ESTIMATING CRASH SEVERITY IN FRONTAL COLLISIONS USING THE VOLVO DIGITAL ACCIDENT RESEARCH RECORDER (DARR)

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ABSTRACT

When analyzing road accidents it is of great importance to have a good knowledge about the type and level of crash severity for different types of accidents. When comparing different proposed occupant protection devices, it is essential to be able to calculate the risk of injury as a function of a relevant crash severity measure. This is also important when correlating accident data and laboratory/simulation data.

The Digital Accident Research Recorder (DARR) provides information about the crash pulse in frontal impacts. The recorder function is integrated in the airbag sensor and is activated at the same time as the sensor triggers the airbag for deployment. Deceleration data is stored in a digital memory for approximately 100 milliseconds after activation of the recorder.

This report describes the techniques and characteristics of the crash recorder as well as the manner in which the data is collected and prepared for analysis.

INTRODUCTION

Safety researcher Professor B.J. Campbell once said: "... when one is forced to use nonhuman subjects (in laboratory crashes) then one is left in the situation of knowing a great deal about the physics of the crash but knowing little of the actual injuries that might have occurred in such a crash. On the other hand, in real world automobile crashes one can learn about the actual outcome in terms of survival and injuries, but the input variables mentioned before are unknown. The need to link these two systems is apparent ..." [quoted from 1].

Although this statement was made about twenty years ago, there is still much to be done to "link the two systems". The report will describe a part of Volvo's attempt to do so, and will primarily deal with frontal collision applications. However, it is also possible to extend the technique to other types of collisions.

VOLVO'S ACCIDENT DATA

In order to gain knowledge of the efficiency of occupant protection systems, we have been collecting data from accidents, involving Volvo cars, for a period of over 20 years. A combination of in depth studies and statistical follow ups of accidents has provided us with a database of more than 40.000

accidents.

The in depth studies, which are carried out by specially trained investigators, comprise detailed information about accident configuration, the vehicle and the occupants (including a detailed injury description).

The statistical data base comprises all crashed Volvo cars in Sweden with a repair cost in excess of approximately 25000 SEK (i.e. 5000 DEM or 3000 US$). These cars are examined by insurance inspectors from Volvia, which is Volvo's insurance company. Information about the accident is also requested and received by mail from the owner or driver of the car. When available, police and medical reports complement the collected information. The data base contains basically 30 items on the road and the accident configuration, 25 items on the occupant and his/her injuries, 35 on the car and its damages, and 20 items on other factors. Totally 110 data fields for each accident..

These two specified procedures are occasionally complemented by special follow-up investigations on topics like child restraint systems, overlap collisions, etc.

This data makes it possible to approximately reconstruct the crashes on a desk-top note-pad, in laboratories, and in computer crash simulation programs. Much knowledge has been drawn from such analyses.

ANALYSIS OF ACCIDENT DATA

One of the important tasks in traffic accident research is to relate the injuries suffered by the occupants to the violence (i.e. the energy released) of the accident. With this knowledge it will be possible to find out where and how the occupant protection systems need to be improved.

For this analysis it is convenient do define two collisions in the accident; the "primary collision" being the car hitting another object or obstacle, and the "secondary collision" being the occupant interacting with the interior or the restraint system of the vehicle.

Up to now, the only information available to us about the damage to vehicles, and occupant injuries (as Campbell pointed out) has come from post crash observations which have sometimes been supplemented by verbal accounts from witnesses and occupants. Over the years the quality of the methods used to calculate the violence of the primary collision has increased.

The first measures of violence were expressed as the deformation of the vehicle. Then, via studies and assumptions about the energy absorption characteristics of the car body, different measures of violence were proposed, all being expressed as some kind of equivalent velocity [2] [3] [4] [5] [6].

Improved measures of violence became expressed as the velocity change and the mean acceleration of the occupant compartment [7] [8]. These measures provide a more realistic basis for the analysis of the secondary collision.

However, the dynamics of the events were still determined in indirect ways, thus the secondary collision is only approximately described. A markedly improved analysis of the secondary collision can be made if the time history of the compartment deceleration - the crash pulse - were available. A tool which can be used to capture this pulse is the Crash Recorder, which has become a practical reality for automobiles thanks to the technical progress of measuring instruments and techniques made during the last ten years.

REVIEW ON CAR CRASH RECORDERS

The Crash Recorder technique has been in use in the aviation industry for quite some time. Its suggested use in automobiles has met with many technical, economical and administrative con straints. A comprehensive analysis of several technical and policy matters was presented in 1975 [1]. A student project in 1980 found about twenty proposed solutions [9]. A systematic account of a possible European program was presented in 1991 [10]. During the 80's the idea of Crash Recorder installation in cars became more realistic and some programs have actually been initiated.

