A CRASH SEVERITY INDICATOR AND ITS USEFULNESS

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ABSTRACT

A simple low-cost mechanical accelerometer capable of recording only the effective peak value of a car deceleration pulse has been designed and tested. The device will be field tested for use as a crash severity indicator for frontal impacts. For this purpose a large number of these devices will be incorporated into rear facing child seats to be used in a loan program starting later this year.

THE PROBLEM

In retrospect it is always possible to classify a specific accident as severe if many people were killed or severely injured. Under identical accident conditions, however, the outcome might not have been the same in other types of cars. In large accident materials differences in the risk of being injured can be seen to differ between e.g. old and new cars and between small and large ones (1). This is believed to be due to differences in car construction and restraint system effectiveness. However, several factors probably influence the collision and injury mechanisms in automobile accidents. Human injury criteria and tolerance levels may not be the same in all crash modes. Therefore it is probably advantageous to discuss different collision types separately. The crash severity concept may then be used within each type as a measure of collision injury potential.

Many attempts have been made to find simple means by which the severity of automobile accidents can be adequately assessed. The term severity has probably not always been interpreted in one and the same way by different researchers or at different occations. The main objective of these attempts, however, seems to have been to provide a method for assessing the risk of serious injury to the occupants of cars involved in real world accidents. Such risk figures could then be used to determine the population at risk (2) but also to evaluate the effectiveness of systems for occupant protection from field accident data.

The Vehicle Deformation Index (VDI), the TAD Vehicle Damage Scale, the Barrier Equivalent Velocity (BEV) as well as the total velocity change (Delta V) are examples of what has been proposed for the assessment of collision severity (3). There have also been some attempts to design and produce crash recorders which would record and store pertinent vehicle parameters during an accident. These parameters could then be used for the calculation of risk indices and for the evaluation of crash protection.

The literature about the earlier attempts is not reviewed and discussed in this paper. A simple and practical approach to the problem is proposed here as a background for the design and construction of low cost devices which are supposed to use only one single parameter value as indication of the severity of an accident.

THE BASIC PRINCIPLE

In this presentation only frontal car collisions are discussed although the same principle and similar devices could probably also be used for the same purpose in other crash modes.

An occupant and his restraint system, e.g. a three point safety belt, can be considered to represent a rather complex and slightly damped mass-spring system. In this case the occupant's body would represent the mass and the belt webbing would represent the spring. The damping occurs in the seat belt straps as well as in other structures.

During a frontal collision the car occupant will continue to move in a forward direction within the passenger compartment. This forward motion is controlled by the properties of the restraint system. Ideally this system is designed in such a way that in the majority of all frontal collisions the "normal" occupant's body would be stopped before reaching the limitations of the passenger compartment. However, the further forward the occupant moves - as a result of the input deceleration pulse of the car - the higher will the belt forces acting on his body become. Should the Delta V be high enough additional loads would occur when the body impacts interior structures in the car.

The degree of the restrained occupant's forward motion could then probably be used as an indication of the magnitude of the total force to which he is subjected during an accident of this kind. Since higher forces are more likely to be injurious to the population at risk than lower ones, this parameter could probably be used to assess the severity of an accident. It would, however, be rather difficult both to find a representative point on the occupant's body and to measure his forward displacement in real world accidents.

Let us therefore assume that instead of using the restrained occupant, we would introduce a standardized, small and simple, mass-spring system. This system should also have incorporated a device which would mark only the foremost position reached by the mass during a frontal car collision. With proper damping of the system this device would then duplicate in a reduced scale the forward motion of a restrained car occupant of "normal" size. The forward displacement of the mass would then of course be correlated to the highest part of the deceleration pulse of the car with the exception of any high frequency peaks superimposed on this pulse. In other words the device would function as an accelerometer which would record only a maximum value of a smoothed input pulse.

If the mass in a device of this construction is restrained by a coil spring the active mass is of course not constant because the parts of the spring which have not yet been stretched out will have to be taken into consideration as well. A straight line relationship between maximum deceleration and the forward displacement of the mass would therefore not be expected.

Some prototype devices of this kind have been made and tested using different g-levels and pulse shapes including some full scale car barrier tests.

THE INDICATOR

Each prototype device consists of a small plastic tube in which a small cylindrical mass can move. The mass has end flanges to fit inside the tube. Parts of the flanges are cut away to allow air in the tube to pass as the mass moves. The mass is anchored to one end of the tube by means of a coil spring. A string - of known length - is attached to the mass and passes through the center of the spring and through a narrow hole in the end plate which closes the rear end of the tube.

