OCCUPANT/VEHICLE CRASH MODELS AND DATA BASES MAINTAINED BY THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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ABSTRACT

In recent years, the National Highway Traffic Safety Administration's (NHTSA) office of research and development has increased its use of computer models in lieu of building and testing hardware, such as experimental vehicles. Consequently, considerable effort has been expended in developing, improving, and using occupant and vehicle models and the data needed to use the models. Many of these models, which were developed with public funds, are available for use by the public, including the safety community. The paper describes the models in current use at NHTSA, summarizes published applications, and specifies the models and data which are available. A suggestion is made that international cooperation on the development and application of models would further the objectives of the International Experimental Safety Vehicles (ESV) Program, while saving resources for all.

INTRODUCTION

As part of its rulemaking and other activities, NHTSA often evaluates the crash safety performance of vehicles and their safety systems. Safety performance is evaluated by a number of means, including analysis of accident data, laboratory and full scale testing, and modeling. In recent years, the use of modeling to evaluate safety performance has greatly expanded as a result of the large increases in capability and reductions in cost of digital computers and software.

To meet its needs, NHTSA has developed a number of computer models for use in studying how injuries occur and how to prevent or reduce them. Equally important, extensive data bases have been developed, in order to characterize the vehicle fleet for those safety features under consideration. The NHTSA models and data bases are available to the public, and can be used by the safety community to assist in the development of safer motor vehicles.

This paper outlines the principal models and data bases developed and maintained by NHTSA to evaluate vehicle crash safety. In most cases the models and data bases are known by abbreviated titles. In the sections to follow, the names of models and data bases are shown in parentheses, and the short name are identified by underlining.

ACCIDENT DATA BASES MAINTAINED BY NHTSA

FARS (Fatal Accident Reporting System) is a complete census of all motor vehicle related fatalities which occur on the public highways in the United States. This file was begun in 1975, and now contains data on more than 500,000 fatalities. The data include information on the make and model of the vehicles involved and the crash direction, but little on the crash severity and the nature of the injury. Occupant information includes age, sex, and seating position. In 1986, the file documented 24,922 fatalities to occupants of passenger cars. Annual reports are available which summarize the data, or the complete annual data file is available from NHTSA (1).

NASS (National Accident Sampling System) is a representative sample of the police reported crashes in the United States. The file for the years 1977-1986 contains records of more than 100,000 motor vehicle crashes. This file contains information on the injuries to the victims and on the crash severity. Crash severity is based upon an estimate of the speed change (delta V), which is calculated from the vehicle damage and trajectory. Injury severity is based upon the Abbreviated Injury Scale (AIS) described in reference (2). The AIS scale rates injuries from 1 (minor) to 6 (fatal) according to threat to life. Injuries with a severity of AIS 3 or greater are considered serious. No consideration of disability is included in the AIS scale. The file also contains information which identifies lesions and the source of the lesion. Annual summary reports (3) and data tapes of the complete file are available from NHTSA. An application of the NASS file is the subject of reference (4).

CARDFile (Crash Avoidance Record File) is a file of accident causation data from police report files of six States for the years 1983-1986. The file contains more than 4,000,000 crashes involving 7,000,000 vehicles. An overview of CARDFile and examples of applications are contained in reference (5).

VEHICLE DATA BASES DEVELOPED BY NHTSA

NVSADB (NHTSA Vehicle Safety Attributes Data Book) contains quantitative dimensional information on more than 5,000 automobiles and light trucks. The data elements for each vehicle contain 29 dimensions based upon SAE J1100 guidelines. The dimensions selected are those generally needed for crash models. This data base is explained in reference (6).

NCPDB (NHTSA Crash Pulse Data Base) contains the 35 mph frontal rigid barrier crash pulse data for more than 200 passenger cars and light trucks which have been crash tested by NHTSA since 1977. More details on the data base can be found in reference (6).

NCTDB (NHTSA Crash Test Data Base) is an electronic file maintained on the NHTSA VAX computer which contains the test results of approximately 1,000 vehicle crash tests conducted by NHTSA since 1977. This data base contains vehicle and dummy data collected from crash tests which include a wide variety of vehicles, crash modes, and crash speeds. The data base was summarized in reference (7).

NVCDB (NHTSA Vehicle Component Data Base) contains the force deflection characteristics of the interior surfaces of approximately 50 vehicles which are sold in the United States. The characteristics include 5 measurements describing steering assembly properties, and several measurements of the properties of dashboards, knee restraints, doors, headers, a-pillars, and side rails. The component test procedures and methods are described and referenced in a recent SAE paper (8).