The use of the crash information shall meet the expectations of many different parties. Some programs aim to investigate and analyse all crashes as correctly and thoroughly as possible. The findings can indicate the cause of the accident, and therefore also be used to resolve questions concerning financial and legal matters resulting from the crash. The findings can also be assembled into statistical information concerning traffic safety.

Crash Recorders intended for thorough analysis of crashes must meet high technical demands in order to yield the expected reliable data. In 1991 we described the cost of a competitive multichannel Crash Recorder as being "in the area of middle-line car radios" [11]. Such recorders have met some aversion in the public debate because of their possible interference with the driver's personal privacy. But if an erase button is available on the recorder the objections can be overcome. In Germany and some nearby countries several thousands Crash Recorders [12] have been voluntarily installed on the car owners' private initiative or approval.

Other programs are mainly of a statistical nature - they collect a limited amount of information from a large number of accidents, and can only afford a very limited time for the data collection and analysis of each case. Such data will lack exactness and depth, but provide an overall picture, good enough for decisions on traffic safety matters.

Crash Recorders intended for research into the dynamics of the collision only, need not record any information about the events preceding the impact. Therefore such recorders are less problematic with regard to the driver's personal integrity. The information is still suitable for studies of the performance of the occupant protection systems and, since the violence of the crasb can be determined, also research into the vulnerability of car occupants when exposed to known loadings.

Such recorders have been tecbnically available for quite some time. They mainly consist of a simple spring and mass system for the sensing and registration of a crash deceleration pulse. For statistical reasons, they need to be installed in large numbers to provide useful aggregated data. Therefore they have also had to await sufficiently inexpensive technical solutions. One early type was Breed's delta-V recorder [13]. Safety researcher Professor Aldman suggested a dcvice of a similar pattern [14] which was then developed into Folksam's crash pulse recorder [15].

Volvo's new Digital Accident Research Recorder (DARR) falls into the same inexpensive category, but works with digital electronic circuitry. It will be described in the next section.

DESCRIPTION OF THE DARR

Since January 1994, DARRs have been installed in all new Volvo cars sold in Europe. The DARR crash recorder is integrated with the airbag sensor unit. The sensor unit is bolted to the car body in the passenger compartment and contains an accelerometer which monitors the presence of any deceleration in the longitudinal direction of the car. The accelerometer's analogue output signal is converted into a digital signal which is continuously analyzed by a microprocessor. An algorithm in the processor senses the imminence of a crash and fires the airbag(s) at a suitable time instant.

Due to limited memory space in the present configuration, the DARR is designed to store the deceleration pulse, only if the airbag actually fires. Therefore, when the beginning of a possible crash is detected (at time t1), the digitized deceleration signal is written onto a temporary memory (RAM). If and when (at time t2) the sensor decides to trigger the airbag, the information in the temporary memory (obtained from t1 to t2) is copied onto a non volatile memory (EEPROM) together with the subsequent deceleration signal values during the crash. The deceleration which occurs before t1 is usually of a very small amount. Therefore, and with regard to the limited memory space, it is never stored. Future versions of the airbag sensor unit are planned to have more memory and more processor capacity available. This will benefit the capacity of the DARR also.
The full scale measurement range is 350 m/s2 with a resolution of 3 m/s2. This is an indication of the limit of inaccuracy for the system, but in practical cases uncertainties are added from the unknown influence of non longitudinal impact vectors. The damage of the car will provide some information on this, and after some time a know-how will be built up which, among other results, will indicate how reliable data is. Future versions of the DARR might have improved characteristics here also.

The bandwidth is approximately 0.7 - 300 Hz. The upper bandwidth limit conforms to SAE-J211 measurement recommendations for vehicle structural accelerations. The lower bandwidth limit is somewhat high for the recording of a crash pulse, but depends on the characteristics of the accelerometer. This frequency limit is compensated for by a filter algorithm in the later Volvo analysis of the crash pulse.

The stored deceleration signal has a duration of approximately 100 milliseconds. It is available as a simple binary file at a multipin connector on the airbag sensor unit.

It has been possible to augment the original airbag trigger unit with the DARR function without making any hardware changes. The changes are in the microprocessor software only. This makes the DARR an extremely inexpensive crash recorder incurring no extra costs for manufacturing and installation. The engineering time for development and implementation has been less than two man-months.

THE COLLECTION OF CRASH DATA

Initially the collection of the crash recorder data is confined to Sweden. It is expected that a few tenths of a percent of the Volvo cars each year will be involved in an accident deploying the airbag. These cars will now also carry a DARR with a valuable crash pulse. See Figure 1 for a picture of the collection procedures.

