

Finite element crash simulations and impact-induced injuries

A bibliography (1980–1998)

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This bibliography lists references to papers, conference proceedings and theses/dissertations dealing with finite element simulations of crashes, impact-induced injuries and their protection that were published in 1980–1998. 390 citations are listed.

Keywords: Finite elements, contact-impact problems, crash simulations, impact-induced injuries, injury protection, bibliography

1. Introduction

Information is the most valuable, but least valued, tool the professional has. The output of scientific papers is growing and it is difficult to remain up-to-date with all the relevant information. The number of channels that researchers and practicing engineers have at their disposal for information retrieval is increasing rapidly. In engineering, informal knowledge channels are often the most frequently used means of obtaining information. Many professionals prefer to rely on personal judgment or on the “wisdom” of their colleagues whenever they have problems to solve. It is the author’s expectation that this bibliography will save time for readers looking for information dealing with the subjects described below.

This bibliography provides a list of references on finite element simulations of crashes and impact-induced injuries. General solution techniques as well as problem-specific applications are included. The entries have been retrieved from the author’s database, MAKEBASE. They are grouped into the following sections:

- crash and impact simulations where occupants are not included (aircraft and helicopter crashworthiness, automobile crashworthiness, and vehicle rail structures)
- aircraft-birdstrike impacts
- impact-induced injuries
- human surrogates
- injury protection

2. Crash and impact simulations where occupants are not included

The subject of this section is the finite element simulation of contact-impact problems and problems where acceleration loading is included. References listed in the bibliographical section are divided into crashworthiness of aircrafts and helicopters, automobiles, and vehicle rail structures. Interactions with occupants are not included. In the past, finite element simulations of vehicle crashworthiness with occupants included have been limited due to the lack of software and limited computing capabilities. Fast developments in computer hardware, implementation of parallel processing techniques, and coupling of finite element analysis codes with multi-body dynamics codes have opened a new era in contact-impact biodynamics studies. The application possibilities of the finite element method have been expanded in order to allow for the complex modeling of vehicle and integrated occupants. Papers on these topics are listed in the next sections.

Topics include: *aircraft and helicopter crashworthiness* – 2D and 3D aircraft and helicopter impact and crash analyses; flutter impact problems; aircraft gas turbine engines and components; fan fuselages; helicopter fuselages; helicopter rotor blades; multiple blade shed incidents; aircraft propellers; helicopter sub-floor structures; aircraft seats; wing-type structures; light aircraft structures; impacted ice in rotating airfoils; aircraft impact with reinforced concrete

buildings; impact of aerospace structures with debris; reentry vehicle response to impact; space modules impacting water; impacted windows for the space shuttle; damage models for impact problems; *automobile crashworthiness* – 2D and 3D automobile impact/crash analyses; front end impact problems; side impact problems; rear crash analyses; crash simulation of rear engine automobiles; two vehicles in frontal impact; rollover simulations; vehicle cab frames; joints under car crashes; roof crush analyses; impact on various car components (wheels and tires, seats, etc.); windshield impact response; analyses of bumper systems; crash energy management; adaptive methods in crash analyses; stochastic analyses of crash problems; identification of parameters; application of supercomputers; *vehicle rail structures crashworthiness* – 2D and 3D analyses of train vehicles and components; wheel/rail impact problems; collapse of rail vehicle bodies.

3. Aircraft-birdstrike impacts

Collisions of aircrafts with birds are a threat to the safety of the aviation transportation and in addition they cause costly material damage to civil and military aviation. To predict the damage and its consequences, finite element simulations can be performed to study the contact-impact phenomena at soft-body impact problems. The impact load in connection with a birdstrike is hydrodynamic, time-dependent and decreases from the centerline of the impact region.

The following topics are handled: 2D and 3D simulations of a birdstrike on an aircraft canopy; bird impact on fan and compressor blades; soft-body impact problems.

4. Impact-induced injuries

Two main types of models in research of impact injuries can be distinguished: crash dummy models and real human body models. The latter category may be subdivided into human body component models and global human body models. As a result of finite element studies, stresses, strains, and also global motions (accelerations, velocities, displacements, reaction forces, etc.) within the human body or specific organs are obtained. These quantities are related to tissue damage or other indicators of injury. References dealing with global human body models as well as dummies are listed in the next section.

Impact-induced injuries under investigation include: 2D and 3D dynamic finite element studies of brain, head, neck, head-neck, head-spine, spine, articular cartilage, thorax, ankle, ankle-foot, knee-joint, patello-femoral joint, cervical spine motion segment, pelvis; thoracic-abdominal impact problems; diffuse axonal injury; injury to blood-brain barrier; whiplash neck behavior.

5. Human surrogates

More and more interest is focused on the dynamic response of the whole human body during automobile impact situations. This response is difficult to study by experimental tests when exceeding injury levels and therefore in some cases the cadavers or hybrid dummies are used to help to define the injury criteria. The hybrid dummies are developed as occupant substitutes in automobile collision testing to measure forces/accelerations on occupants during collision tests. Finite element models are used either to predict the behavior of a new system or to study aspects of an existing system that cannot be measured experimentally. An accurate mathematical model of the human body contains head, neck and skeleton represented by bones, their joints, various soft tissues, and internal organs.

Topics in this section are: occupant dynamic responses; occupant kinematics; human body impact problems; integrated occupant-car crash simulations; dummy models for crash simulations; SID dummy; BioSID dummy; EuroSID dummy; DotSID dummy; Hybrid III dummy; laminated glass head model; vehicle-dummy-airbag modeling.

6. Injury protection

At least a half million people die each year as a result of automobile accidents and about 15 million are injured. What we need is to increase safety of vehicles and thereby reduce occupant injuries as well as costs generated by these accidents. Seat belts, airbags and collapsible structures are three primary components of the safety systems in cars seeking to reduce serious or fatal injuries of occupants. Finite element techniques have been implemented to analyse and simulate injury protection systems and this is a main subject of this section.

The following topics are included: occupant protection in frontal and side impacts; occupant–airbag simulations; airbag modeling; seat side impact airbags; belt modeling; seat–seat belt design; helmet–head under impact; side impact protection; design of steering column; aircraft crash injury protection; pedestrian-safe car hood and bumper design; barrier impact test simulations; guardrail systems.

Acknowledgement

The bibliography presented is by no means complete but it gives a comprehensive representation of different finite element applications on the subjects. The author wishes to apologize for the unintentional exclusions of missing references and would appreciate receiving comments and pointers to other relevant literature for a future update.

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Automobile crashworthiness

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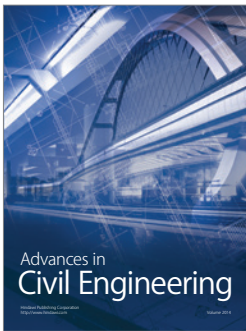
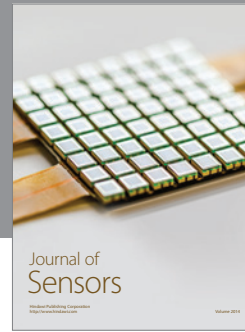
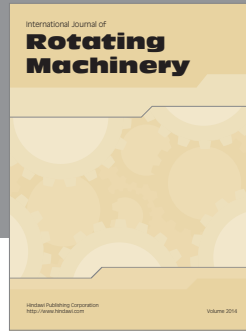
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