VEHICLE/OCCUPANT CRASH MODELS

CRASH3 is used extensively by NHTSA accident investigation teams to estimate the crash severity (delta V) from the damage and trajectory information. The CRASH3 program attempts to find the velocity change and force direction which would produce the observed damage, based upon the laws of motion and conservation of momentum. The program is interactive and is available in a PC version. The program requires damage measurements from the vehicles in the crash. Default values are available for vehicle stiffness and inertial properties. The program outputs include vehicle delta V, principal direction of force, and a plot of the vehicle trajectory. Many papers dealing with CRASH3 are in the literature. A recent publication is reference (9).

SSOM (Safety Systems Optimization Model) was developed by the Ford Motor Company to evaluate how safety system design parameters interact to minimize the harm caused by the vehicle fleet. The model was provided to NHTSA as a result of the Research Safety Vehicle contract, and was further developed during follow-on studies funded by NHTSA. The model simulates an experiment of 1,000 different accidents which can be structured to be representative of the population of crashes found in an accident data base such as NASS. Therefore, the model must estimate each crash pulse for the variety of vehicles, crash modes, and crash severities which comprise the experiment. The model must also include a vehicle/occupant crash simulation capable of simulating different crash modes and occupant sizes. These capabilities from the SSOM model have been incorporated into other NHTSA models which are less complex and provide better insight into the effect of each parameter variation. More detailed applications and descriptions of SSOM may be found in reference (10).

CRUSH (Crash Reproduction Using Static Histories) is a generalized lumped mass structural model developed by the Ford Motor Company. The CRUSH model was originally the part of SSOM which generated the crash pulses for a variety of crash conditions. However, it is also useful as a structural model, and has been used for simple vehicle occupant simulations.

SDSIM (Segmented Door Side Impact Model) is one of several variations of the side impact lumped mass models in use. This model uses a generalized lumped mass structural model CRUSH to simulate the impact to an occupant in a side impact collision. The occupant is simulated by 4 masses and 6 nonlinear springs and dampers. The striking vehicle is represented by a single mass and 2 energy absorbing units which interact with a door represented by two horizontal segments. The struck vehicle is simulated by 10 masses and 23 energy absorbing units. Values for the model parameters are determined by analysis of experimental data with the assistance of lumped mass analysis programs such as SISAME. The model outputs the parameters measured on the SID and EUROSID dummies. A description of the model and a side impact application appears in reference (11).

SISAME (Structural Impact Simulation and Model Parameter Extraction) is the central program for generating and exercising one-dimensional lumped-parameter vehicle crash models. Model masses and energy absorber properties may be extracted from a set of crash test data and a user supplied model configuration. The methodology includes programs for filtering, initializing, and bias correction of the input data. In the simulation mode, the model predicts the crash pulse and other dynamic responses for impact velocities less than the test data.

PADS (Passenger and Driver Simulation) is a two-dimensional model which employs a simple three mass occupant model, and a detailed model of the steering assembly. The model output includes plots of the occupant kinematics, and the injury parameters which are commonly measured on dummies. The program includes a 3-point belt, and allows for vehicle compartment intrusion to be simulated. Data requirements include the crash pulse, occupant compartment geometry, interior surface impact properties, and the physical representation of the occupant. Auxiliary programs to assist in running PADS include CSCAL3, PCFG, and several plotting packages. Reference (12) contains a study using the PADS model.

CSCAL3 (Crash Pulse Scaling) is a program that scales crash deceleration data from 35 mph frontal barrier collisions to lower speeds, more compliant objects, and offset crashes. The model is based upon application of scaling principles to the crash data in the Vehicle Crash Test Data Base. Input data required includes the crash pulse for the 35 mph barrier crash test of the vehicle. The output is the crash pulse for the crash mode and speed being modeled. The development of the model is discussed in reference (13).

PCFG (Pads Control File Generator) provides for multiple sequential operation of the PADS program to simulate vehicle/occupant responses for a wide range of frontal collisions. With an adequate data base, the PCFG and associated software may be used to evaluate the safety performance of the baseline fleet of vehicles, and the fleetwide effects of alternative injury mitigation strategies. The results of a study using PCFG were reported in the 1986 IRCOBI Conference Proceedings (14).

The CVS-3D/ATB (Crash Victim Simulator-3 Dimensional/Articulated Total Body) program solves the equations of motion in three-dimensional space for a set of rigid bodies connected by joints. The program permits the specification of contact interaction properties between the rigid bodies and the surrounding environment. It is, therefore, possible to specify initial conditions of motion for the rigid bodies, and calculate the subsequent motion resulting from the forces imposed by the environment. The program is sufficiently general that it can be applied to a wide range of physical dynamic situations. However, the principal motivation for its development was to evaluate the interactions of the human body with the environment inside a motor vehicle during a crash. The data required is similar to that required by PADS. The program outputs include tabular and graphic displays of virtually any parameter of interest, at the discretion of the user. Auxiliary programs to assist the CVS-3D/ATB include VIEW and GEBOD. Applications of the CVS-3D/ATB are described in reference (15).