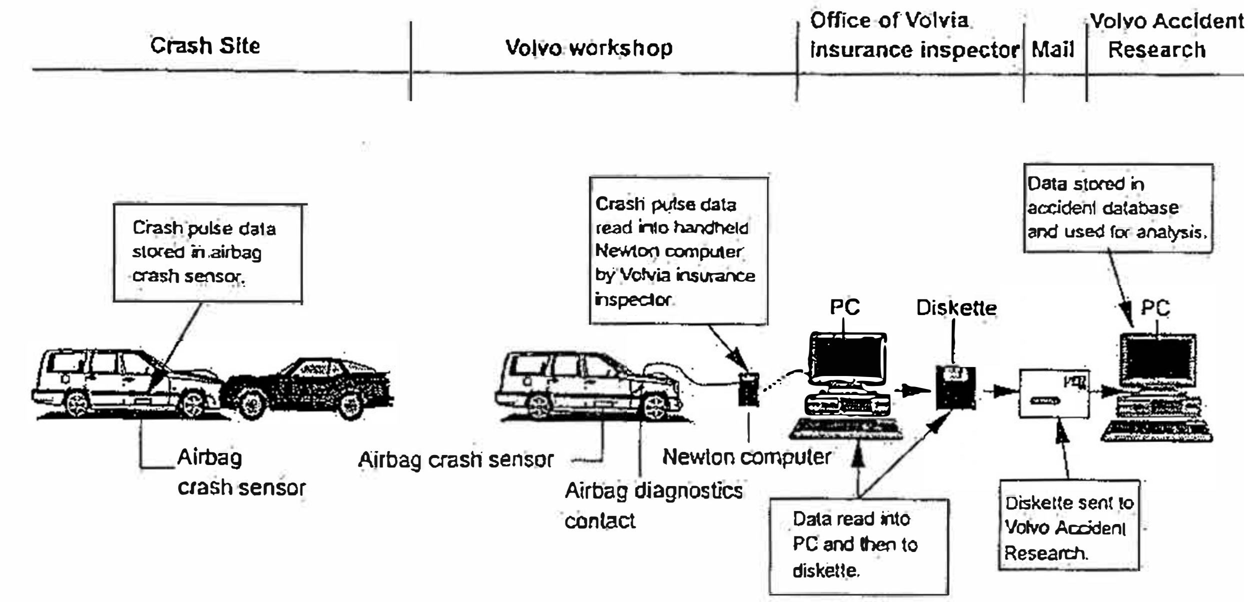

Figure 1. The transport of the crash pulse from the accident site to the statistical accident data base.

The inspector connects a hand-held Apple Newton computer to a diagnosis connector for the electrical system in the car. (If vehicle damage is extensive the connector on the DARR can be used, or one can even remove the DARR from the wreck.) This connector transfers the crash pulse data from the DARR to the Newton computer. This data is later copied onto a diskette via a desk-top computer.
Diskettes, usually containing information from several crashes, are regularly forwarded to Volvo's Traffic Accident Research Group. The crash pulse data is reformatted to the new computer environment. Crash severity measures (Delta-V, Pulse shape, etc.) are calculated and stored in the accident data base together with all other collected information from each accident, as described earlier. This information is then ready for different types of analyses.

The total amount of extra time required to forward the DARR information from crashed car to accident data base is less than one man-hour per accident and is expected to be shortened in the future.

THE DARR OFFERS NEW WAYS TO ANALYZE CRASH DATA

The inclusion of crash recorder data which provides the crash pulse is expected to substantially increase the quality of the conclusions from different types of analyses and makes it easier to understand the "secondary collision".

The passenger interaction with the occupant restraint system is closely connected to the time history of the deceleration of the occupant compartment, i.e. the crash pulse. The new prospect to discriminate between different pulse shapes makes possible new classifications and correlation's between injuries and specific details of the violence exposure. It will take some time until collected experience can indicate the most suitable way(s) to characterize deceleration pulse shapes. An new field of research seems underway here.

Given the crash pulse and occupant injuries from a particular crash, there is now a better possibility to expose a crash test dummy to the same deceleration pulse in the same compartment environment as in the accident. This simulation can be done in a computer program or physically on a test sled in a crash test laboratory. Several such simulations will provide a set of dummy responses which we can try to match to a corresponding set of occupant injuries. This will improve the possibilities to interpret dummy responses as expected injury risk in proposed new car designs [16] [17]. This leads to product development and improved occupant protection systems in Volvo cars.

CONCLUSIONS

Summarizing the advantages of DARR the following items are noteworthy for safety research and product development:

* Improved possibilities for distinguishing between crash categories earlier considered as "fairly identical".

* Better and clearer conclusions can be inferred from the improved accident statistics.

* Analysis of the function, working, and efficiency of the occupant protection systems.

* Improvement of the occupant protection system, e.g. by a smarter trigger algorithm for the airbag.

* Easily augmented to the recording of more crash parameters and, if considered suitable in the future, also of pre-crash data.

Thus we hope that the DARR will contribute to a better "linking of Campbell's two systems", as mentioned in the introduction.

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