

Effect of lateral confinement on penetration efficiency as a function of impact velocity
C. E. Anderson, Jr. & I. S. Chocron ...................................................... 149

Improvement of penetration performance of linear shaped charges
H. Miyoshi, H. Ohba, H. Kitamura, T. Inoue & T. Hiroe ......................... 159

A computational study of ballistic transparencies
D. W. Templeton & T. J. Holmquist ...................................................... 171

Influence of the constitutive relation in numerical simulations of the perforation of steel plates
S. Dey, T. Borvik, O. S. Hopperstad & M. Langseth .............................. 181

Resistant performance of perforation of layered targets using an estimation procedure with marine application
C.-C. Liang, T.-L. Teng & P.-W. Wu ........................................................ 193
Section 4: High rate loads, shock and impact

Computer simulation of an F-4 Phantom crashing into a reinforced concrete wall
*M. Itoh, M. Katayama & R. Rainsberger* .......................................................... 207

Impact of boulders on granular strata:
a geotechnical rheological model
*C. di Prisco & M. Vecchiotti* ................................................................. 219

Deformation and failure behaviour of Ti-6Al-4V alloy under high rate shear loading
*W. S. Lee & S. Z. Huang* ........................................................................ 229

Dynamic compression failure of two metals at 0.5 and 1.5 GPa
*H. Couque* ............................................................................................ 239

Modelling, simulation and experimental investigation of plates subjected to blast loading conditions
*R. Schmidt & M. Stoffel* ........................................................................ 249

Section 5: Interior ballistics

Minimisation of accelerations during load ejection
*E. A. Brizuela & G. Trinidad* ................................................................. 261

Numerical analysis for double-base propellant combustion
*A. Peratta, C. Gonzalez & E. Dick* ........................................................ 269

Nonsteady interior ballistics of cylindrical-grain solid rocket motors
*D. R. Greatrix* ........................................................................................ 281

Two-phase flow simulation for interior ballistics
*H. Miura & A. Matsuo* .......................................................................... 291

Section 6: Fluid flow and aerodynamics

Analytical calculation of trajectories using a power law for the drag coefficient variation with Mach number
*W. Roetzel* ............................................................................................ 303

Numerical calculation of the unsteady gas flow around a projectile moving through a gun barrel
*V. Ponyavin, Y. Chen & D. W. Pepper* .................................................. 313
Study of asymmetric vortical flow on forebody at high angle of attack
A.-ul-Haque & F. Umar ............................................................ 325

The use of computer algebra and nonlinear optimisation for real time computation of fire orders for direct fire
A. Kuhrt & H. Rothe ............................................................... 337

High performance computation of compressible flows on the Cray X1
S. Tu, S. Aliabadi, A. Johnson & M. Watts ................................. 347

Unconstrained flight and stability analysis of a flexible rocket using a detailed finite-element based procedure
D. J. McTavish, D. R. Greatrix & K. Davidson ............................ 357

Section 7: Systems and technology

Ballistics studies applied to offshore platforms
A. A. Motta & N. F. F. Ebecken ............................................... 371

Computational support of the development of a mortar simulator with re-usable shells
A. Fedaravicius, M. Ragulskis & Z. Klimavicius ............................ 381

Fire control algorithms and software for the modular naval artillery concept (MONARC) of the German navy
H. Rothe, A. Kuhrt, S. Schroeder & S. Trebing ............................ 391

Author Index ............................................................................. 401