VIEW is a post processor of the CVS-3D/ATB output which draws pictorial 3-dimensional representations of the position of the occupant and the vehicle interior at user specified times.

GEBOD (GEnerator of BODy Data) scales data from the 50th-percentile-male occupant to generate data on different size occupants. The resulting data set can be used by the CVS-3D/ATB program which requires information for each body segment and joint. This information includes: the mass, center of gravity locations, principal moments of inertia and their associated directions, contact surface dimensions, joint locations, and joint properties. A minimum of 15 body segments and 14 joints are required to represent an occupant or dummy. Consequently, the problem of scaling the data set to different size occupants requires tedious work, if done manually.

OPPORTUNITIES FOR APPLICATIONS AND IMPROVEMENTS

The combination of models and data bases outlined by this paper offers opportunities to study vehicle safety performance through simulations of a complete vehicle fleet and by simulation of individual events. The models and data are generally available to the public, including members of the safety community. Additional cooperation among community members in the development of data, and application of the models could result in additional applications and increased confidence in their use.

An example of the application of models and data libraries to assess benefits of alternative safety designs was described in reference (14). The linkage of models and data libraries required for this study is shown in Figure 1. The methodology employed involves simulating hundreds of crashes of baseline vehicles and then measuring changes in harm when safety designs of the vehicles are modified. The first level in the Figure 1 methodology requires the selection of an accident data file such as NASS to simulate. The second level requires the selection of a sample of the accident file for simulation. The resulting simulation is for a variety of vehicles, crash modes, crash severities, occupant sizes, occupant positions, and restraint systems. The data needed for these simulations are stored in the libraries shown in the third level of Figure 1. The libraries include crash pulses, occupant properties, vehicle interior dimensions, force-deflection properties of interior components, and restraint properties. Some of the data in the libraries require processing for use as input data to a crash simulation model. The fourth level shows scaling models for crash pulses and occupant sizes. Data from the libraries are provided to a automated control file generator which exercises a vehicle/occupant model hundreds of times to predict the occupant injuries and harm which would occur in the fleet being simulated.

Many of models and data bases described in this paper are suitable for use in the blocks shown in Figure 1. They have been validated individually and as a group. The group validation is accomplished by comparing the injuries and harm predicted by the models with that in the national accident file.

Another application of particular value would be the routine reconstruction of the occupant motion in accidents documented in data systems such as NASS. In addition to reconstructing the delta V through the application of CRASH, an occupant simulation could be included as well, to provide additional factors for determining crash severity.

The basis for beginning this in-depth accident simulation already exists. The PADS and CVS-3D/ATB provide well developed simulations of occupant/vehicle interaction. However, these models require data on the crash mode and pulse, the occupant, the vehicle dimensions, and the properties of the vehicle components. Much of the needed data can now be generated from existing models and data bases.

Crash pulse data is available from data bases such as NCPDB. Crash pulse data can be scaled to specific cases using CSCAL3, CRUSH or SISAME. The crash delta V, which is an input required by these models, can be obtained from the CRASH model, which uses data routinely collected by accident investigators.

Vehicle dimensions can be determined by the crash investigation team, or can be recalled from a data base such as NVSADB. The emerging technology of stereo photography could be employed to further identify critical vehicle dimensions including deformations caused by occupant contact.

Considerable data exist in the NVCDB data base on the interaction between vehicle interior surfaces and body components. Data also exist on body to restraint system interaction; however, no organized data base for restraint system performance currently exists.

Finally, the capability of occupant sizing can be accomplished through the use of GEBOD.

NHTSA research is currently underway to evaluate the feasibility of reconstruction of a large sample of accidents collected in a special in-depth accident study. In addition, improved photographic techniques are being evaluated, with the objective of simplifying the accident scene data collection, and gaining additional deformation data which can be processed by computer.

CONCLUSIONS

Extensive data bases and computer models are now available to permit improved insight into injury causes in accidents. The National Highway

Traffic Safety Administration maintains analytical resources which can be used by other researchers to contribute to the reduction and prevention of motor vehicle injuries. In the past decades, the exchange of experimental safety vehicles served as a mechanism for sharing safety research. However, the great strides in analytical capability of the present decade offer a less expensive alternative for sharing ideas. Cooperation among members of the safety community through the sharing of models and data can save resources for all, and assist in improving the understanding of how to design safer vehicles.

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CRASH PROTECTION BENEFITS ASSESSMENT

FIGURE 1