TEST RESULTS

The devices were attached to pendulums and test vehicles in such a way that at impact the inertia of the mass would overcome the spring force, the friction, and the air resistance and move forward in the tube pulling the cord through the hole in the end plate. When the mass had reached its foremost position it was of course pulled back by the spring. After each test the part of the cord which had not been pulled through the end plate was measured. The maximum forward displacement of the mass was calculated and the cord stretched out again to reset the device for another test.

Tests were performed at different g-levels and with pulse shapes varying from square and two level step functions to halfsine pulses of different durations. The the peak value over 3 ms was considered as the effective deceleration in these cases. The maximum forward displacement of the mass calculated from measurements of the residual length of the cord in 24 tests are shown in Figure 1. The curve represents the function $Y = ax^b$, where $a = 4.80$, $b = 0.713$. The coefficient of determination is $R^2 = 0.948$.

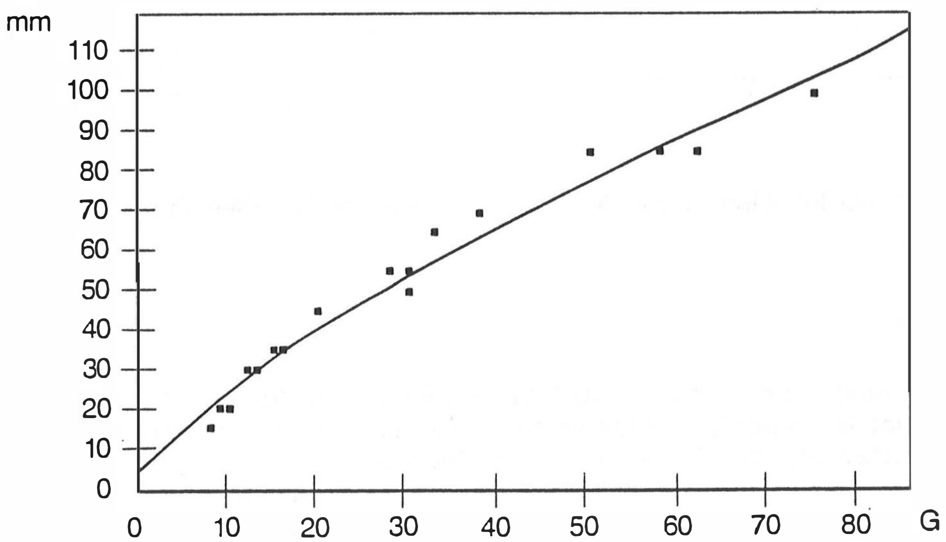

Figure 1. The relationship between forward displacement of the mass and maximum g-level in 24 tests. $y = 4.80\ x^{0.713}$.

A test series was also performed in which restrained adult and child size anthropometric test dummies were used as passengers of cars in 50 km/h barrier collisions. Crash severity indicators were fitted to the structures of the cars and the rear facing child seats. Analysis of high speed films from these tests showed that the forward displacement of the adult dummies and the mass of the crash severity indicators took place simultaneously. In the rebound phase there were some differences as could be expected. The difference in maximum forward displacement recorded in two crash severity indicators fitted to the car structure and one fitted to the frame of a rear facing child seat was less than 5%.

Two cars A and B of the same make and model were impacted into a barrier in this series. The impact speeds were 48.7 kmh and 48.5 kmh respectively. The deceleration pulses of these two cars were different as shown in Figures 2 and 3. The crash severity indicator showed a forward displacement of the mass of 70 mm in car A and 55 mm in car B. At inspection of the two cars the deformation looked rather similar but car B was found to have been weakened by corrosion.

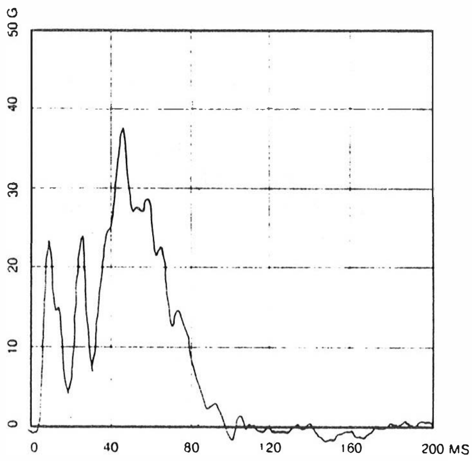

Figure 2. Deceleration of car A.

