BIOKINETIC LIMITS IN AUTOMOTIVE ENGINEERING

by

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Introduction

This paper was chosen to form a link between the scientific sessions at Chalmers University of Technology and the visit to Volvo in conclusion of the 1979 IRCOBI International Conference. On this occasion, therefore, we would like to present a brief summary within the IRCOBI areas of main interest in relation to Volvo's research activities, which are being made in response to compliance with future legal requirements placed by governments on automotive engineering. Such response is shown as a systems approach in Figure 1.

IRCOBI's area of greatest concern in this systems approach overview would lie within Crashworthiness Systems and the two subsystems of Occupant Compartments and Vehicle Crash Energy Management.

Volvo's Automotive Safety History

During the 1940's, Volvo decided to design and produce its passenger cars based on the monocoque theory of structures, which means that the automobile body is selfsupporting and requires no extra frame for engine and chassis suspension. This promoted extensive knowledge with regard to sheet metal structural engineering, which was essential for body crashworthiness development (1).

About ten years later, Volvo made another important safety decision: to introduce seat belts as standard equipment in all cars wherever Volvos were sold.

These two decisions, we believe, laid a solid foundation for Volvo's subsequent endeavors in automotive safety. Together with the decision to conduct multidisciplinary accident investigations on a continuous basis, with rapid feedback to design, engineering and production, they have formed a considerable safety engineering experience which is now part of Volvo's empiricism (2,3,4).

Biokinetic Considerations in Volvo Engineering

Before the early 1970's, biokinetic limits had only an indirect bearing upon motor vehicle design and engineering. Seat belts and other protective measures were hardly ever evaluated as part of an overall, vehicle-designed, crashworthiness system. Instead, components of the various safety systems were tested as isolated items. Nor was the integration of the restraint-crash protective system into the vehicle crashworthiness system measured in a quantitative manner which could be related to injury-reducing potentials of the complete design package.

One obvious reason for this shortcoming was lack of technology to perform such tests in a meaningful way. Basically there were no anthropomorphic dummies which could simulate occupant kinematics during a crash with sufficient confidence. The other main reason relates closely to the immediate objectives of the IRCOBI conferences and centers around the parameters to be measured in or on the dummies during tests for a confident safety evaluation. The science of biomechanics has made fruitful progress during recent years with regard to such testing, especially regarding frontal crash evaluations. Today we have available at least some developed dummies which we believe can give us reasonable test values when we want to compare different solutions for occupant protection in frontal crashes. Of course, dummies must be further developed to satisfy new demands emerging from extended knowledge in the field of biomechanics, as has been demonstrated during this conference. This is also recognized in the rulemaking and standard-setting process (5,6) which is shown at the end of the paper.

Recent Biokinetic Limits in Crashworthiness Research

Despite the lack of well-defined biokinetic limits in most automotive safety areas, pertinent injury criteria have been applied to crashworthiness ratings of vehicles and restraint systems in a number of car crash safety programs.

The most extensive of these endeavors is the Experimental Safety Vehicle (ESV) program, in which all the major automobile producers of the world are participating. In addition to this international program, the US government has supported a number of national car crash safety developmental programs, such as the one for research safety vehicles, and evaluation projects for various restraint systems integrated in both ordinary production vehicles and in slightly structurally modified ones.

For one of these developmental projects, designed to establish suitable future crashworthiness goals for production vehicles, the Volvo 240 was chosen as a research platform, or base-line, for evaluation of advanced restraint systems based on developed 3-point seat belt technology and advanced inflatable (air bag) restraints.

In this project, injury criteria were evaluated from dummy measurements in order to map the performance of different restraint systems under a variety of crash conditions of the frontal impact type. Thus the project included fixed-barrier and vehicle-to-vehicle impacts. In the latter crash tests, Volvos were impacted against other Volvos in full frontal engagement and in offset impact positions.

Additionally, full-sized US automobiles were staged to collide with Volvos in head-on, offset and frontal oblique impact positions. During this extensive crash testing it was established that the limiting biokinetic criteria were the chest acceleration for almost all impact modes. For the force-limited belt restraint system, however, during head-on impact conditions, the present head injury criteria were shown to be the critical ones.

(A short film of this research shown here.)

From these crash tests the NHTSA concluded that frontal crash protection within biokinetic limits could be achieved up to crash velocity changes of 45-50 mph with advanced (air bag) restraint systems (5).

It must be borne in mind, however, that these results were obtained in an automobile providing a large distance of structural collapse and with a rather low average deceleration during the velocity change.

At a 40 mph fixed-barrier impact, for example, a dynamic structural collapse of 38-40 inches could be utilized. Furthermore, crash testing with other cars having a similar capacity of structural collapse in the frontal impact mode (e.g. the Minicars Research Safety Vehicle) showed that occupant injury criteria could be kept within present biokinetic limits up to crash velocity changes somewhat exceeding 50 mph.

