BIOMECHANICAL MODELS IN VEHICLE ACCIDENT SIMULATION

E. HAUG
ESI Group
20 rue Saarinen, Silic 270, 94578 Rungis-Cedex, France

Abstract

An overview on biomechanical modelling and its application in simulations of vehicle accidents is given. For the fabrication of biomechanical finite element models, acquisition of geometrical data, material properties and validation tests are needed. The utilization of biomechanical models is discussed and demonstrated on examples.

1. Introduction

1.1. PREVIOUS ESI GROUP WORK IN BIOMECHANICS

The present paper may be considered to follow the line of presentations given on PUCA'93 [1] and PUCA'94 [2]. In the first reference the authors discuss the numerical modelling techniques of mechanical occupant surrogates (dummies), using several "generations" of rigid, articulated rigid body, deformable articulated and finite element models of mechanical dummies. The paper ends with the outlook: "Towards the Human Surrogate?", in which then available models and results of human and mammalian "parts" (head, knee, cervical spine) were presented.

In the second reference the authors discuss the needs for biomechanical tests and simulations by describing head injuries, neck injuries, thorax injuries, abdominal injuries, spine injuries, pelvis injuries and injuries of the extremities. Next, these authors give an overview on methods of testing, including the use of biofidelic mechanical dummies, cadavers, animals and live human volunteers. A following paragraph mentions data collection from police reports on automobile crashes, reports by accident investigation teams, hospital reports, autopsy reports and numerical autopsies. Finally, simulation techniques are discussed, starting with models of mechanical dummies, gradually evolving towards biomechanical finite element models, with the needs of biomechanical material modelling. Acquisition of geometry data, interface modelling and validation are also discussed. Perspectives announce the creation of a library of biomodels by which the prediction of injury and trauma of mammalian vehicle occupants can be done best by computer simulation, which may in this case be the only valid alternative.

The present paper comes at a time when biomechanical finite element simulations of accidental injuries are starting to be considered realistic means of obtaining refined information on occupant injuries by the research and development departments of car companies, i.e., when the subject is about to transit from the realm of academic research at universities and government laboratories to industry. Reasons for this progression are found in the continued general progression of numerical simulation techniques and software packages, the growing efficiency of computer hardware
platforms and code architecture that permit to envisage numerical models of sufficient
detail and complexity, the growing databases and improved techniques for the
fabrication of geometrical and material data and models, more accidentological and
trauma data, and the general recognition that simulation is the only practical way to
include and obtain mammalian occupant response in the crashworthy design of
transport vehicles, constituting perhaps the ultimate consecration of this discipline.

The paper outlines ways to obtain geometrical data of mammalian parts. It then
demonstrates how such information can be transformed into finite element models.
The all important aspects of material data acquisition and modelling are addressed
next. The paper then gives an overview on currently developed biomodels and
simulation results, for the human head, neck, thorax, knee and ankle. Finally, a
biomedical application on the impact of a small missile on the human eye, currently
under investigation at Nihon ESI, and one on the operative repair of skin lesions,
demonstrate the great potential of biomechanical modelling beyond standard transport
vehicle accident simulation.

2. Geometry of Biomechanical Human Models

The acquisition of geometrical data of biomechanical human models can be a
considerable task and requires novel techniques, where the establishment of a
geometrical description as CAD data, clouds of points, etc., may be expensive and
time consuming. Once established for a given part, the question arises whether this
geometry is representative, e.g., for a 50-th percentile cross section of male or female,
child or adult, young or old population of a given continent. Recently data bases are
established that collect CAD geometries of the human body, for example, the
BIOCAD data base fostered by the NHTSA organization of the United States.

Several techniques are utilized to establish human part geometries, such as

- computer tomography (CT) scans, where the geometry of slices of the parts is
  recorded, slice-by-slice, and digitalized; finite element models can be obtained
  by connecting the digitalized slices with finite elements; an example is shown
  in Figure 1, where CT scans of a human skull were transformed into a finite
  element model of the bony structure of a human skull without the lower jaw,
  consisting of 1342 solid elements in 31 slices [3];
- external laser scanning or similar techniques, leading to clouds of points that
  serve as a basis for elaborate CAD models of the outer surfaces of bone,
  ligaments, muscles, tendons, etc.; such models are available, e.g., by Viewpoint
  Datalabs [4]. A representative sample of human parts is collected in Figure 2;
- mechanical slicing, abrasion or laser cutting, where human parts are embedded
  in a supporting matrix, slices of 2 to 0.33 millimeter thickness are prepared or
  exposed at low temperature, photographed, then detailed by anatomists and
  ultimately digitized; due to the identification of bone, ligament, muscle, tendon,
  skin, fat and other tissue materials, 3D models of the interesting constellations
  (e.g., bones + ligaments) can be prepared from the slice geometries; Figure 3
  shows the photograph of a typical slice ready for digitization (from the Visible
  Human Project, available on CD-ROM);
- copying from textbooks on the human anatomy (e.g., [5]) and anatomical
  atlases, which contain views of slices through human parts with corresponding
  explanations, which can be most helpful in the understanding of the overall and
detailed human anatomy, Figure 4.