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BOOK REVIEW

IMPACT—EFFECTS OF FAST TRANSIENT LOADINGS, W. J. Amman, Wing Kam Liu, J. A. Studer and T. Zimmermann (eds).

Impact simulation has become big business. There are journals dedicated to the topic. At least three conferences every year in Europe and U.S.A. feature impact. There are a dozen codes specializing in impact simulation, using element and difference formulations, and most finite element codes claim to have an impact package. The drive for this activity arises from several sources. The low-velocity 'crashworthiness' type of impact stems from the need to prove survivability of all vehicles on land, at sea or in the air, but particularly road vehicles. Other forms of safety-critical structures subject to low-velocity impact are any nuclear plant or fuel container which may suffer accidental drop, or petrochemical plant containing hazardous or inflammable liquids. Higher-velocity impact events range from blast loadings through ballistic and missile impact up to 1500 $m s^{-1}$ up to hypervelocity re-entry or micrometeoroid impact at up to 70 $km s^{-1}$. All these events have one thing in common: they are experimentally expensive, dangerous or impossible in laboratory conditions. Hence the interest in numerical simulation.

This book is the proceedings of a conference held in Lausanne in 1987 as a post-event to the SMIRT conference. It consists of 17 invited lectures plus four from poster sessions. The big advantage of invited lectures is that they can review an area as well as present original material, and hence this book will be of much interest to analysts wishing to obtain overviews and comprehensive references. Many of the well known numerical and constitutive modellers have contributed articles, but there are also many well known absentees. The coverage is not complete, particularly in the fields of dynamic fracture or impact of fibre-reinforced plastics and metals.

The three main problem areas in impact simulation are well known. Firstly, if strain rate effects are important, there is a dearth of information for many materials, particularly in the range 10^{-1}–10^{4} s^{-1}. Secondly, three-dimensional finite element simulation is expensive and many algorithmic tricks are being exploited to reduce computational costs. Finally, the modelling problems are extreme in complex structures subjected to impact, in addition to the material modelling. In crashworthy investigations, for example, it is not necessary to expect precise forecasts of the stress field; the final collapsed state will suffice. Unfortunately, the progressive collapse history can be extremely sensitive to local detail design, particularly the joint detail between components. Thus many numerical/experimental comparisons will be needed to gain confidence. All three aspects are addressed in this book.

Strain rate effects are reviewed as engineering approximations and based on scientific reasoning for FCC and BCC metals involving elastoplastic thermal interactions covering the whole spectrum up to 10^6 s^{-1}. In contrast, the behaviour of concrete is presented with nuclear containment or missile silos in mind, but limited to 1 s^{-1}. A very comprehensive review is made of experimental work showing failure thresholds increasing with strain rate, and analytical models validated for stiffness and failure.

Ballistic penetration into soil is reviewed using engineering approaches with various simplified models of soil layers. The penetration, complete and partial, by high-velocity projectiles is reviewed as a ballistic code approach or engineering model satisfying conservation of mass, momentum, energy, etc. in integral form only. It is concluded that aerodynamic codes are presently better than solid codes for predicting terminal velocity states.

Hypervelocity impact is presented, including debris dynamics, melting and vaporization. The importance of thermal modelling is demonstrated in one dimension, but material properties and algorithmic limitations remain the main problem when large changes in state and/or geometry occur. Nuclear reactor materials sre further complicated by the effect on flow stress and ductility of creep, fracture and irradiation, as well as strain rate.

The six purely computational papers cover the pros and cons of explicit versus implicit, Lagrange versus Euler, or mixed combinations. Mixed methods and subcycling are discussed as strategies to overcome small critical time steps in algorithms, particularly in the presence of erosion or possible penetration through an element during a small time step. Implicit (Newmark) solutions deploy an element-by-element procedure as preconditioner to the line search and conjugate gradient methods designed to use various versions of Crout, Gauss–Seidel and Lancos.

Two papers discuss arbitrary Lagrange–Euler codes (ALE) which are a compromise allowing large distortions, which would embarrass a Lagrange description, by continuous rezoning but keeping the necessary interfaces between regions intact. The convective terms which complicate the Euler descriptions can be much reduced by stipulating mesh movements to follow the deformations. mesh adjustment is both selective and adaptive, and examples presented use both volumetric and shear distortions as the trigger. Problems addressed are the algorithms for node movements and 'upwinding' for shock stabilization without diffusion.

There are several useful case studies, all using available commercial codes, and the predictions are reconciled with experimental tests. A thin-walled aluminium cylinder is subjected to blast pressure over a 'spot', but rupture is based on principal strain only and rate effects are ignored. Reinforced concrete shells are impacted, using different models for the steel and concrete: again fracture is predicted as a maximum strain. Some useful comparisons are made for low-velocity buckling of a thin-walled beam column, for high-velocity plate perforation and for the usual squashed cylindrical billet with rate dependences and metal melting.

Finally, the results are presented of Japanese evaluation of 10 impact codes using several very comprehensive benchmarks which incorporate strain rate effects on flow stress and moduli, bouncing, sliding with friction, dissimilar materials (lead and steel) and artificial viscosity limits.

This book is not a complete coverage of impact simulation, but it does cover most of the currently recognized problems and presents the capabilities of codes, including some limitations. (Hourglassing in cheap brick elements is not mentioned.) It will therefore serve as a good summary and introduction for practitioners and newcomers to the field of impact.

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