A Look into the Future

The downsizing of large, resource-demanding vehicles for personal transportation was forecast many years ago by several authors, including the present ones (7,8).

In Reference 8 it was predicted that the transition to smaller, or compact, automobiles need not result in an increase in occupant fatalities, if sensible crashworthiness technologies are used. We believe that this prediction still is valid.

Now the crucial question is: Does this mean that vehicle-to-vehicle crash goals of 50 mph could be met in future, downsized production vehicles? We believe that such goals should not be attempted without careful consideration of the injury criteria and their relation to the biokinetic limits. The reason for this caution is, of course, the downsizing effort due to fuel economy gains --- hence the smaller distances for structural collapse and the lesser weights of future vehicles must be taken into consideration.

For the sake of compatibility with the present vehicle population, the smaller and lighter cars of the future should be made with a high structural stiffness in order to maintain the integrity of the occupant compartment which is essential for a successful performance of the restraint system.

This will raise the average crash deceleration level of the smaller future automobiles as compared to present design levels. This further means that the present injury criteria limits will become critical at a lower test velocity.

If, on the other hand, it is essential to be below certain limits for a given test velocity, for example due to legal requirements, there would be a more difficult design task to be performed as the vehicles are getting smaller.

It will also be necessary to use the biokinetic limits with lower margins when designing the restraint systems for use in smaller vehicles than when used in a larger vehicle. Therefore, the pressure for well-founded and acceptable limits will increase, and the importance of biokinetic limit research will obviously also increase during the years ahead.

Higher Legal Requirements on the Horizon

So far, the US lead in application of biokinetic limits to design goals of automotive engineering has not been followed by other car-producing countries. Consequently, the automotive industry has to comply with several different requirements to reach the established safety goals.

From the automotive engineering point of view, therefore, it is also essential that knowledge of biokinetic limits should be increased, so that the application of such knowledge to vehicle safety designs can be made in a uniform and confident manner on a worldwide basis.

During the Seventh International Technical Conference on Experimental Safety Vehicles, held in Paris in June 1979, it became apparent that many of the IRCOBI areas of concerns will become subjects of new and upgraded rulemaking. In the 1979 ESV discussion areas of vehicle crashworthiness, namely: 1) frontal crash protection and passive restraint development, 2) biomechanics and dummy development, 3) side impact protection, 4) accident investigation and data analysis and 5) pedestrian protection, about a dozen papers attributed to the NHTSA dealt with crash injury, dummy development, vehicle downsizing and the proposed upgrading of the crashworthiness standards.

The main area of biokinetic development, as seen from an automotive industry point of view, is related to the evaluation of systems designed to protect vehicle occupants during side impact conditions. Here we have a number of problems. First of all, the kinematics of the dummies used today do not seem to resemble the kinematics of a human being in a similar crash environment. Secondly, the parameters used for evaluation are not at all as clear as for the frontal impact mode. Thirdly, side impact biokinetic limit data are still very rare in the literature. Recommendations for biokinetic limits in this crash situation must be a high-priority item during the years to come, so as to make it possible to develop the cars in a rational and cost-beneficial manner for injury reduction. The 1979 International Technical Conference on Experimental Safety Vehicles gave some indications of the road to be attempted (9,10).

The next biokinetic area of concern to the automotive designer is the evaluation of vehicles in regard to protection of children in different crash modes. Also, in this area we have a twofold problem with respect to system safety evaluation. One concerns the kinematics of the child dummies, and the other which parameters to select for a quantitative judgment of a given protective system. Regarding child tolerance data, our knowledge today is very sparse in the frontal as well as in the lateral body-loading conditions. One area of special concern is related to the future use of various passive restraint systems which are mainly designed to transfer acceptable biokinetic loads to grown-up occupants. This incongruence may create unwanted load configurations, for instance from an automatic (passive) belt system, as well as unacceptable load levels from an inflating air-bag system. Today we lack confident recommendations from the scientific community for both of these conditions in regard to biokinetic limits.

Another area of concern to the automotive designer, from the biokinetic point of view, is pedestrian protection (11,12). While possibly the fuel economy needs have created front and bonnet designs with rounded corners which might reduce the injury-producing potentials in many pedestrian impacts, we have no good tests today by which we can compare different bumper designs. Hopefully, some guidelines will evolve from the research which has been presented during this conference.

Concluding remarks

The discussions above have attempted to explain our concern regarding biokinetic limits in relation to our work on vehicle design, and to express the importance we see in the IRCOBI conferences.

We hope that we have succeeded in conveying to you our thoughts and ideas, and we now want to welcome you to Volvo's facilities.

Literature

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FIGURE 1: LEGAL REQUIREMENTS ON AUTOMOTIVE ENGINEERING AS A SYSTEMS APPROACH