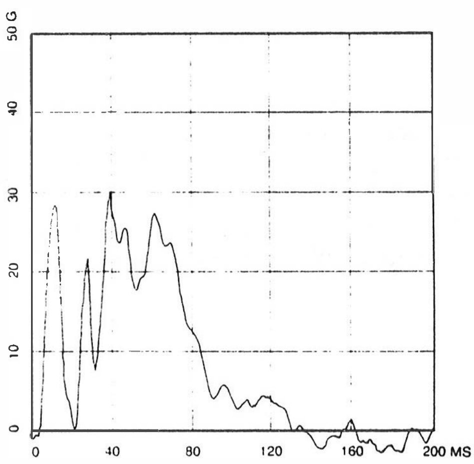

Figure 3. Deceleration of car B.

DISCUSSION

The risk of being injured in a frontal car collision is influenced by several factors. If the occupant is properly restrained these factors can be grouped into three main categories: external, vehicle, and occupant factors.

Intrusion of external structures into the passenger compartment may cause injuries either by direct blows to the occupant or by limiting the free space in front of him. The rate of onset of the forces are probably of importance in this context. The shape and size of external objects may influence the extent to which the front structures of an impacting car are engaged during the collision.

The vehicle factors are related to the strength and stiffness of the car body as well as to the space available in the passenger compartment. The restraint system should be matched to these factors in such a way that it will give protection over a large range of real world accident conditions.

Among occupant factors body size, weight, and age are probably the most important ones. Some parts of a tall person's body may be closer to dangerous structures than those of a shorter person. A heavy occupant will need a long stopping distance and may not always, because of his larger body, be able to get enough space for his forward displacement. The tolerance of the human body to inertial loading varies with age and physical fitness.

A system for protection of occupants against accidental injury must be simple and comfortable to use. Too many variables can therefore not be taken into consideration when a system of this sort is designed. In order to be able to protect as many people as possible the extremes of occupants and accident conditions will have to be left out of account. A standard procedure is therefore used for testing and approval of cars and restraint systems.

If restrained people are injured in real world car accidents it is usually not possible to tell whether the accident was too severe or the protection system did not function properly. The reason is of course that it is difficult to compare the severity of one particular accident with the conditions of the standard approval test.

An evaluation of how well production cars protect their restrained occupants in real world accidents will therefore have to be made statistically and this requires quite large accident samples. This will also take a long time to achieve. For this reason several attempts have been made to overcome this difficulty.

The results from impact tests over a large range of possible impact situations briefly presented in this paper show that it is possible to indicate, even with a rather simple and low cost device, the magnitude of the forces acting on a restrained occupant as expressed by the maximum forward displacement recorded from a standardized mass-spring system sensitive to the maximum car deceleration.

In the full scale tests two cars of the same make and model were used in barrier collisions at the same impact speed. The crash indicator showed different values for the two cars. The recorded car decelerations were also different and the reason for this was probably that one of them was weakened by corrosion. The severity of this accident as indicated by the device was lower for one of the cars although the barrier impact speed was almost the same.

The close resemblence between the outputs from crash severity indicators fitted to the car structures and to properly anchored rear facing child seats was of great interest. A decision was made to take advantage of this fact for a field test of the device. In a first attempt crash severity indicators will be produced and built into rear facing child seats which will be used in a loan program organized by the Folksam Insurance Group. The first face of this program will begin in the fall of this year and which may continue for several years. 20,000 of these seats will be equipped with this kind of crash severity indicators.

This kind of device can not indicate if intrusion into or deformation of the passenger compartment has occurred. This on the other hand can easily be checked by the investigator reporting the accident.

The indicated value can not be used to calculate pre-impact speed. It can therefore not be used to incriminate the driver. For this reason a device of this kind may be more acceptable to the general public than genuine crash recorders. If crash severity indicators of this basic construction are fitted to a fleet of cars it will be quite simple to compare accidents of similar severity and to use this information for evaluation of the protection offered in real world accident situations. It will then probably be possible to evaluate the protective effect of cars and restraint systems based on rather small samples of real world accidents.

CONCLUSIONS AND RECOMMENDATIONS

A simple device sensitive to the acceleration pulse of a car involved in a frontal collision can be used as an indication of the magnitude of the forces to which a restrained occupant is subjected. Devices of this kind could be standardized, mass produced at low cost, and used for indication of crash severity in real world accidents. The crash severity would be based on a single value on an open scale. This value could be used for the assessment of the population at risk as well as for the evaluation of crash protection of cars and restraint systems.

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